# **Solar Cooking** (Lesson Plan)

*(Warming Up to the Properties of Solar Radiation & Its Uses in Our Homes)*

**Suggested Grade Level** 6-8

## Overview

Students experiment with a virtual solar cooker to discover the mathematical relationships among reflection, transmission and absorption. They won't stop there, though! Students then apply their knowledge to building and testing a solar cooker of their own invention. In an extension, students investigate how these principles can be used as sustainable energy sources for homes in Pennsylvania through passive solar heating. Approximately two to three (2-3) 50-minute class periods are required for this lesson.

## Standard Statements

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|---|---|
| 3.1.7 A | Explain the parts of a simple system and their relationship to each other. |
| 3.2.7 C | Apply the elements of scientific inquiry to solve problems. |
| 3.2.7 D | Identify and apply the technological design process to solve problems. |
| 3.4.7 B | Analyze energy sources and transfers of heat. |
| 3.5.7 B | Recognize earth resources and how they affect everyday life. |
| 3.6.7 C | Explain physical technologies of structural design, analysis and engineering, personnel relations, financial affairs, structural production, marketing, research and design. |
| 3.8.7 C | Identify the pros and cons of applying technological and scientific solutions to address problems and the effect upon society. |
| 4.8.7 B | Explain how people use natural resources. |
| 4.8.7 D | Explain the importance of maintaining the natural resources at the local, state and national levels. |

## Content Objectives

*Students will know that*

1. Incident sunlight is reflected, transmitted, and absorbed when it falls upon a surface.
2. A solar cooker is a solar collector; it "collects" and traps the sun's energy, creating heat.
3. Solar cookers require three (3) components: glazing, insulation and reflectors.
4. There are limitations to how we can maximize solar energy depending upon our geographic location.

## Process Objectives

*Students will be able to*

1. Describe how passive solar energy can be used in our everyday lives and homes.
2. Discuss the mathematical relationship among reflection, transmission, and absorption: incident solar radiation (I) must equal reflected (R) plus transmitted (T) plus absorbed (A) radiation ($I = R + T + A$)
3. Predict the relative transmission, reflection, and absorption properties for various materials.
4. Construct a solar cooker that fully cooks a food of the students' choice.

## Assessment Strategies

1. Observation of students' interaction with the virtual solar cooker as a pre-instructional tool.
2. Evaluation of the completed student handouts, and of the students' participation in class discussions.

## Materials

*Part 1:*

- Student computers with internet access
- Student handouts
- Virtual Solar Cooker interactive simulation
- Solar incidence equation lecture notes

*Part 2:*

- Model solar cookers
- Cardboard cutting tools
- Thermometers or electronic temperature sensor data loggers

*Per Group*:

- Various household/classroom materials for demonstration and cooker components
    - Mirror
    - Window glass
    - Frosted glass
    - Aluminum foil
    - Unpainted copper sheeting
    - Wood
    - Waxed paper
    - Clear plastic wrap, sheet protectors or transparencies
    - Cellophane: clear, yellow, red, blue, green
    - Construction paper: black, yellow, red, blue, green
    - Cardboard boxes or foam board
    - Black paint
    - Torn-up paper
    - Scissors
    - Tape (clear and masking tape)
    - Rulers/meter sticks
    - Compass
    - Thin wooden skewers
    - Hot dogs or S'mores ingredients
    - Sunglasses
    - Light source (including the sun)

*Multimedia Resources*

- Background movie on solar cooking around the world and types of solar cookers from http://solarcooking.org/media/presentations/voa_files/default.htm (requires Internet Explorer 5.5 or higher)
- Box cooker design plans and FAQ: http://solarcooking.org/sbcdes.htm
- Panel cooker design and rationale: http://solarcooking.org/cookit.htm
- Parabolic cooker examples: http://solarcooking.org/DATS.htm

*External Websites*

- Passive solar design homes: http://www.solaror.org/ftp/Lesson2.pdf and check out this PDF for great visuals: http://www.solarminnesota.org/heatbuilding/hppassivesolar.pdf.
- A sun path chart can be made for your town/school at the University of Oregon's Solar Radiation Monitoring Laboratory using the "Sun Chart" program: http://solardat.uoregon.edu/SunChartProgram.html
- Figure 1. Diagram of Azimuth Source: http://www.heavens-above.com/gloss.asp?term=azimuth
- Figure 2. Reflection of Light Source: http://www.colormatters.com/seecolor.html

**Procedures**

*Part 1: Experimenting with a Virtual Solar Cooker* *(30 minutes)*

1. Begin the lesson with a lively discussion that investigates students' conceptions about radiant energy. Describe what a solar cooker is and spend several minutes eliciting students predictions about what types of materials will be best for use in constructing a solar cooker.
2. Allow students to investigate the virtual solar cooker and prompt them to try to figure out which combination of materials performs the best as a solar cooker. Remind students to make notes about their virtual solar cooker's performance in Part 1 (Virtual Solar Cooker Wrap-up) of the student handout. (A link to the virtual solar cooker learning object can be found on the Solar Cooking lesson page and in the multimedia objects table of the E-21 website.)
3. Discuss the results of investigating the virtual solar cooker with the students. Define transmission, reflection and absorption for the students and introduce the expression, I= T + R + A. Depending upon the level of your students, this may be more of a lecturing activity rather than discussion. Having sample materials to cite examples from the list for Part 2 is suggested. *[A suggested demonstration is to throw crumpled pieces of paper at students and illustrating how this is an example of what happens when light strikes a surface (the pieces of paper caught are absorbed, those falling to the floor are transmitted and those bouncing off are reflected.)]*
4. Have students work in small groups to rank the materials included in Data Table 1 on page 2 of the student handout.

