What's Cooking?

Student Objective:
The student:
- understands how the Sun's radiation, as heat, can be captured and used
- given a solar oven, can explain what makes it work and how to improve on the design.

Materials (construction):
- file storage box, or other box 12" x 15" x 10" (1 per group)
- foil backed foam insulation board, approx. ½ sheet per group
- plexiglass, pre-cut to 12" x 15" (1 per group)
- aluminum duct tape, 20 feet (per group)
- black construction paper, 12" x 15" (1 per group)
- aluminum foil, 18" x 21" (1 per group)
- scissors (1 per group)
- wooden dowel, stick or pencil (1 per group)
- razor knife (1 per group)
- yardstick or tape measure (1 per group)
- Science Journal

Materials (cooking):
- oven thermometer, or thermometer that has a range to at least 300°F (1 per group)
- pot holders
- disposable aluminum cooking pans ('brownie' size works well)
- clear glass covered casseroles

Key Words:
conduction
convection
glazing
insulation
radiation
reflector
solar collector
solar thermal
thermal energy
thermal equilibrium

Time:
1 class period to build oven
1 class for cooking

Background Information:

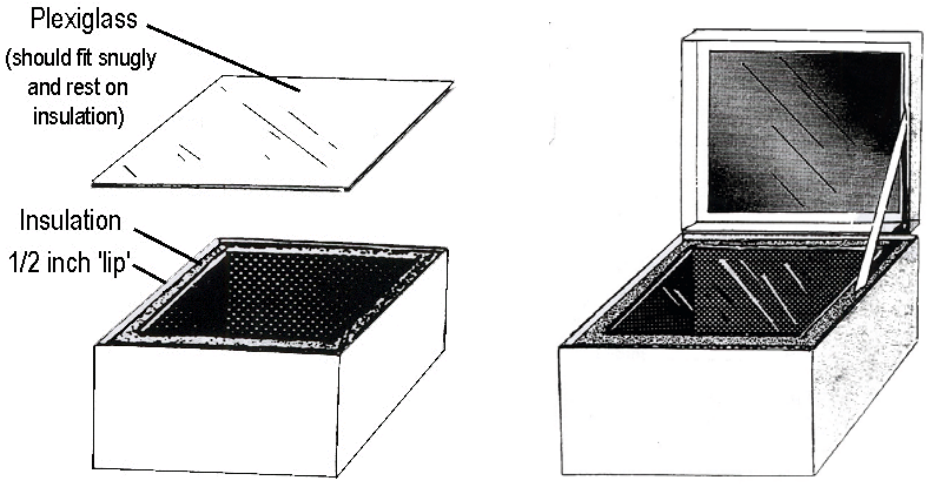
1. A solar cooker is a type of solar thermal collector. It 'collects' and traps the sun's thermal (heat) energy. For example, on a sunny day your car with the windows rolled up becomes a collector. The glazing lets in the sun's energy, traps the thermal (heat) energy, and the air inside your car becomes hot. As more light enters the car, the air gets even hotter, until we say that it feels like an oven inside!
2. Solar ovens are improving the quality of life for many people around the world. Solar ovens have been introduced in parts of South America, Africa and India. In these areas, it is typical for a woman to spend nearly half her workday looking for and collecting firewood. Also, respiratory problems in the children of these areas have been linked to fumes created by the burning of poor quality wood. The use of solar ovens helps to reduce the dependency on firewood. In addition, some women have turned their talents for building cookers into businesses--building and selling cookers for added income.
3. Besides cooking, solar ovens can be used to purify water. This is beneficial for areas where obtaining safe drinking water is a problem.
4. There are many types of cookers, and ways to build them. Cookers generally have 3 elements or components:
    - Glazing to allow heat to enter (glass, clear plastic wrap, etc.)
    - Insulation to retain heat and maintain temperature (strofoam, feathers, cardboard, paper, etc.)
    - Reflectors to concentrate more sunlight into the cooker (foil, mirrors, etc.)
5. There are three basic types of solar ovens on the market today – box, parabolic reflector and multi-reflector (truncated cone or pyramid). Box ovens produce lower temperatures, but are the least expensive and the most portable. Parabolic reflector ovens produce the highest temperatures but must be constantly adjusted to focus directly on the sun. Multi-reflector ovens combine a good temperature range and can be designed to have a large cooking capacity.

Procedure (prior to class)

1. It would be helpful to construct one oven that can serve as a model for the class to look at during the construction process.

