The Science Behind Solar Cookers

Overview

Parabolic solar cookers are a trend of innovative cooking device that harvests sunlight, one of the most abundant and sustainable energy sources, to cook. Here we discuss the science and environmental effects of a solar cooker through hands-on activities.

Objectives

By splitting into 2-3 person groups, students work in teams to build a mini solar cooker model that embodies the basic principles of a parabolic solar cooker, form hypothesis of related parameters and test them through various investigation activities.

Activities Guide

Part A: Introduction of Parabolic Solar Cooker (5-10 min)

- Part B: Build Your Own Solar Cooker (~ 20 min max)
- Part C: Explore Your Solar Cooker (Optional)
 - a. Melting Chocolate
 - b. Deep Bowl vs. Shallow Bowl
 - c. Indoors vs. Outdoors
 - d. S'mores Under the Sun!

Part D: Test Your Understanding (Exercise Questions)

Part E: Further Readings (Optional)

Part F: In-Class Alternative Demonstration (Optional)

Appendix I: Commercial Parabolic Solar Cooker (SolSource) Specification Reference

Appendix II: State Science Curriculum Requirement

Appendix III: Customize the Plan for Your Classroom

Classroom Preference

Outdoors, or indoors space where sunlight reaches

Sunny and clear

Relatively little or no wind, dry

Temperature preferably above 50° F/ 10° C, the warmer the better

Educational Kit

Science: Sustainability 6th Grade Classroom

Materials

Part B: Building (for one model)

aluminum foil hard paper /thin cardboard tape/glue stick scissor, paper knife a ruler or other straight edge plastic wrap or clear plastic bags two printed design sheets

Part C: Investigation

milk chocolate chip mini marshmallows graham crackers / sliced bread a watch/stop watch

With a SolSource Cooker

pg 2

pg 5 If you have a SolSource concentrator, set it up with a pot of water right after the introduction while students proceed to Part B. At the end of class, compare the time it takes to boil the water to that of the student experiments. You can also cook some food

pg 14 pg 17 for the class during student experiments.

pg 18 Other Resources

- pg 20Interactive Virtual Experiment by Scootle:
Energy from the Sun, Design a Solar Cooker:pg 21http://www.scootle.edu.au/ec/viewing/L1140/index.html
SolSource Technology Illustration by One
- Earth Designs: pg 23 <u>http://www.oneearthdesigns.com/solsource/technology</u> Solar Cookers International
- pg 24 <u>http://www.solarcookers.org</u>
- pg 27

No-Sun Alternative

An A-type heat lamp with 250 Watts can be used as the substitute for sunlight to conduct the same activities indoors, though this alternative is not encouraged if natural sunlight is present. Another option is the indoor alternative demonstration (see pg. 21).

The Science Behind Solar Cookers Part A: Introduction to Solar Energy and Solar Cookers

Time: 5-15 minutes, depending on the class need (See Appendix III for recommendations).



What is energy? We use energy in every aspect of our daily lives – watching TV, cooking dinner, doing laundry, using computers, heating the house, etc. Almost every human activity uses energy in one form or another, such as electricity and heat, but we can't always see it through our own eyes. The most commonly used form of energy in our daily lives is thermal

energy. In the United States, Australia, and some other parts of the world, thermal energy takes up about 70% of the energy end-use consumption in the residential sector¹, in which space heating and water heating are the top two areas for thermal energy consumption.

Where do we get thermal energy? The sun, for example, provides the cleanest and most sustainable thermal energy on earth, comparing to other traditional sources such as fossil fuels and gas. The light that travels from the Sun to the Earth is called solar energy. While many solar panels nowadays absorb light and convert it to electricity, they are inefficient – only about 15% of the light rays that strike a solar panel are converted to electricity. Many cooking devices use electricity or gas to produce thermal energy to cook, but there is also energy lost when electricity is converted to heat.

A solar cooker is a smart cooking device that collects sunlight and converts it to heat directly. By eliminating the step of converting to electricity back and forth, a high-performance solar cooker can convert more than 80% of the incoming sunlight into heat. Using solar cookers and similar heating devices at home helps cut down the energy cost and reduces the carbon emission from using gas or fossil fuels.