*Part 2: Collecting Solar Energy* *(2, 50-min Class Periods)*

1. Share physical models of each of the three types of solar cookers (box, panel, parabolic.) If presenting physical examples is not possible, digital images will work well and the Solarcooking.org website referenced in the Multimedia Resources section of this lesson is a great source. Give a short lecture describing the function of each component of a solar cooker (cover or glazing, insulation, reflector). Instructions for constructing each type are included in the Additional References section of the Teacher Notes. A short movie link available from The Solar Cooking Archive may also be of interest: http://solarcooking.org/media/presentations/voa_files/default.htm (requires Internet Explorer 5.0 or higher).
2. Divide the class or allow students to sort themselves into teams of 2 to 3 and set them to work on Part 2 (Select a Solar Cooker and Test Your Predictions) of the student handout. While working through Part 2 each student team needs to decide what type of solar energy collector will best cook the food that they choose. Students may not realize that the cooker cannot reach temperatures much higher than about 300° F, so they may need some coaching away from cooking things like raw meat. They will also need to generate their list of materials based upon their relative properties of transmittance, reflectance and absorbance.

An extensive sample materials list is provided in the materials section and the Frequently Asked Questions document from The Solar Cooking Archive embedded in the Teacher Notes may be a useful document to share with students. (Internet Explorer versions 5.0 or higher are necessary for viewing.)

3. Assist students in making connections to the mathematical expression, I = T + R + A in question #3 (Part 2) on page 4 of the Student Handout.
4. Students will then sketch their solar cooker (question #4 of Part 2 of the Student Handout.) Question #5 prompts them to figure out how to measure the temperatures reached by the solar cooker. If necessary, interject a short lecture on how to collect temperature data, otherwise, allow students to devise their plan and make a data table.
5. Allow students to proceed with construction and testing of their cookers.
6. Once all teams have had an opportunity to test the cookers, allow students to investigate others' designs and debrief the experience by sharing the data collected for each cooker and analyzing the success of each type of cooker. Students may do questions 6-10 in the Student Handout (Solar Cooking Thought Questions) as part of the in-class wrap-up or for homework.

## Extension

*Part 3 (Extension): Applying Solar Principles to Building Design* *(2, 50-min Class Periods)*

1. Allow students to explore some of their ideas from question 10 in the Student Handout. Visit the Solar Energy Association of Oregon's site for a lesson complete with overheads on passive solar design homes: http://www.solaror.org/ftp/Lesson2.pdf and check out this PDF for great visuals: http://www.solarminnesota.org/heatbuilding/hppassivesolar.pdf.
2. A sun path chart can be made for your town/school at the University of Oregon's Solar Radiation Monitoring Laboratory using the "Sun Chart" program: http://solardat.uoregon.edu/SunChartProgram.html.

# Solar Cooking (Teacher Notes)

*(Warming Up to the Properties of Solar Radiation & Its Uses in Our Homes)*

*Notes on Part 1 from School Power Naturally's Solar Kit Lesson #9*[1]

Radiation incidence upon a surface is typically described as interacting with the surface in one or more of three ways: it will be absorbed into the material, transmitted through the material, or reflected off the material. The proportions of each will depend on the wavelengths of the radiation, the chemical composition and physical structure of the material, and the angle of incidence at which the radiation strikes the material.

Hard polished surfaces reflect light differently from rough textured surfaces. The amount of radiation reflected also depends on the angle of the incident light, with low angles of incidence typically reflecting more light than high angles of incidence. Radiation can reflect off a surface more or less equally in all directions at once or in only one direction as light reflects off a mirror. Radiation reflected in all directions is called "diffuse reflection" and radiation reflected as occurs off a mirror is called "specular reflection."

Materials that absorb many wavelengths of visible light look darker to us than those that absorb fewer wavelengths. The mirror and aluminum foil should show the highest level of reflection. Window glass and clear plastic sheeting should show the highest level of transmission. The mirror, aluminum foil, copper sheeting, wood, and construction paper should not transmit light energy. Students should be expected to predict that the darker colored construction papers, black-painted copper sheeting, and wood will absorb the most light energy.

*Notes on Part 2*

*Adapted from the PSU GREATT Project Lesson, "Solar Power: The History, Chemistry and Application of Photovoltaics*[2]

**Tracking the Sun**

The angle at which the sun's rays strike the Earth varies by geographical location and time of year. This is a result of the Earth's natural tilt on its axis and its revolution around the sun. For example, in Europe during the summer months, the northern hemisphere is tilted toward the sun, and therefore, the sun traverses a high, nearly vertical arch through the sky.[3] As the Earth continues its revolution and the northern hemisphere tilts away from the sun, Europe experiences winter. During these months, the sun travels a flatter, more southerly path.

The angle is also influenced by the Earth's daily rotation which causes the sun to travel an arching path through the sky. The term **azimuth** is defined as the direction of a celestial object, measured clockwise around the observer's horizon from north (see the visual included in Figure 1 on the next page). So an object due north has an azimuth of 0°, one due east 90°, south 180° and west 270°.[4] After sunrise, the sun is positioned in the East at an azimuth of approximately 90°, while at midday it is located high in the sky at nearly a 0° azimuth. Repositioning a solar collector so that it follows the sun's path is called **tracking,** and it increase the energy output of the device.

