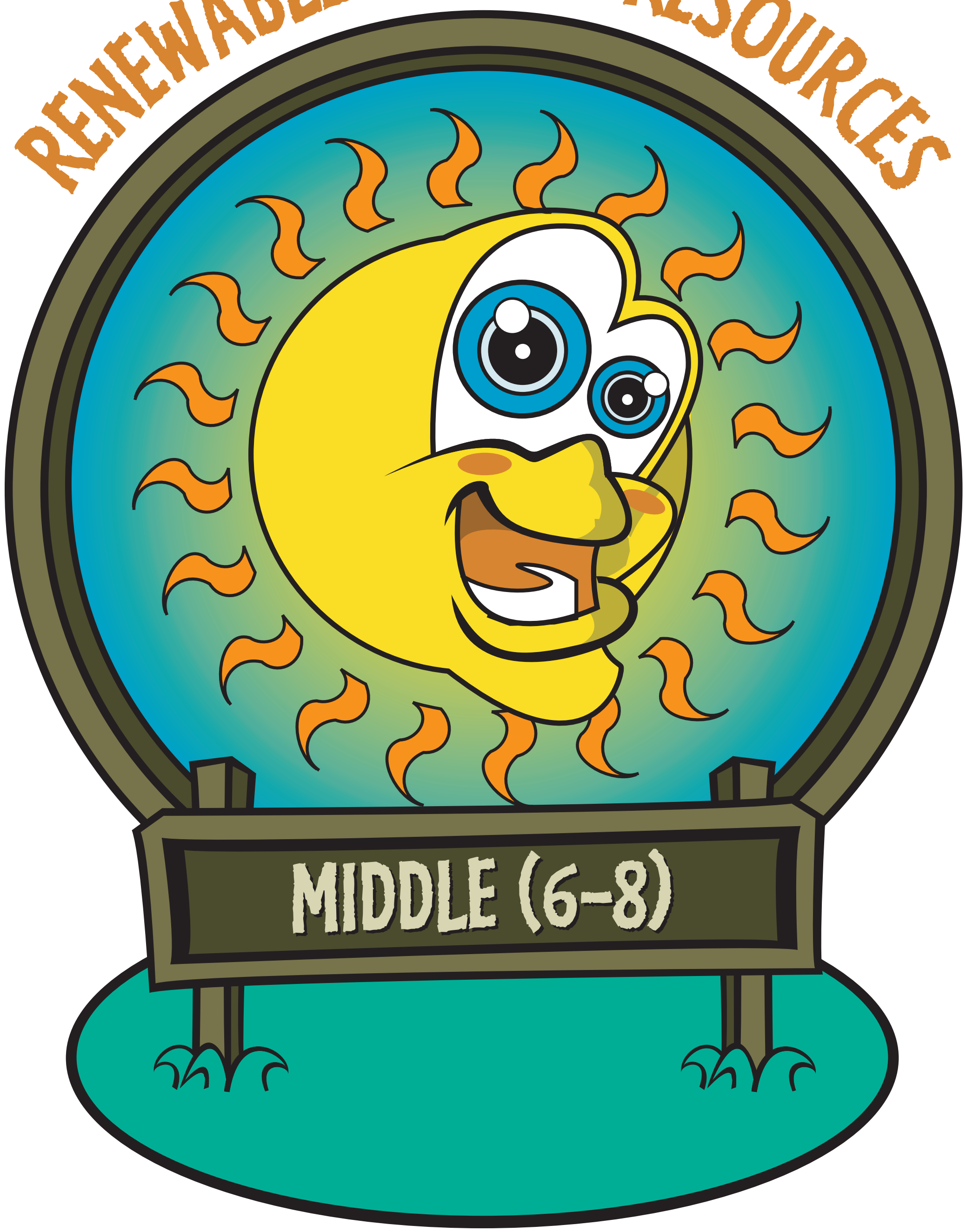
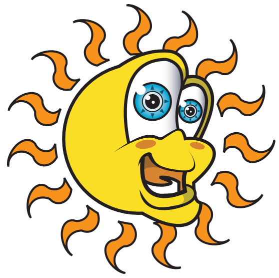
RENEWABLE ENERGY RESOURCES



BRAVE NEW WORLD



SUBJECTS: Life Science, Earth Science, General Science

TIME: 3 class periods

MATERIALS: 1 roll 6-mil plastic *(20' wide x 100' long)*, 1-2 rolls good duct tape, scissors, window fan, small balloons, large balloons, hot plate, water, measuring tape *(or string and ruler)*, water squeeze bottles, box of books, roller skates, 2 chairs with rollers, ball, muddy water, coffee filter, jar, teacher sheets, student sheets

Objectives ***The student will do the following:***

1. Identify the requirements for sustaining human life and how these requirements are met on earth.
2. Identify the problems of creating a human habitat in space.
3. Identify waste products and how they can be recycled into usable resources.
4. Simulate some of the conditions of living in space.