Procedure (during class time)

1. Explain construction procedure (refer to diagram):
    - put insulation inside the box on the bottom
    - put insulation around all the walls of the inside of the box
    - tape all seams--bottom, sides, and around the inside top of the box
    - cover the inside of the box lid with foil for a reflector
    - cover the inside bottom of the oven with black construction paper
    - place the glazing on the top of the oven
    - attach the box lid by one long edge to the oven with an aluminum tape 'hinge'. The rod or stick is used to adjust the tilt of this lid to capture more sunlight.



2. Explain common problems to avoid that can cause the ovens not to seal tightly and therefore not hold in heat:
   - all seams are not sealed tightly with aluminum tape. Make sure that all the seams are covered, both inside and around the inside top opening of the of the oven. The box lid is used as a reflector, so the tape is not critical there
   - the plexiglass glazing does not sit tightly on the top of the oven. Make sure that the top edges of the insulation are level and flat. Low spots may be filled in with extra pieces of aluminum tape
   - sides of boxes are squeezed in while being taped, thereby making the top opening too small for the plexiglass to fit.
3. Remind students of the safety rules and the proper way to use a razor knife.
4. Divide the class into groups of 4 - 5 students per group.
5. Pass out materials.
6. Have students construct ovens referring to the model as necessary.

Procedure (cooking day)

1. Mix or prepare the food to be put in the oven according to the recipe.
2. Put the food in a covered dish, or cover tightly with plastic wrap.
3. Lift glazing, set the dish and an oven thermometer on the bottom of the oven, and replace the glazing.
4. Set the oven facing the sun.
5. Adjust the tilt of the oven (objects can be placed under one edge), and the tilt of the reflector (with a rod or stick) so that the Sun's rays are directed into the body of the oven.
6. When food is done, be sure to use a pot holder to remove the glazing and also the food. **Solar Cookers can get extremely hot!**
7. Students should complete their Science Journal pages.

Related Research

1. Research food preparation in other times and in other places. When, where and how was the sun used in food preparation and food storage? What were the advantages and disadvantages to the cultures of using the sun's energy for cooking?
2. Biomass (fuel wood) is the world's largest source of cooking fuel. What are some of the social, economic and environmental impacts of the widespread use of fuel wood for cooking?
3. Cooking over an open fire is a terrible waste of energy. Several international agencies have developed 'energy efficient' ovens for cooking with wood. What do they look like and what has prevented its widespread introduction and use?

Related Reading

- ***Cooking With the Sun: How to Build and Use Solar Cookers*** by Beth Halacy & Dan Halacy (Morning Sun Press, 1992)
  Cooking With the Sun gives simple directions for solar cookers and solar hot plates along with a host of recipes including pizza, chicken and pecan pie.
- ***Cooking With Sunshine: The Complete Guide to Solar Cuisine with 150 Easy Sun-Cooked Recipes*** by Lorraine Anerson and Rick Palkovic
  Whether you're new to solar cooking or have been doing it for years, Cooking with Sunshine is your definitive guide to making a variety of tasty sun-cooked meals. The book includes instructions on building and buying cookers, recipes for main dishes, accompaniments and desserts and ideas for special occasions

Internet Sites:

http://www.fsec.ucf.edu/en/education/k-12/energywhiz_olympics/solar_cookoff/index.htm
Florida Solar Energy Center's annual solar cooking competition, the Solar Energy Cook-off for grades 4 through 12. Includes rules and information on how to enter a team.

http://www.fsec.ucf.edu/en/education/k-12/energywhiz_olympics/solar_cookoff/cookbooks.pdf
Cookbook of winning recipes from the 2009 Brighthouse Solar Energy Cook-off at the Florida Solar Energy Center

http://solarcooking.org/
Solar Cooking International, solar cooking archive includes solar cooking plans, documents and a list of resources and manufacturers.

http://www.sunoven.com/
Sun Ovens International. Includes solar oven history, recipes, and photos.

What's Cooking?

Answers - Laboratory Manual

1. Answers will vary, but students should show understanding of good cooker design.
2. a) 100° C
   b) 439.53 kJ
   c) The water volume will decrease as the water evaporates; the temperature of the water in the container will remain at 100° C
3. 326.586 kJ
4. Answers will vary, but students should show an understanding of the social and economic implications of:
   - decreasing forests and associated wildlife
   - health problems (and lowered life expectancy) associated with burning wood/charcoal/dung
   - impact of women spending time collecting firewood instead of contributing in other ways to the family/society
   - inability of children to attend school thus hindering the chances for them (and society in general) to improve their standard of living

What's Cooking?