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[1] School Power Naturally. "Solar Kit Lesson #9: Properties of Solar Radiation: Reflection, Transmission, and Absorption." http://www.schoolpowernaturally.org

[2] The GREATT Project. "Solar Power: The History, Chemistry and Application of Photovoltaics." http://csats.psu.edu/files/GREATT/SolarPower/Solar%20Power.doc

[3] Hug, Rolf. "The Solarserver: Forum for Solar Energy." http://www.solarserver.de/solarmagazin/anlageapril200-e.html

[4] Peat, Chris. "Heavens Above." http://www.heavens-above.com/gloss.asp?term=azimuth

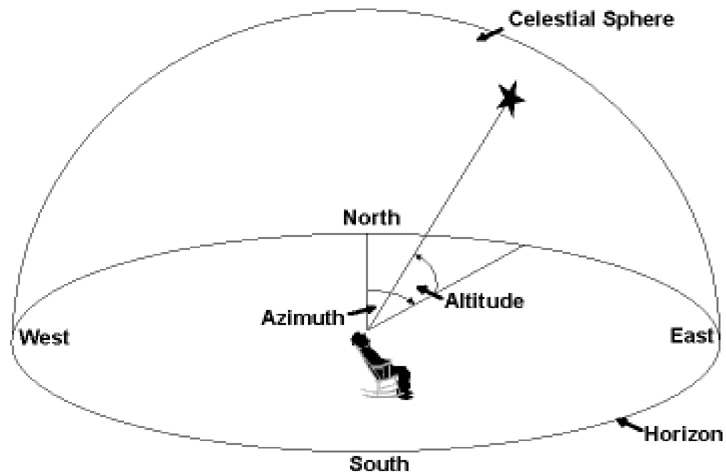



**Figure 1. Diagram of Azimuth**
Source: http://www.heavens-above.com/gloss.asp?term=azimuth

## Reflection of Light

We see colors because different objects reflect different colors of the visible spectrum. An object that appears red (Figure 2) does so because it absorbs the yellows, greens, and blues, reflecting red back to the human eye. Different colors (frequencies) carry different amounts of energy. Within the visible spectrum, blue light has the highest frequency, and therefore the greatest energy.

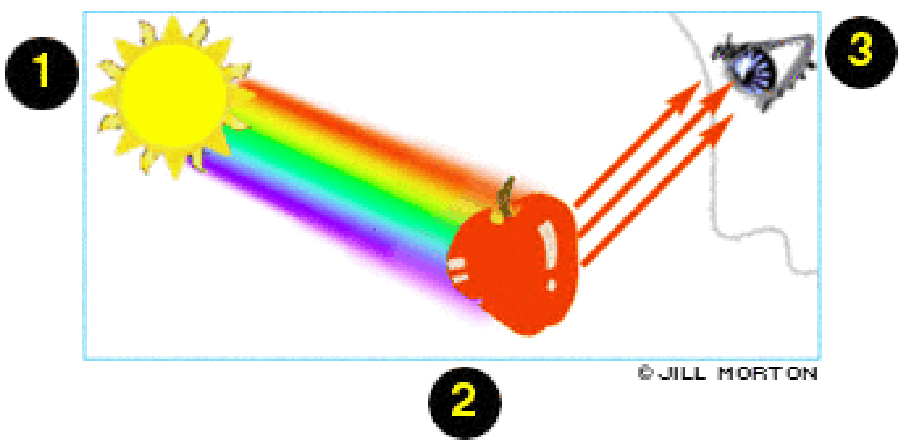



**Figure 2. Reflection of Light**
Source: http://www.colormatters.com/seecolor.html

**Light Intensity**

Due to the Earth's natural tilt on its axis, the amount of direct sunlight that geographical locations receive varies with latitude. Locations near the equator are positioned at nearly ninety degree angles in reference to the sun, whereas locations at higher latitudes are positioned at much greater angles and receive far less direct sunlight. Therefore, the amount of solar energy that can be harnessed varies. For example, in Central Europe the power per square meter that can be generated by solar radiation is approximately 1000kWh/$m^2$ annually; whereas, in Africa the amount of power per square that can be generated by solar radiation climbs to 2200kWh/$m^2$.[5]

## Solar Cooking Frequently-Asked Questions[6]

Version 2.4 -- October, 2004

**What are the basic kinds of solar cookers?**

There are three basic kinds:

- Box cookers
  This type of cooker has been the advantage of slow, even cooking of large quantities of food. Variations include slanting the face toward the sun and the number of reflectors. You'll find an article discussing solar box cooker designs here.

- Panel cookers
  This recent development was sparked by Roger Bernard in France. In this design, various flat panels concentrate the sun's rays onto a pot inside a plastic bag or under a glass bowl. The advantage of this design is that they can be built in an hour or so for next to nothing. In Kenya, these are being manufactured for the Kakuma Refugee Camp project for US$2 each.

- Parabolic cookers
  These are usually concave disks that focus the light onto the bottom of a pot. The advantage is that foods cook about as fast as on a conventional stove. The disadvantage is that they are complicated to make, they must be focused often to follow the sun, and they can cause burns and eye injury if not used correctly. Some of these concerns have recently been reduced by Dr. Dieter Seifert's design.