¹ Data reference from 1) Buildings Energy Data Book, US Department of Energy, <u>http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx</u> 2) Energy Use in the Australian Residential Sector 1986 – 2020 – Department of Environment, Water, Heritage and the Arts (DEWHA), 2008

Other concepts to cover/reinforce:

- The sun is a parallel source of light.
- Three main types of solar cookers: (image and text: http://jknappcommunications.com/cookingwithsunshine/about.htm)



High-temperature reflector cookers typically use a parabolic mirror to focus sunlight on a cooking vessel. The focal point of the parabola can become very hot indeed—typically reaching temperatures of 600°F and above—in a very short time, making cooking with one of these similar to cooking on a conventional stovetop. Besides a parabola, other mirror geometries can be used to create the focal point: segmented near-parabolas, Fresnel mirrors, and the "three-circle" geometry popular in China. All use the same principle.

Other creative designs of solar cookers can be found here: <u>http://solarcooking.org/plans/</u>

Question: which type of solar cookers is the most efficient and powerful? Answer key: parabolic.

- To help students understand the performance of solar cookers in real life, please see *Appendix I* (*pg. 21*) for reference on real-life commercial cookers specification.
- Although the parabolic high-temperature cookers are the most efficient, they are hard to build in a short amount of time. For the purpose of this class, we provide students a modified version of the CooKit panel cooker model provided by *Solar Cookers International* to build for the activities.

Solar energy as a form of sustainable energy source
 Question: How is solar energy different comparing to conventional energy sources, such as fossil fuels? What environmental impact does it have?
 Answer Key: Solar energy is abundant, sustainable and clean, and has no negative environmental impact, whereas fossil fuels are unsustainable and emit large amount of greenhouse gases and pollution.

■ Form of Energy

Energy has many different forms. Temperature change results from adding or taking away heat energy from a system. Heat moves in predictable ways, from warmer to cooler objects until reaching equilibrium.

- Energy transformation in the process of solar cooking Example: Solar energy (light) – thermal energy (heat)– chemical or kinetic energy (food and body)
- Parabolic light collection

Teacher should draw the diagrams on the board, and have students draw the reflected light rays for both diagrams before introducing this geometrical principle.



A mirrored surface reflects a ray of light at the same angle at which it strikes the surface.

A parabola's unique shape has a slope that is proportional to the distance from the center. This means the further from the center a light ray strikes the parabola, the narrower its incident angle, and the broader its change in direction when it is reflected. In this way, all the light rays get reflected back to a single point.



Other basic designs of solar cookers

Example images at <u>http://solarcooking.org/plans/</u>, i.e. box oven, panel cookers, etc. **Question:** What are some of the central ideas behind all of these models? **Answer Key:** reflective surface, concentrated light, heat absorption, heat loss control, etc.

Question: What are some of the parameters to consider when designing a solar cooker?

Answer Key: Shape, size, materials, weather, capacity, etc.

Other image source: One Earth Designs: Technology

http://www.oneearthdesigns.com/solsource/technology

Part B: Build Your Own Mini Solar Cooker

Time: ~ 20 minutes

Objective:

In order to explore the basic principles of a parabolic solar cooker with a mini solar cooker model that is easy to construct, here we adopt the model of a panel cooker (source: Solar Cookers International CooKit) that embodies elements and principles of box and curved concentrator cookers. Students learn how to construct a prototype with proper tools and instruction, as well as teamwork with others.



Image Source:

Solar Cookers – How to Make, Use and Enjoy, 10th edition, by Solar Cookers International

Building Instructions:

(note: 1) the hard paper can be substitute with thin cardboard. 2) The teacher should inform the students about the safety of the using the tools.)

- 1) Take 1 piece of a hard paper (equal or more than regular US letter size). Tape or glue the aluminum foil smoothly and completely on one surface of the paper. The shiny side of the foil should be on the outside. Take 1 copy of the printed cooker design (half of a cooker, see *Pg. 5* for printable design sheet). Align and loosely tape the design sheet on the other side of the paper (non-reflective side).
- 2) Use a scissor to cut along the contour of the sketch (black bold lines). Make sure to use a paper knife/scissor and a ruler to cut out 3 sets of slots on the front panel, as drawn.
- 3) Fold the piece towards the aluminum foil surface along the dotted lines.
- 4) Repeat step 1-3, except this time, loosely tape the sketch sheet on top of the aluminum foiled surface. Now you should obtain two opposite halves of the solar cooker. When put together, it should resemble the original shape:





- 5) (Optional) Paint the central area of the bottom panel black.
- 6) Insert the flaps on the side into slot 2 (default) on the front panel. Adjust the angle of the panel.