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 4	**SC.912.N.4**		**X**																		
Earth and Space																					
Standard 6	**SC.912.E.6.**						**X**														
Physical Science																					
Standard 10	**SC.912.P.10.**	**X**			**X**										**X**						
Life Science																					
Standard 17	**SC.912.L.17.**																	**X**			
Mathematics Standards		**MA.912.A.1.4**																			

Science Standards
Standard 4: Science and Society

- SC.912.N.4.2 - Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Standard 6: Earth Structures

- SC.912.E 6.6 - Analyze past, present, and potential future consequences to the environment resulting from various energy production technologies.

Standard 10: Energy

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.4 - Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or state of matter.
- SC912.P.10.14 - Differentiate among conductors, semiconductors, and insulators.

Standard 17: Interdependence

- SC.912.L.17.17 - Assess the effectiveness of innovative methods of protecting the environment.

Mathematics Standards
Algebra - Standard 1: Real and Complex Number Systems

- MA.A.912.A.1.4 - Perform operations on real numbers (including integer exponents, radicals, percents, scientific notation, absolute value, rational numbers, irrational numbers) using multi-step and real-world problems.

What's Cooking?

conduction - the movement of heat or cold through materials that are solid.

convection - the movement of heat through fluids such as air and liquids

glazing - the clear material (for example glass or plastic wrap) that transfers (lets in) light and traps heat

insulation - material used to reduce heat loss or gain

radiation - the way we receive heat from the sun each day. The energy is emitted in the form of electromagnetic waves and photons, and can move from one object to another without heating the area in between.

reflector - shiny device used to bounce and return (alter) the path of light

solar collector - a device that absorbs (collects) and traps solar energy

solar thermal - using the Sun's energy to heat something

thermal energy - internal energy; sum of kinetic and potential energy of random motion of particles making up the object. Commonly thought of as 'heat'.

thermal equilibrium - state between two or more bodies where temperatures are the same

What's Cooking?

Cooking Tips

- Always either use lids on pans, cover tightly with plastic wrap, or use cooking bags to avoid condensation on the oven glass which blocks the solar radiation.
- Temperature:
  - On a clear and sunny day the oven will heat up to 250°F or above. On these days you can cook or bake anything.
  - On a partially cloudy day the oven will heat to 200°F to 250°F. On these days you can easily cook meats, rice, baked potatoes, and frozen vegetables, but baking is not recommended.
- Adjust your cooking time to account for the lower temperature. A rule of thumb is to figure twice the regular cooking time.
- Use a meat thermometer instead of a timer to determine if the food is done.
- Any conventional recipe that would be suitable for your oven will work in a solar oven, as well as crock pot recipes.
- Foods generally use less liquids or cook in their own juices. This produces better tasting and more nutritious food.
- Foods never burn and rarely overcook in a solar oven.
- Foods particularly suited for the classroom include: hot dogs, slice and bake cookies, brownies, rice mixes, cocktail sausages in barbeque sauce, and nachos.
- Some specific food tips:
  - cook (steam) yellow and green vegetable in dark colored casseroles to prevent discoloration
  - reduce liquids in cake recipes by one half
  - cook foods in their natural state (i.e. potatoes in skins and corn in husks)
  - chewy dessert recipes such as brownies come out better than crispy ones
  - meats cook better if cut into small pieces.

Recipes

Solar S'Mores 1

24 squares from chocolate bars
12 graham crackers, halved
6 large marshmallows

Place 4 squares of chocolate on each of 6 graham crackers, top with marshmallows. Cover with remaining graham cracker squares to form sandwiches. Press to seal. Wrap with foil. Place in oven. Bake until heated and chocolate begins to melt. Serve immediately. Makes six servings.

Solar S'Mores 2

½ cup crunchy peanut butter
12 graham crackers, halved
6 large marshmallows

Spread peanut butter on 6 graham crackers, top with marshmallows and place in oven. Cover with remaining graham cracker squares to form sandwiches. Press to seal. Bake until heated. Serve immediately. Makes six servings.

Banana Boats

6 bananas
chocolate bar squares, kisses, or chocolate chips
marshmallows, large or miniatures

Peel one strip of skin from banana. Remove small amount of banana or cut slit into banana. Place chocolate and marshmallows inside banana. Wrap in foil. Heat until chocolate begins to melt. Serve immediately. Makes six servings.

Backyard Baked Beans

2 slices bacon (optional)
16 oz. can (1¾ cups) baked beans
¼ cup firmly packed brown sugar
1 small onion, chopped
1 teaspoon prepared mustard
1/4 cup catsup
2 Tablespoons Worcestershire sauce

Cut bacon into small pieces. Combine chopped onion and bacon in container with lid. Cook covered until bacon is brown and onion is tender. Add remaining ingredients. Bake covered for one hour or until beans are thickened and heated through. Makes four servings.