There is a detailed document here showing a large number of variations on these themes. You can also listen to a good introduction to solar cooking here.

[5] http://www.fns.uniba.sk/zp/fond/dieret/solar.html
[6] http://solarcooking.org/solarcooking-faq.htm

**Who made the first solar cooker?**

The first solar cooker we know of was invented by Horace de Saussure, a Swiss naturalist experimenting as early as 1767. See this article for more info.

**Where are solar ovens being used the most?**

There are reliable reports that there are over 100,000 cookers in use in both India and China. We are aware of solar cooking projects in most of the countries of the world. Solar Cookers International has recently had a breakthrough in Kenya using the CooKit panel cooker. More than 5000 families are now solar cooking there.

**How hot do solar ovens get?**

Place an oven thermometer in the sunny part of then oven to get a reading similar to what the cooking pot if "feeling". The temperature reached by box cookers and panel cookers depends primarily on the number and size of the reflectors used. A single-reflector box cooker usually tops out at around 150° C (300° F) as the food approaches being done. High temperatures, however, are not needed for cooking. Your oven will cook just fine as long as it gets up to about 90° C (200° F) or so. Higher temperatures cook larger quantities, cook faster, and allow for cooking on marginal days; However, many people prefer to cook at lower temperatures, since then they can leave the food to cook while they go about their business. With a single-reflector box cooker, once the food is cooked, it just stays warm and doesn't scorch. It's good to keep in mind that no food can go above 100° C (212° F) at sea level anyway, unless a pressurized cooking vessel is used. The high temperatures you see in cookbooks for conventional ovens are just for convenience and for special effects such as quick browning.

**How long does it take to cook a meal?**

As a rule of thumb, you can figure that food in a single-reflector box cooker will take about twice as long as in a conventional oven. However, since you can't really burn your food, you don't have to watch the cooker or stir any food as it cooks. You can just put in a few pots with different foods and then come back later in the day and each pot will cook to perfection and then stay hot until you take it out.

Panel cookers cook smaller portions, usually only in a single pot, but often they cook slightly faster. Some people have reported the need to stir food every once in a while when using this kind of cooker to assure that the food heats evenly.

Cooking with a parabolic cooker is very similar to cooking on one burner of a conventional stove. Since the concentrated sunlight shines directly on the bottom of a pot, the pot heats up and cooks very quickly. The food will burn though. So you have to stir it and watch it carefully.

**Do you have to turn the cooker to follow the sun?**

Box cookers with one back reflector don't need to be turned unless you are cooking beans which take up to 5 hours. Panel cookers need to be turned more often than box cookers, since they have side reflectors that can shade the pot. Parabolic cookers are the most difficult to keep in focus. These need to be turned every 10 to 30 minutes, depending on the focal length.

**Should I take the time to build a box cooker out of "real" materials like plywood or glass or is cardboard good enough?**

Unless you need a cooker that can stay outside even in the rain, you'll do just fine with a cardboard cooker. Cardboard is much easier to work with and holds heat just as well. Some people we know have used the same cardboard box cooker for over 10 years.

**Would a mirror make a better reflector?**

While mirrors are more reflective than simpler materials such as aluminum foil, but the added gain is probably not worth the increased cost and fragility involved with using a mirror.

**Does it help to paint the walls black?**

Some people prefer to paint the walls black thinking that the oven will get hotter. It seems, however, that the walls will get hotter, but the food won't necessarily get hotter. We prefer to cover the inner walls with aluminum foil to keep the light bouncing until it hits either the dark pot or the dark bottom tray. Since the bottom tray is in contact with the pot, the heat the tray collects will move into the pot easily.

**What type of paint should I use?**

In developed countries you can buy flat-black spray paint that says "non-toxic when dry" on the label. Otherwise, black tempera paint works, but you have to be careful not to wash it off when you wash the pot. Solar cookers in Uganda report that they use aluminum pots that have been blackened on the outside by fire.

**Is glass better than plastic for the window?**

People generally report that glass provides about 10% better performance than plastic. And there is reason to believe that under windy conditions, glass is preferred since it doesn't flap in the wind and dissipate heat from the cooker. Plastic, however, is often recommended since is much less fragile and easier to transport and works plenty well. One excellent, easily-obtained plastic film is oven cooking bags. These are for sale in grocery stores and cost less than US$1 per bag. Other plastics will also work. Plexiglas also works well.

**What kind of pots work best?**

Ideally, you want to use a dark, light-weight, shallow pot that is slightly larger than the food you will cook in it. Metal pans seem to cook best. Hardware stores in the US usually carry dark, speckled, metal pans called Graniteware. Shiny aluminum pots--so common in developing countries--can be painted black or can be blackened in a fire. Cast iron pots will work, but extra solar energy is used to heat up the pot as well as the food, so they will not work in marginal conditions.

**What is the best insulation to use?**

If you wish, you can insulate the walls of a box cooker with various substances. Fiberglass or Styrofoam is usually not recommended since they give off ill-smelling gases as they heat up. Natural substances such as cotton, wool, feathers, or even crumpled newspapers work well. Many people, however, leave the walls empty of any stuffing, preferring instead to place a piece of foiled cardboard as a baffle inside the wall airspace. This makes a lighter cooker and seems to be adequate. Most of the heat loss in a box cooker is through the glass or plastic, not through the walls. This is why a few percentage points of efficiency here or there in the walls doesn't affect the overall temperature and cooking power that much.