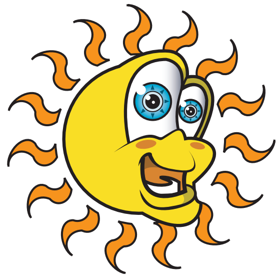
Background Information

The earth's habitat supports life for millions of organisms that are, as far as we know, unique to this planet. The critical external influence on the earth's habitat is the sun. Solar energy, in the form of light and heat, is the "*engine*" that sustains the habitat on earth. The earth must have a constant input of energy from the sun to function as a living habitat. The earth's habitat has an incredibly complex, interrelated web of cycles by which water, minerals and organic materials are naturally recycled, providing a continuous supply of the essential requirements for life. The earth's habitat, with all its complex interactions and its living organisms, is called the earth ecosystem.

Every organism on earth has requirements which must be met if it is to grow and reproduce. Heat energy, gravity, small quantities of many minerals, oxygen, and water are essential to all living organisms *(although some do live without oxygen)*. Plants must also have light and carbon dioxide for use in photosynthesis, a biochemical reaction which results in the formation of energy-storing simple sugars. Animals must have a source of food and so ultimately depend entirely on the presence of plants.

As human activity increases, the ecological balance of the earth is affected by our increasing use of nonrenewable resources and by our production of tremendous amounts of un-recycled wastes and toxic pollutants. The challenge for humans is to use and reuse the earth's resources much more wisely and to greatly decrease the negative effects of wastes on the delicate systems on which we depend. Although the earth seems a huge place to us, it still is a closed system *(with the exception of solar energy)*. As far as we know, no other planets offer us a suitable habitat.

Space exploration has given us opportunities to solve smaller-scale problems about how to live in a closed system. The insights gained from creating a self-sustaining habitat designed for prolonged human use in space are important in our understanding of the problems of the earth's habitat. In this activity, students will examine what is essential to human life in our habitat. Using this information, the students will investigate the problem of designing a self-sustaining human habitat, such as must be accomplished if we are to live in space for extended periods of time.



Terms

closed system: a system that requires nothing from outside itself to sustain itself and that releases nothing to the outside.

ecosystem: a self-regulating community of living organisms interacting with each other and with their environment.

environment: all the physical and organic factors that surround and affect living organisms.

gravity: the force which attracts anything that has mass toward the center of the earth.

habitat: the place where a plant or animal lives, grows, and reproduces.

photosynthesis: the biochemical process in which green plants use energy from the sun to combine carbon dioxide and water into simple sugars; these simple sugars are the basis for all food on the earth.

recycling: reusing waste products.

waste: materials generated as the result of an activity and discarded as no longer wanted or needed.

Procedure

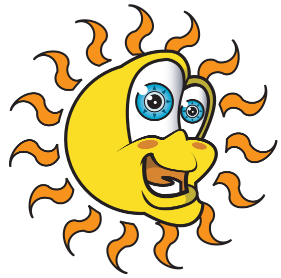
I. *Setting the stage*

A. *Discuss the uniqueness of our planet with the students*.

If you have a space photograph of the earth *(such as a poster)*, show it to the students. Use the following terms as you talk with them about our planet: habitat, environment, ecosystem, cycles. **NOTE:** You might want to illustrate cycles with a simple diagram of the water cycle or the carbon cycle, waste, solar energy and photosynthesis.

B. *Discuss with the students the concept of the earth as a habitat.*

1. Ask the students to describe the habitat of one particular species of plant or animal *(for example: squirrel, otter, palm tree, whale)*.
2. Discuss the interaction and overlap of habitats and the slightly different requirements of different species of organisms. Ask the students to think of their town and the country around it. How many different kinds of plants and animals live there? Point out that most of them have interacting habitats.
3. Make the point to the students that to list the characteristics of the earth's habitat means listing characteristics which are broad enough to cover all the different, smaller habitats and all the requirements for the different forms of life found on earth.