- - FOLD LINES

L

L

Part C: Explore Your Solar Cooker a. Melting Chocolate

Objective:

Students learn to test the basic cooking ability of their solar cooker model from Part A by melting a chocolate chip. Students learn how to test a hypothesis and record the observations in scientific reasoning, as well as how the near - parabolic shaped solar cooker concentrates energy.

Materials:

Mini solar cookers from Part A Milk chocolate chip Graham cracker/ cracker/ bread **Procedure:**

1) Assemble the cooker model from Part A with default angles.



- 2) Place the mini solar cooker models the student just made on a flat surface under the sun, facing the direction of the sunlight so that the shadows are directly behind the cookers. Tilt the mini cooker if necessary (i.e. put a book below) to gather maximum sunlight.
- 3) Put a small piece of cracker in the middle of the bottom black box. Put a chocolate chip on top.
- 4) Next to the solar cooker model, put a small piece of white paper on the surface. Also put a piece of chocolate chip on top of the paper.
- 5) In teams, students observe and time the melting process of both chocolate chips. Recommend to record the observation of chocolate chips every 30 sec/1 minute (depending on how fast the chocolate is melting). Students should record their observations and result on the worksheet (see pg. 7). Students can eat the melted products.

Tips:

- A nice dry, sunny day is essential. If it's a bit windy, use small pebbles or heavy objects to hold the cooker on the ground. The temperature should not be less than 40°F/5°C.
- Orient the solar cooker directly towards the sun so that there's no shadow inside the cooker, and the shadow of the cooker should be directly behind its back.
- Adjust the angle of the front panel so the size of its shadow underneath is at most half the size of the panel.
- Indoors space where the sunlight reaches are also good location for this experiment. For optimal result with the sun most intense, the experiment should be done between 10 am and 2pm. The higher angle the sun, the better and faster result.

Activity C.a. Student Worksheet 1

Date		Outdoors/Indoors?	
Temperature		Describe the environment	
Test Objects:	А.		
	В.		
What's your hypothesis?)		
Start Time:			
End Time:			
Time lapse (either template)	Observation A		Observation B
30 sec / 1 min			
60 sec / 2 min			
90 sec / 3 min			
Conclusion:			

Compare your results to that of a real parabolic solar cooker (Appendix I). Which one is more powerful? Why?

Activity C.a. Student Sample Response

Date	1/13/14	Outdoors/Indoors?	Outdoors		
Temperature	47 °F	Describe the environment	Sunny, windy		
Test Objects:	A. A chocolate chip pl	aced in the center of the solar coo	oker		
	B. A chocolate chip pla	aced on a piece of paper			
What's your hypothesis?	?				
Object A melts faster that	an object B under the sun				
Start Time: 12:50pm					
End Time: 12:55pm					
Time lapse	Observation A		Observation B		
1 min	Color turned light. Looked moist.		No change.		
2 min	Started melting on the very tip.		No change.		
3 min	Largely melted, both on the tip and on the bottom		No change.		
5 min	Completely melted and became liquid		No change.		
Conclusion:	Object A started melting under 3 minutes and completely melted in 5 minutes, whereas object B did not melt throughout the experiment. The solar cooker does indeed concentrate energy from the sun.				
		• • • • • • • • •			

Compare your results to that of a real parabolic solar cooker (Appendix I). Which one is more powerful? Why?

Part C: Explore Your Solar Cooker b. Deep Bowl VS. Shallow Bowl

Objective:

This experiment explores relationship between the steepness of the solar cooker concave (slope of the parabola shape) and its cooking capacity. Students get to learn the mathematical concept of parabola and its focus, and by comparing the results of different concave shapes, they can determine the optimal concave for their solar cooker model.

Materials:

Mini solar cookers from Part A Milk chocolate chip Graham cracker/ cracker/ bread

Procedure:

- 1) Insert the flaps on the side of the mini cooker model into slot 1 (the outermost slot on each side)
- 2) Place the mini solar cooker models the student just made on a flat surface under the sun, facing the direction of the sunlight so that the shadows are directly behind the cookers. Tilt the mini cooker if necessary (i.e. put a book below) to gather maximum sunlight.
- 3) Put a small piece of cracker in the middle of the bottom black box. Put a chocolate chip on top.
- 4) In teams, students observe and time the melting process of both chocolate chips, and record their observation on the activity worksheet (see pg. 10). Students can eat the melted products.
- 5) Insert the flaps into slot 2 and 3, and repeat steps 3-4 respectively.
- 6) Compare and discuss the results for each of these slot settings. What changed? How did the change affect the result? Why?