Newton's Apples

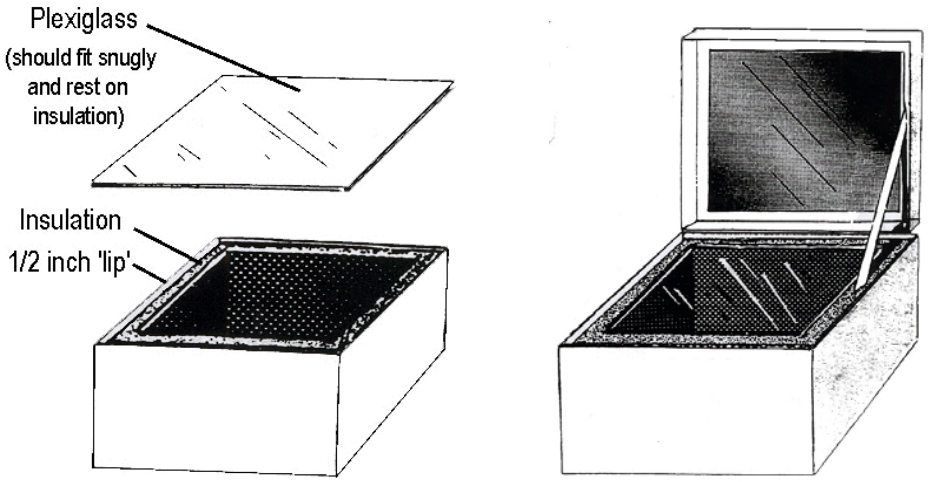
6 baking apples, cored
3 Tablespoons sugar
6 teaspoons butter
1/4 cup raisins
1/3 cup firmly packed brown sugar
1 Tablespoon flour
½ teaspoon cinnamon
1 Tablespoon water

Place apples in a 12 x 8 inch baking dish. Place ½ tablespoon sugar and 1 teaspoon butter in cavity of each apple. Cover tightly with plastic wrap. Bake 1 hour in solar oven or until apples are tender. Combine brown sugar, flour, cinnamon, raisins and water. Spoon mixture in and over apples. Continue baking uncovered until sauce is thick.

What's Cooking?

Directions for constructing your solar cooker

1. Cut insulation material. Each oven requires:
   - (1 piece) 12" x 15"
   - (2 pieces) 12" x 9 ½ "
   - (2 pieces) 15" x 9 ½ "
2. Put piece of insulation inside the box on the bottom
3. Put pieces of insulation around all the walls of the inside of the box
4. Tape all seams: bottom, sides, and around the inside top of the box
5. Cover the inside of the box lid with foil for a reflector
6. Cover the inside bottom of the oven with black construction paper
7. Place the glazing on the top of the oven
8. Attach the box lid by one long edge to the oven with an aluminum tape 'hinge'. The rod or stick is used to adjust the tilt of this lid to capture more sunlight.



2. What is the function of the plexiglass top?

3. What is the importance of the insulation?

4. What was the highest temperature you observed in your oven?

5. What are some advantages and disadvantages to using a solar cooker?

What's Cooking?

1. You are an engineer contracted by a foreign agency to design a solar oven that is easy to use and economical for the local economy to build. The parameters to follow are:
   - it must not weigh more than 40 lbs.
   - it must not cost more than $50. to build (assume that this country's prices are roughly the same as ours)
   - it must reach temperatures high enough to cook meat and purify water
   - it must be able to stay outside in inclement weather without falling apart

   Draw a diagram of your design, list your parts and an approximate cost of each

2. 1.5 kg of 30° C water is placed in a solar oven. After 30 minutes in the sun the water begins to boil.
   a) What temperature is the water?

   b) What is the amount of heat that has been added to the water to raise it to the boiling point? Hint: use the formula **Heat gain/loss = mass (Q $\triangle$ T)**, where Q is the specific heat of a substance. The specific heat of water is 4180 J/kg · K

   c) If the water remains in the oven in direct sun, how will the water's temperature and volume change? How much will the temperature of the water rise?

3. You place 1 kg of 20° C water in your oven. After 15 minutes, the temperature of the water is 98° C. How much heat will be added to the water?

4. In some areas of the world where people cook by wood, women and their children spend up to 70% of their time gathering firewood. How would a solar oven improve their lives? Include economic, health, societal benefits as well as the general standard of living for the individuals.