**Could I use high-tech materials to make a more efficient solar cooker?**

You may find that creating a high-performance cooker using fancy materials will make solar cooking more attractive to people in developed countries. In these countries, cooking only makes up a small percentage of daily energy use, but this is because people in developed countries consume enormous amounts of energy for other purposes (driving, lighting, air conditioning, etc.). Introducing these people to solar cooking is a good way to show them that they can integrate alternative energy into their lives. Solar cooking and drying clothes outside on a line are the simplest, least expensive ways to use solar energy to offset some of this high energy consumption. This will hopefully open them to the possibility of using alternative energy in other ways.

Millions of poor people around the world, however, still cook over a smoky fire everyday. To find wood for the fire, they have to walk many hours everyday. Other poor city dwellers don't have access to wood, so they have to spend up to half of their income on cooking fuel. These people could never afford an oven made of high-tech materials.

So it's up to you to decide which population you want to serve. You could work on creating the most practical solar cooker for people in developed countries to help lead them into a greener future, or you can investigate how to make cookers out of cheap, locally-available materials for people in poor countries who can't afford more.

**Can you sterilize water in a solar oven?**

Yes. In all three types, water can be brought to a boil. A little-known fact, however, is that to make water safe to drink, it only has to be pasteurized, not sterilized. Pasteurization takes place at 65° C (150° F) in only 20 minutes. This treatment kills all human disease pathogens, but doesn't waste the energy needed to bring the water to a boil. One reason that people are told to boil their water is that thermometers are not readily available in many places and the boiling action serves as the temperature indicator. Dr. Robert Metcalf has written a very informative piece called Recent Advances in Solar Water Pasteurization. You will find other references in the Documents page of the Solar Cooking Archive.

**Can you use a solar box cooker for canning?**

Yes, but for fruits only! Do not can vegetables or meat in a solar box cooker, since these foods need to be canned under pressure! You'll find information on canning here.

**Can you cook pasta in a solar box cooker?**

To keep the pasta from getting pasty, use two pans. Heat the dry pasta with oil in one pan; heat the liquid with herbs in another. Fifteen to 20 minutes before eating, combine the two. If you are going to use a sauce, heat that in a third container.

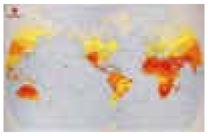
**If solar ovens are so good, why isn't everyone using one?**

There are many factors at work here. First and foremost, the vast majority of the world's population does not even know that it is possible to cook with the sun. When they find out about it there is almost universal enthusiasm, especially in regions where the gathering of cooking fuel and the process of cooking over a smoky fire is a great burden. There are many factors that need to be in place to make it possible for poor people to solar cook on an on-going basis. The most successful projects have been ones where the need was the greatest, the weather the most favorable, and where the solar cooking promoters have taken a long-range approach to the transition. An example of this is the work by Solar Cookers International in the Kakuma refugee camp in Kenya.

**If you build a box cooker out of cardboard, won't it catch fire?**

No. Paper burns at 451° F (233° C) and your cooker won't get that hot.

**How much of the year can you cook?**



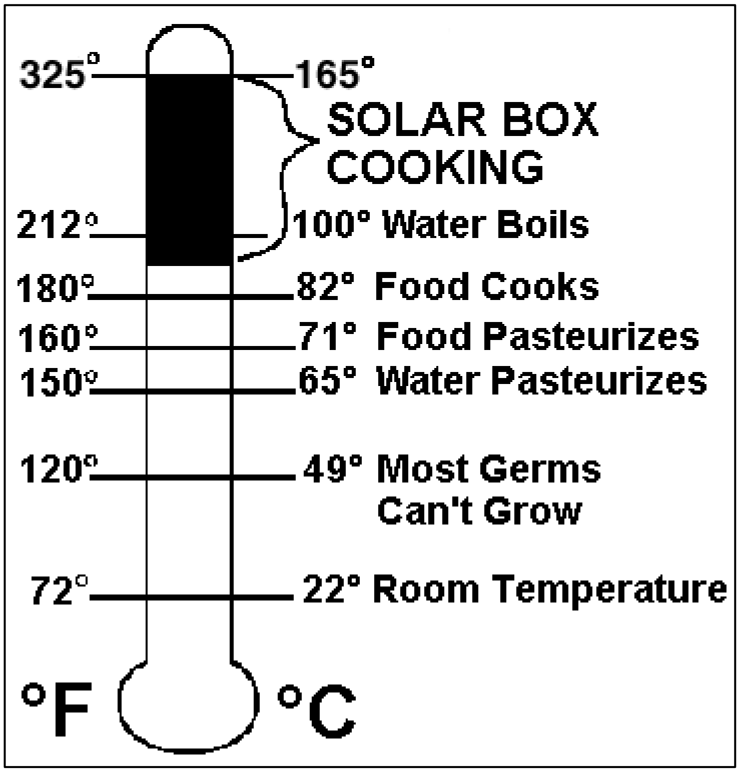
In tropical regions and in the southern US you can cook all year depending on the weather. In areas as far north as Canada you can cook whenever it is clear except during the three coldest months of the year. Click the picture to see a map showing the amount of sunlight each part of the world receives.