Tip:

- This experiment goes faster if students are separate into at least three groups, with each group test a different setting simultaneously.
- Adjust the position of the cooker and the front panel accordingly to the changing angle of the sun.





Activity C.b. Student Worksheet 1

Date		Outdoors/Indoors?			
Temperature		Describe the environment			
Test Objects:	А.			1	
	В.				
	C.				
What's your hypothesis	5?				
Slot setting	Start time	End time 1	Time it took for chocolate to start melting	End time 2	Time it took for chocolate to completely melt
Slots 1 (Shallowest)					
Slots 2 (Less Shallow)					
Slots 3 (Steepest)					
Conclusion /					
Question:					
How do you explain the different result in regards to the steepness of the cooker's bowl-shape?					

Activity C.b1. Student Sample Response

Date	1/15/14	Outdoors/Indoors?		Indoors	
Temperature	77°F	Describe the environment		Very sunny, dry, no wind	
Test Objects:	A chocolate (on a piece of bread) placed in the center of the solar cooker which A. flaps inserted in slots 1 (outermost slots, the shallowest bowl) B in slots 2 (middle slots, less shallow) C in slots 3(innermost slots, steepest bowl)				
What's your hypothesis	5?				
Shape A cooks the faste	est, while shape C co	oks the slowest. (whic	ch is proven wrong	by the data)	
Slot setting	Start time		End (Melt) time		Time Lapse
Slots 1 (Shallowest)	12:27pm		12:30pm		3 minutes
Slots 2 (Less Shallow)	12:34pm		12:36pm		2 minutes
Slots 3 (Steepest)	12:41pm		12:45		4 minutes
Conclusion / Question: How do you explain the different result in regards to the steepness of the cooker's bowl-shape?	The 2 nd slot is the lot faster than E wind. So tempe	he optimal shape t Ex.2. because of th erature and wind a	hat gathers most e much higher in lso greatly affect	t energy. The or ndoor temperat is the effect of t	verall melting time is a ure and absence of he solar cooker.

Activity C.b. Student Worksheet 2

Remind yourself about how sunlight is reflected by the surface of your solar cooker (Please draw the reflected light ray and label the angle on the following diagram:



For each of the following diagrams, please draw the reflected sunlight. Where is the focus? How is the focus related to the shape of the parabola? How does this difference in shape affect the speed of melting chocolate?



The Science Behind Solar Cookers

Part C: Explore Your Solar Cooker c. Indoors Vs. Outdoors

Objective:

Besides the sunlight, what other conditions might affect the cooking results? This experiment explores the different conditions involved in the indoor vs. outdoor environment. Students learn to determine the variables in a scientific experiment, compare different results, and draw conclusions.

Materials:

Mini solar cookers from Part A Milk chocolate chip Graham cracker/ cracker/ bread Plastic wrap / clear plastic bags/glass cover (optional) *Note: This experiment should only be conducted when there is quite a temperature and/or wind difference indoors (or with a clear cover outdoors) and outdoors without a cover. Both spaces should be covered in direct sunlight. Also, all experiments should be done simultaneously or back to back in a short period of time to better control other variables, such as the changing position of the sun.

Procedure:

- 1) Insert the flaps on the side of the mini cooker into the optimal slot determined from activity C.b (or slot 2, the default setting if not done C.b).
- 2) Find an indoor space under the sunlight, and place the mini solar cooker models appropriately, facing the direction of the sun.
- 3) Put a small piece of cracker in the middle of the bottom black box. Put a chocolate chip on top. observe and time the melting process of both chocolate chips, and record their observation on the activity worksheet (see pg. 10).
- 4) Simultaneously or right after step 3, repeat step 3 outdoors.
- 5) Simultaneously or right after step 4, cover the solar cooker model with a layer of plastic wrap or clear plastic bag. Then repeat step 3 outdoors.

Alternative:

If there is no indoor space with direct sunlight, students can do this experiment outdoors with a clear cover over the food. In the above mentioned procedure, skip step 2, and the rest stays the same.

Activity C.c. Student Worksheet

Date						
	Indoor Setting		Outdoor Setting			
Temperature						
Wind						
What's your hypoth	nesis?			1		
Slot setting	Start time	End time 1	Time la (starting melt)	pse g to	End time 2	Time Lapse (melt completely)
Indoors						
Outdoors (without						
plastic cover)						
Outdoors (with						
plastic cover)						
Conclusion:						
result with both of the						
outdoor results, what pattern can you see?						
How might different						
affect the result?						