**What foods should I try first in my new Cooker?**

A good first food to try is a small quantity of rice, since it is fairly easy to cook and looks very different cooked than it does raw. Chicken or fish is also very easy to cook. See cooking hints or cooking times.

**My cooker only gets up to 250° F (121° C). Is this hot enough to cook when recipes call for 350°F (177° C) or even 450° F (232° C)?**

A temperature of 250° F (121° C) is hot enough for all kinds of cooking. Remember that water cannot get hotter than 212° F (100° C). Thus if you are cooking food that contains water, it cannot get hotter than this either. Conventional cookbooks call for high temperatures to shorten the cooking time



and for browning. Food just takes longer in most solar cookers, but since the sun is shining directly on the lid of the pot, the food browns just about as well as in a conventional oven.

**What happens if the sun goes in front of the clouds while I'm cooking?**

Your food will continue to cook as long as you have 20 minutes of sun an hour (using a box cooker). It is not recommended that you cook meats unattended when there is a possibility of substantial cloudiness. More information on food safety, go here. If you can be sure that the sky will stay clear though, you can put in any type of food in the morning, face the oven to the south and the food will be cooked when you get home at the end of the day.

**I'm planning to do a science project on solar cooking. What should I study?**

If you're planning a science project, Solar Cooker International wants you to know that your research can help extend the world's knowledge of solar cooking and be of great help to people around the world. You should be aware that it's easy to build a high-performance solar cooker if you have access to modern materials. However, the more than a billion poor people in the world, who could really benefit from having a solar cooker, don't have access to such materials. This means that your research will be most useful if it concentrates on the simplification of cooker design or on the use of low-tech, local materials. For more information, see Topics Needing Research.

**What resources are available online?**

Solar Cookers International sponsors the Solar Cooking Archive on the World Wide Web at http://solarcooking.org where you will find illustrated construction plans, photographs, documents, and an international directory of solar cooking promoters. Their thrice-yearly newsletter, the Solar Cooker Review, is also available there. An excellent document for further reading is The Expanding World of Solar Box Cooking, by Barbara Kerr. You'll find a number of audio programs that you can listen to online here. Don't forget to read about eye safety here.

The above-referenced Frequently Asked Questions document can be found at: *http://solarcooking.org/solarcooking-faq.htm* if you are interested in specific solar cooking information.

*Additional References*

Websites that you might find helpful:

- The Solar Cooking Archive: http://solarcooking.org/
    - Box cooker design plans and FAQ: http://solarcooking.org/sbcdes.htm
    - Panel cooker design and rationale: http://solarcooking.org/cookit.htm
    - Parabolic cooker examples: http://solarcooking.org/DATS.htm
- Solar Now, Inc.: www.solarnow.org
- Florida Solar Energy Commission Teacher Resources: http://www.fsec.ucf.edu/ed/teachers/
- Renewable Energy Policy Project: www.repp.org
- U.S. Department of Energy: Energy Efficiency and Renewable Energy Information Center (EERE IC): www.eere.energy.gov
- U.S. Department of Energy: National Renewable Energy Laboratory (NREL): www.nrel.gov/education

Optional Student Reading Assignment:

- The following is an optional reading assignment to introduce students to solar power and research on renewable technologies.

# Solar Power: It's not just a modern idea.


**Figure A.**
Source: Solar Power-Tables for Student Handout.xls

***Thinking about Energy***

What did you do this morning before coming to school? Maybe you were awoken by your blaring alarm clock. You rolled out of bed and, still sleepy, walked over to your computer. You had left it running all night because you were anxiously awaiting an Instant Message from your friend about a party he is having this Friday night. You then proceeded to chat online about the upcoming day and Friday's party, before you decided to take a shower. Maybe you listened to the radio while you were getting ready and used a blow dryer on your hair. Off to the kitchen, where you made yourself breakfast, toasting a bagel or heating a bowl of oatmeal in the microwave, all while watching TV instead of talking to your annoying little brother or sister. Finally, you gathered your books, got into your sports car (the one you got on your 16$^{th}$ birthday) and drove to school.

Now, think about how your morning would have been different if you didn't have electricity in your home or fuel in your car. Our story described a typical morning for many people who live in the United States, so it is easy to see why we consume 25% of the world's energy resources. To provide additional perspective, think about the fact that the online bookseller Amazon.com loses $1 million per minute when a power disruption forces its Internet sites to be unavailable.[7] We have energy intensive lifestyles, and our main sources of energy - nonrenewable resources such as fossil fuels – are running out. Yet most of us have done very little to change our daily routines.

Consider that in direct sunlight, a single acre of land receives solar energy equivalent to four thousand horsepower, which is enough power to move a large railroad locomotive. The solar energy that reaches the Earth in less than three days time is equivalent in energy to all of our fossil fuel resources combined.[8] Why, then, are we not using solar energy more extensively?

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[7] US Department of Energy. "Solar Energy Technologies Program: Why PV is Important To You." http://www.eere.energy.gov/solar/to_you.html. (2 June 2005).
[8] Go Solar Company. "History of Solar Power." www.solarexpert.com/pvbasics2.html. (2 June 2005).

***It's Not Just a Modern Idea***

In ancient times, Greeks and Romans saw the utility of this natural renewable resource. Romans would cover the windows in their homes with glass or mica in order to trap the heat from the sun during the cold winter months.[9] In today's demanding, fast-paced society, merely capturing heat from the sun is certainly not enough. Furthermore, the abundance and low cost of fossil fuels make them a much more attractive means of obtaining energy.

However, even as long as 100 years ago, scientists were concerned about the supply of our fossil fuel resources. The engineer of the very first solar-powered motor, Auguste Mouchout, expressed his fears regarding the fossil fuel supply. In 1860, he wrote, "Eventually industry will no longer find in Europe the resources to satisfy its prodigious expansion. Coal will undoubtedly be used up. What will industry do then?" Mouchout did not merely voice his concern; he worked hard to develop a steam engine that used solar energy to create the steam. To optimize the amount of steam produced to power the engine, he built a large conical shaped reflector to concentrate a large amount of solar heat onto a tank of water. In 1865, because of the implementation of this reflector, he was successful in developing an engine which produced one-half horsepower! Unfortunately, not many others considered this a worthwhile venture, and due to lack of government funding, he was forced to abandon his research efforts.[3]

Mouchout was not the only scientist with the grand idea of harnessing solar energy. In 1885, John Tellier developed a solar panel that was filled with ammonia. Ammonia has a lower boiling point than water; therefore, after exposure to sunlight the panels released enough pressurized ammonia gas to pump 300 gallons of water per hour. This was a true success; however, like Mouchout, Tellier did not continue his research beyond its initial stages.[3]

In 1870, engineer John Ericsson developed a steam engine that closely resembled Mouchout's; however, his method of collecting and reflecting solar rays differed. Ericsson used a parabolic trough that focused radiation in a line rather than at a point. Because it didn't focus the solar radiation onto one spot, the design wasn't as effective at increasing the temperature of water to create steam, so the efficiency of his engine was much lower than Mouchout's engine. However, his collector design was much simpler and cheaper to construct. It was a good compromise between efficiency and ease of operation, and it became the design of choice for modern solar collectors.[3] Unfortunately, Ericsson passed away before his design was further developed.

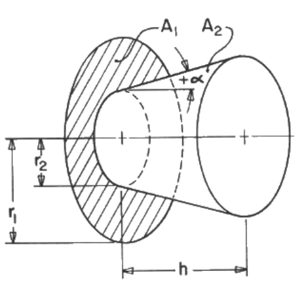


**Figure B. Conical Shaped Reflector design**
Source: www.me.utexas.edu/~howell/sectionc/C-49.html

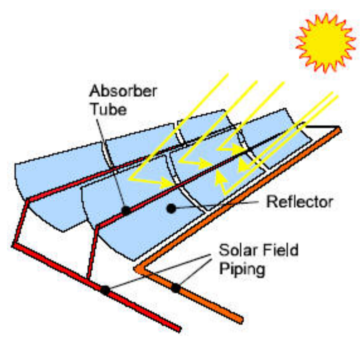


**Figure C. Parabolic Trough design**
Source: www.solarpaces.org/ csp_technology.html

[9] Smith, Charles. History of Solar Energy: Revisiting Solar Power's Past *Technology Review*: July 95 http://www.solarenergy.com/info_history.html.

The first real commercial venture to supply solar power to the public began in 1900 when Aubrey Eneas opened the first solar-power company. Due to the high cost of operation and setbacks with equipment, Eneas was forced to discontinue his business venture, but not before he increased public awareness about the utilization of solar energy. Later, in the mid-1980's, engineers tried yet again and started the Solar Motor Co., which opened a power plant based entirely around solar energy, utilizing the parabolic trough design for its solar collectors. This time, it was not design flaws that forced the efforts to come to a halt – it was the US economy. Oil prices were falling and investors were not making enough money in solar energy. Therefore, they withdrew from the project and the company couldn't afford to continue business operations.[3] Today, we have made many advances in the utilization of solar energy, but the costs are still not comparable to fossil fuel-run utilities. As a result, few American families have invested in solar technology for their homes. Research is on-going and there are many advances being made to improve the efficiency and cost of solar power.

***<u>Benefits that Could Change Lifestyles</u>***

If so many scientists have tried and failed to implement the usage of solar energy as a means of harnessing power, why are we still trying? Well, solar power has many advantages. It is environmentally friendly. "Compared to utilities generated from fossil fuels, each kilowatt of PV-produced electricity offsets up to 830 pounds of oxides of nitrogen, 1,500 pounds of sulfur dioxide, and 217,000 pounds of carbon dioxide every year." [1]This elevates the effects of global warming that are causing rises in sea levels and eroding shorelines. Solar cells have low maintenance because they have few moving parts, and therefore produce electricity quietly, without the noise of loud generators.[1] Growing realization of the "full" costs of fossil fuels (e.g., with respect to their contributions to global warming) is prompting nations, industries, and individuals to take a fresh look at solar power.

Currently solar power is used in calculators, satellites, emergency road signs, and parking lot lights. Where the cost of stringing a conventional power line is high (such as for temporary road signs), solar can be a very cost-effective solution. Some homes even have solar panels as a means of producing some of their electricity.

If used properly, solar energy can even power a light-weight car such as the one pictured below. The world record for the farthest that any solar-powered vehicle has traveled is 4,375 miles across Canada. However, the vehicle that accomplished this feat was a mere 700lbs and used an average of only 1kW (as much as a hairdryer). The typical gasoline-powered car uses 20kW when cruising![10] Therefore, one obvious implication of converting to solar-powered transportation is that we would need to drive smaller, more energy-conservative vehicles. The same is true if we were to use solar energy to power our homes. If a home's maximum energy requirement is a mere 5,000 watts, and solar cells are only 10% efficient, then 50m$^2$ of solar panels would be needed in order to provide it with enough power.[4] To implement the use of solar energy using current technology, we would need to make some adjustments to our daily routines and try to live a less energy- intensive lifestyle. Is this a choice we are willing to make?