What other conditions do you think might affect the solar cooker's performance?

Activity C.c. Student Sample Response

Date	1/15/14						
	Indoor Setting			Outdoor Setting			
Temperature	77°F (25°	C)		44	.6°F (7°C)		
Wind	No wind			M	Moderate wind		
What's your hypothesis	?						
Stronger wind and lowe	er temperature make t	he cooker cook slow	er.				
Slot setting	Start time	End time 1	Time la (starting melt)	pse g to	End time 2	Time Lapse (melt completely)	
Indoors	11:43am	11:45am	2 minute	es	11:48am	5 minutes	
Outdoors (without plastic cover)	12:02pm	12:07pm	5 minute	es	12:12pm	10 minutes	
Outdoors (with plastic cover)	12:10pm	12:14pm	4 minute	es	12:18pm	8 minutes	
Conclusion: Comparing the indoor result with both of the outdoor results, what pattern can you see? How might different wind and temperature affect the result?	Comparing indoors result with outdoors without plastic cover, we see that with the presence of both lower temperature and stronger wind, it takes almost twice as long for the solar cooker to melt the chocolate than indoors. Comparing the cooker's indoor performance with outdoors with the plastic cover, we eliminated the effect of the wind. With only the lower temperature, it still takes longer to melt chocolate, but not as long as the one with the presence of strong wind. In summary, both lower temperature and stronger wind will slow down the work of the solar cooker.						

What other conditions do you think might affect the solar cooker's performance?

i.e. Angle of the sun, time of year and day, humidity and precipitation, amount of sun, size of food, etc.

Part C: Explore Your Solar Cooker d. Let's Make S'mores!

Objective:

On a hot, dry and sunny day, what can be a more memorable way to end the class than making delicious S'mores with the students' self-made mini solar cookers? If the weather and condition are good, this is a highly recommended activity to do as the students can enjoy their delicious products while learning about the effect of different surface (white vs. black surface) on heat absorption.

Recommendation with SolSource:

For teachers with a SolSource solar concentrator, make a S'more on SolSource as a class before the student experiments and record the time it takes. After student experiments, each group should compare their result with the SolSource result and answer the following **questions**:

- 1) Which one cooks S'mores faster?
- 2) What do you think makes one cooks faster than the other? How can you improve the slower one?

Materials:

Mini solar cookers from Part A

Milk chocolate chip or Hershey's milk chocolate bars

Graham cracker

Mini marshmallows

(optional) clear plastic cover (Plastic wrap / clear plastic bags/glass cover)

Procedure:

- 1) Insert the flaps on the side of the mini cooker into the optimal slot determined from activity C.b (or slot 2, the default setting if not done C.b).
- 2) Find an indoor or outdoor space when the sun is strong, and place the mini solar cooker models appropriately, facing the direction of the sun.
- 3) Put a small piece (About ¼) of a graham cracker in the bottom black box. Put a couple chocolate chip or a Hershey's bar on top of the graham cracker. At last, layer 1 or 2 mini marshmallows on top of the chocolate.
- 4) Wait and enjoy the delicious mini S'mores! You can also test the capacity of the solar cooker by putting several S'mores at the same time.
- 5) Remember to adjust the position and angle of the solar cooker during the process if necessary. If the environment is not ideal, put a clear plastic cover over the solar cooker (plastic wrap, glass, or bag) to retain heat.

Student Question:

As you may have observed, why does the chocolate melt a lot faster than the marshmallow?

(black surface absorb heat > white surface)

Part D: Test Your Understanding Exercise Questions

Objective:

The following question sheet (see pg.18) can be used by teachers to test students' understanding of the topic. Students can work in teams or individually either in class or as an after-class assignment.

Answer Keys:

1. Is solar energy a sustainable or unsustainable source? Please list two sustainable and unsustainable energy sources each.

Sustainable.

Sustainable sources: solar, wind, geothermal, hydroelectricity, tidal power, biofuels, etc. (note: nuclear is renewable but creates enormous amount of by-products.) Unsustainable sources: fossil fuels, gas,

2. In principle, how does a solar cooker work?

A solar cooker captures the sun's light energy and converts it into heat energy.

3. What role does the shape of the solar cooker play in the process? Explain how the parabolic shape of your solar cooker helps collect sunlight. A diagram may help.