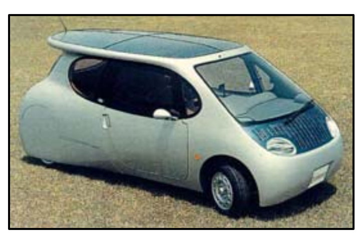

**Figure D.**
Source: www.censolar.es/solarcar.htm

[10] Gerdes, Berk; Medina, Francelys. "Solar Power." *Penn State GREATT Project.*

Name: ________________________________

# Solar Cooking

*(Warming Up to the Properties of Solar Radiation & Its Uses in Our Homes)*

**Part 1: Virtual Solar Cooker Wrap-Up**

*In this section, you need to start by making some notes about what you observed while investigating the properties of radiant (light) energy using the "Virtual Solar Cooker." You will then answer a series of questions as you work through the process of selecting materials and constructing a solar cooker with your team.*

| Virtual Solar Cooker Notes |
| --- |
| |

**What happens when solar energy strikes an object?**

Here are three possibilities: it may be *transmitted* through the object, the object may *reflect* the solar energy, or the object may *absorb* it. Most objects do all three, but some are better at each than others.

It is useful knowledge to understand how different materials transmit, reflect and absorb solar radiation. For instance, in the case of a solar cell, it is important to coat the surface with a material that is a poor reflector—we want as much light as possible to enter the cell. Accordingly, creating comfortable, well-lit homes, schools, and offices requires an understanding of which building materials transmit, reflect, and absorb solar radiation. (After experiencing this lesson you may even begin to select the color and texture of new clothing purchases depending on the strength of sunlight during the seasons!) For your solar cooker, choosing materials based on their ability to transmit, reflect and absorb is important and may make a big difference in your cooking success.

From your experience using the virtual solar cooker and in your daily life, make some statements about how well various materials reflect or transmit solar radiation and how well each material absorbs solar radiation.

1. **Transmission**: On the basis of your observations, rate each material's ability to transmit light as *Excellent, Good, Fair, Poor, No Ability* and record it as the description in the Data Table.
2. **Reflection**: On the basis of your observations, rate each material's ability to reflect light as *Excellent, Good, Fair, Poor, No Ability* and record it as the description in the Data Table.
3. **Absorption**: On the basis of your observations, rate each material's ability to absorb light as *Excellent, Good, Fair, Poor, No Ability* and record it as the description in the Data Table.
4. For each column, rank each of the materials so that the number 1 represents the material that is the best transmitter, reflector and absorber.

**Data Table 1.**

| Material | As a Transmitter | As a Reflector | As an Absorber |
|---|---|---|---|
| | Description-Rank | Description-Rank | Description-Rank |
| Mirror | | | |
| Window Glass | | | |
| Frosted Glass | | | |
| Aluminum Foil | | | |
| Mylar | | | |
| Copper Sheeting: Unpainted | | | |
| Copper Sheeting: Black-painted | | | |
| Wood | | | |
| Waxed Paper | | | |
| Cellophane: Clear | | | |
| Cellophane: Blue | | | |
| Cellophane: Red | | | |
| Construction Paper: Black | | | |
| Construction Paper: Yellow | | | |
| Construction Paper: Red | | | |
| Construction Paper: Blue | | | |
| Construction Paper: Green | | | |

**Part 2: Select a Solar Cooker and Test Your Predictions**

Now it's time to start field-testing your ideas! First take a look at the questions below to help you select a type of cooker and materials:

1. What food(s) do you want to cook? Explain the type of solar cooker that would be best for the job.

| Food(s): | Explanation: |
|---|---|
| Cooker Type: | |

2. What properties of transmission, reflection, and absorption of light would you look for in the materials used to build a solar cooker? (For example, should your cover be a better transmitter, reflector or absorber?) Make a materials list for the three (3) parts of your solar cooker and explain your reasons for choosing them in the boxes below.

| Cover (Glazing) | Insulation | Reflector |
|---|---|---|
| | | |

3. Think back to the equation: $I = T + R + A$, now use this relationship to describe the materials you have chosen.

| Cover (Glazing) | Insulation | Reflector |
|---|---|---|
| | | |

4. Make a sketch of your solar cooker below.

5. What else might you want to find out about your solar cooker (Hint: it may also let you know that your food is done.) Work with your team and teacher to devise a way to collect this data and create a data table below or using an electronic spreadsheet.

Please review all of the safety instructions with your teacher and team.
**Now you are ready to construct and cook (test)!**

**Solar Cooking Thought Questions:**

6. Look back at Data Table 1. Did your observations from the virtual investigation help you to make decisions about how your cooker would measure up in real life?

7. What are the limitations of using a solar cooker? Describe how they may be overcome.

8. What could you do to improve your design?

9. Using what you learned, what exterior and interior colors and materials would you want in a car if you lived in a hot sunny climate? What colors and materials would you pick if you lived in a cold sunny climate?

10. How might you use the principles of solar radiation in other parts of your life or home?