With a reflective surface, the parabolic shape of the solar cooker reflects the incoming parallel light rays and concentrates them into a single focus point, thus greatly increases the energy at the focus. A diagram see pg.3.

4. What angle or position is the most effective for generating heat in a parabolic solar cooker?

For maximum heat, align the axis of the parabola with the direction of the sunlight. Adjust the angle of the solar cooker if necessary throughout the day as the position of the sun changes.

5. What aspects can you improve to increase the efficiency of your solar cooker?

Bigger size, smoother and shinier surface, better parabolic shape, black cooking device, transparent cover to insulate the cooker from the outside elements, etc.

6. Besides cooking food, can you think of other ways to use a solar cooker around your house?

One other way is to heat water for household use. Other creative answers are also acceptable.

- 7. What are some limitations of your solar cooker? Is there any way to overcome these limitations?
- Dependent on the sun. The cooker should be flexible and portable to change location of the solar cooker during the day to maximize collection of the sunlight.
- Dependent on the temperature and wind. Design an insulation or cover to shield the cooker from outside elements.
- Other answers are also acceptable.

The Science Behind Solar Cookers

Test Your Understanding

Student worksheet

Please answer the following questions based on what you've learned about solar cookers and hands-on experiments:

- 1. Is solar energy a sustainable or unsustainable source? Please list two sustainable and unsustainable energy source each.
- 2. In principle, how does a solar cooker work?
- 3. What role does the shape of the solar cooker play in the process? Explain how the parabolic shape of your solar cooker helps collect sunlight. A diagram may help.
- 4. What angle or position is the most effective for generating heat in a parabolic solar cooker?
- 5. What aspects can you improve to increase the efficiency of your solar cooker?
- 6. Besides cooking food, can you think of other ways to use a solar cooker around your house?
- 7. What are some limitations of your solar cooker? Is there any way to overcome these limitations?

Part E: Further Readings (Optional) Solar Cooker -- A Small Tool for Big Problems

Objective:

In reality, solar cookers are used in various ways to improve livelihood of people around the world. After understanding the basic science behind the solar cookers through hands-on activities in class, students should also conduct some research to understand the bigger picture of technology in the context of society and communities.

Objectivity/Assignment:

Student work in 2-3 person teams to conduct internet research on current solar cooker development, such as projects, companies and organizations that are using solar cookers as a tool to solve regional problems and improve livelihood of the people in the region. In class, students should report or present their research on one of these organizations and projects to the class.

Recommended Resources:

One Earth Designs

A social enterprise that promotes environmental health and local innovation in the Himalayan communities in Western China.

http://www.oneearthdesigns.com/

http://solarcooking.wikia.com/wiki/One_Earth_Designs

Solar Cooker Project: Protecting and Empowering the Women of Darfur

http://www.solarcookerproject.org/

SCINet: Solar Cookers International Network

http://solarcooking.wikia.com/wiki/Solar_Cookers_International_Network_(Home)

http://solarcooking.wikia.com/wiki/Solar_Cookers_International

Part F: In-Class Alternative Demonstration

With a Laser Pointer

Objective:

Although not the ideal result, if weather does not permit outdoor experiment, students can explore the principle of light reflection in the solar cooker model by an indoor demonstration using a laser pointer. The laser pointer emits a beam of light that resembles a beam of sunlight. After building the solar cooker model, students can test and predict how well their models concentrate sunlight by observing the reflection of each light beam on the surface of their models. The outdoor experiments in Part C can be saved for later when weather is good.

Materials:

A pre-made teacher's model from Part B

Same materials as Part B

A laser pointer

(Demo B only) A wide strip of white and black paper each (same width as middle section of the back panel)

Class Demo A Procedure:

- 1) Use a teacher's pre-made model of the panel cooker. After Part A and before students move on to Part B, drew the following diagram of the model on the board and asked students to come up and draw their prediction on how light reflects in this particular model.
- 2) Use a laser pen to emit a beam of red light representing a beam of sunlight.Point the laser pointer to the reflective surface of the back panel of the cooker model at a steep angle (about 75° to the level surface). You should be able to see a red dot on the bottom panel of the model as the reflected point from the light beam.
- 3) Keep the pointer and the light beam parallel to the one in step 2. Move your arm horizontally so that the pointer points to other panels of the panel cooker around the bottom. Go around the panels and the reflected red dot should mostly stay within the bottom panel.
- 4) Ask the students to summarize their observation and draw the following reflected beam on the board to formulate their ideas of how the solar cooker concentrates incoming sunlight.
- 5) Return to Part B and students build their own models. After Part B, students can use the laser pointer to test the concentrating ability of their own device.



Class Demo B Procedure: Surfaces

- 1) Use a teacher's pre-made model of the panel cooker. After Part A and before students move on to Part B, cover the central back panel of the model and the center of the bottom panel with the white strip of the paper. use a laser pen to emit a beam of red light representing a beam of sunlight.
- 2) Point the laser pointer to the reflective surface of the back panel of the cooker model at a steep angle (about 75° to the level surface). Ask students to record their observations.
- 3) Repeat step 2 with the black strip of paper.
- 4) Repeat step 2 without the paper cover (point the laser pointer directly to the reflective aluminum surface.
- 5) Students compare the observations on three surface, and make conclusions on the reflectivity of the three different surfaces.

Questions:

- 1) Which surface reflects the most light? Which one reflects the least light?
- 2) Which surface absorbs the most light? Which surface absorbs the least light?
- 3) How does the ability of the surface to reflect affect the solar cooker?
- 4) What surface should we use in a solar cooker and why?

Answer Keys:

- 1) Aluminum surface. Black surface.
- 2) Black surface. Aluminum surface.
- 3) The better the surface of the solar cooker reflects the light, the more efficient / stronger the solar cooker is.
- 4) We should use the most reflective surface because it helps concentrate sunlight the most.

Class Demo C Procedure: Heat Lamp

1) If there's a heat lamp (~ 250 Watts) available for the class, it can be used instead of sunlight for activity C.a, b, and d. Rest of the procedure is the same as those Part C activities respectively.

The Science Behind Solar Cookers

Appendix I

Commercial Parabolic Solar Cooker (SolSource) Specification Reference

It is important for students to understand the power for solar cookers in real life nowadays. The teacher can either present the following material in *Part A. Introduction*, or have students compare their experimental data in Part C, wherever indicated, to the following parabolic high-performance commercial solar cooker specifications.

Parabolic High-Temperature Cookers

Example: SolSource Solar Concentrator by One Earth Designs

Product Feature:

- 360° rotatable reflective panel for sun tracking
- $5^{\circ} \sim 60^{\circ}$ elevation angle adjustable (High sun and low sun settings available)
- Powerful pot stand can support most kettles, pots and grill plates
- Foldable tripod legs
- Easily installation and tool-free disassembly for storage

Power (On sunny days):

- boils 1 liter of water in 10 minutes
- reaches grilling and baking temperatures in 5 minutes
- reaches searing temperatures within 10 minutes

Appendix II

State Science Curriculum Requirements Concurring with This Lesson

This lesson plan satisfies the following parts of the middle school science curriculum framework in the US states of Massachusetts and California, and Australia.

Massachusetts, USA

Reference from Massachusetts Science and Technology/Engineering Curriculum Framework October 2006, MA Department of Education

Target Age: Grade 6-8

Broad Topics	Elaborations	Corresponding Parts in this Lesson Plan	Check?
Energy in the Earth's System	 Radiation, conduction, and convection transfer heat through the earth's system. Energy provided by the sun 	Part A & C	
Forms of Energy	 Temperature change results from adding or taking away heat energy from a system. Heat moves in predictable ways, from warmer to cooler objects until reaching equilibrium. 	Part A & C	
Heat Energy	 Temperature change results from adding or taking away heat energy from a system. The effect of heat on particle motion during a change in phase. 	Part A & C	
Materials, Tools, and Machines	 Appropriate materials for design tasks based on specific properties and characteristics. Appropriate tools used to hold, lift, carry, fasten, and separate, and their safe and proper uses. Safe and proper use of tools and machines needed to construct a prototype. 	Part B	
The nature of science	 Sources of the motivation to understand the natural world Basis in rational inquiry of observable or hypothesized entities 	Part C & E	
Benefits of science and technology/engineering	 Continuous progress in personal and public health, resulting in increasing longevity 	Part E	
How science and technology address negative effects from uses of science and technology/engineering	 Examples of products and systems that address negative effects How to balance risk-taking and creative entrepreneurial or academic activity with social, personal, and ethical concerns 	Part E	

California, USA

Reference from Science Framework for California Public Schools (Kindergarten Through Grade Twelve) Sacramento, 2004, California Department of Education

Target Age: Grade 6-8

Broad Topics	Elaborations	Corresponding Parts in this Lesson Plan	Check?
Standard Set 3: Heat and Thermal Energy (Physical Science)	d. Students know heat energy is also transferred between objects by radiation (radiation can travel through space).	Part A & C	
Standard Set 4: Energy in the Earth System	b. Students know solar energy reaches Earth through radiation, mostly in the form of visible light.	Part A & C	
Standard Set 6: Resources	 a. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process. b. Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable. 	Part A & C	
Standard Set 7: Investigation and Experimentation	 a. Develop a hypothesis. b. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data. c. Construct appropriate graphs from data and develop qualitative statements about the relationships between variables. d. Communicate the steps and results from an investigation in written reports and oral presentations. e. Recognize whether evidence is consistent with a proposed explanation. 	Part B & C	

Australia

Reference from

1) Australian Science Curriculum Framework (Year 6) http://www.australiancurriculum.edu.au/Year6

2) Cross-Curriculum Priorities – Sustainability http://www.australiancurriculum.edu.au/CrossCurriculumPriorities/Sustainability

Target Age: Grade 6

Broad Topics	Elaborations	Corresponding Parts in this Lesson Plan	Check?
Science Understanding/Physical	 Considering whether an energy source is sustainable 	Part A	
Sciences			
Science as a Human Endeavour/ Nature and development of science	 Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena 	Part C & D	
Science as a Human Endeavour / Nature and development of science	 Investigating how knowledge about the effects of using the Earth's resources has changed over time Important contributions to the advancement of science have been made by people from a range of cultures Investigating how people from different cultures have used sustainable sources of energy, for 	Part A & E	
	example water and solar power		
Science as a Human Endeavour / Use and Influence of Science	 Considering how personal and community choices influence our use of sustainable sources of energy 	Part E	
	 Recognizing that science can inform choices about where people live and how they manage natural disasters 		

Science Inquiry Skills	 Questioning and predicting: With guidance, pose questions to clarify practical problems or inform a scientific investigation, and predict what the findings of an investigation might be(ACSIS232) Planning and conducting With guidance, plan appropriate investigation methods to answer questions or solve problems (ACSIS103) Decide which variable should be changed and measured in fair tests and accurately observe, measure and record data, using digital technologies as appropriate (ACSIS104) Use equipment and materials safely, identifying potential risks(ACSIS105) 	Part C
Science Inquiry Skills	 Processing and analyzing data and information Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate(ACSIS107) Compare data with predictions and use as evidence in developing explanations(ACSIS221) 	Part C & D
Science Inquiry Skills	 Evaluating Suggest improvements to the methods used to investigate a question or solve a problem (ACSIS108) 	Part C & D
Science Inquiry Skills	Communicating Communicate ideas, explanations and processes in a variety of ways, including multi-modal texts (ACSIS110)	Part C, D & E
Cross-Curriculum Priorities – Sustainability/World Views	 OI.4 World views that recognize the dependence of living things on healthy ecosystems, and value diversity and social justice are essential for achieving sustainability. OI.5 World views are formed by experiences at personal, local, national and global levels, and are linked to individual and community actions for sustainability. 	Part A & E
Cross-Curriculum Priorities – Sustainability/Futures	 OI.6 The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future. OI.8 Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgments based on projected future economic, social and environmental impacts. 	Part A & E

Appendix III Customize the Plan for Your Classroom

This lesson plan has many parts for the teacher to choose and plan for their own classrooms depending on the need. Here we recommend the following combinations based on the age and time of the class.

Age: 7 – 10

Class time: 40 min

Part A + Part B (30 min)

Part C.d (10 min)

Age: 7 – 10 Class time: 60 min

Part A + Part B (35 min)

Part C.a/b/c (10 min)

Part C.d (15 min)

Bad Weather Alternative Age: 7-10 Class time: 40 min Part A (10 min) Part F (10 min) Part B (20 min)

Age: 11 – 13 Class time: 40 min

Part A + Part B (25 min)

One of the Part C activities with worksheets (15 min)

Part D/Part E as assignment

Age: 11 – 13 Class time: 60 min

Part A + Part B (30 min)

One or two of the Part C activities with worksheets (20 min)

In-class Part D (10 min)

Part E as assignment

Bad Weather Alternative Age: 11 – 13 Class time: 40 min Part A (15 min) Part F (10 min)

In-class Part B (15 min)

Part E as assignment