II. *Activities*

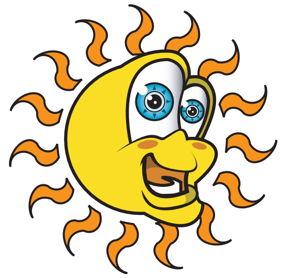
A. *Have the students list the essential requirements of life on earth.*

1. Divide the class into discussion groups of five to-seven students each. Have each group make a list of the essential requirements for life on earth and explain why each is essential. Remind them that they must consider plants as well as animals.
2. Using the background information and the discussion group lists, lead a class discussion on the essential requirements. Asking the students to identify *(in general)* how the requirements are met. *(Heat energy, gravity, small quantities of many minerals, and water are essential to all living organisms. Almost all organisms require oxygen. In addition, light and carbon dioxide are essential for plants and, indirectly, for food for animals. All living things need a place to live and for many animals that includes shelter.)*

B. *Have the students focus on the essential requirements of human life.*

In the process of developing a closed system for long-distance space travel, the first consideration is providing the basic needs of humans for sustaining healthy human life. This exercise will help the students focus specifically on human requirements *(although the same requirements would serve for many other organisms)*.

1. Have the students list the basic requirements for human life in the earth habitat. Then discuss why each one is needed and how it is provided.
   NOTE: You may choose to do this as a group activity first, then a class discussion.
   These requirements, and the *"how"* and *"why"* concerning them, follow.
   a. FOOD:
      Why Needed? Provides energy for basic body functions and activities; required to build and maintain the structure of the body *(bones, muscles, organs, etc.)*.
      How Provided? Directly or indirectly from plants. Photosynthesis uses the energy from sunlight to produce simple sugars *(food)*.
   b. OXYGEN:
      Why? Essential for the chemical reactions *(respiration)* that enable the body to utilize the energy contained in the chemical bonds of food.
      How? From the atmospheric oxygen released by plants. Light energy, carbon dioxide and water are combined during photosynthesis to produce simple sugars *(food)*; oxygen is a waste product which is released into the atmosphere.
   c. WATER:
      Why? Medium in which chemical reactions in the body take place; also dissolves harmful waste products so they can be eliminated.
      How? By the earth ecosystem's water cycle.



d. HEAT FROM THE ENVIRONMENT:
Why? The chemical reactions within the human body occur only within a narrow range of temperatures. The body has regulatory mechanisms *(producing heat from food or sweating to reduce heat),* but these are limited to a small range of environmental temperatures.
How? By the heat energy of the sun. Solar heat energy, combined with the rotation of the earth, creates the overall climates of different areas of the earth, as well as seasonal and daily weather.

e. AIR PRESSURE:
Why? Essential to keep oxygen dissolved in the blood and for the inflation of the lungs.
How? The atmospheric layers around the earth result from the gravitational pull of the earth on gas molecules. Gravity decreases as the distance from the center of the earth increases. This causes the gas molecules in the atmosphere to move further from each other as the altitude increases. In general, air pressure is highest at sea level and decreases as the altitude increases. Natural air pressure is caused by gravity. One example of artificially maintained air pressure is the air in an airplane during flight.
NOTE: Nitrogen constitutes about 78 percent of the atmospheric gases, while oxygen is about 21 percent. Carbon dioxide constitutes 0.03 percent, and a variety of other gases and water vapor make up the rest.

f. LIGHT:
Why? Indirectly, as the source of energy in all food *(captured by photosynthesis).*
How? By the sun.

g. **NOTE:** Although a place to live and shelter are needs for living things, for the purposes of this exercise, we will assume that the provision of this need is a given. When we apply this information to the problem of creating a habitat in space, the space vehicle will serve as our shelter.

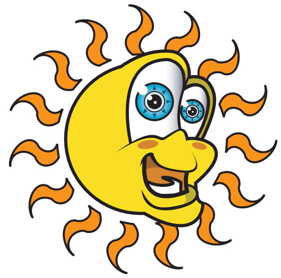
2. Give each student a copy of each of the student sheets *"Basic Needs for Human Life" (page 83)*, and *"Sources for Basic Human Needs" (page 84)*. Have the students complete them.

a. The answers for *"Basic Human Needs"* are as follows: 1) food; 2) food, oxygen; 3) air pressure; 4) oxygen; 5) water; 6) light; 7) heat.

b. The answers for *"Sources for Basic Human Needs"* are as follows: Food – animals, plants; oxygen – atmosphere *(and, indirectly, plants)*; water – streams, lakes, wells; heat – sun; air pressure – atmosphere; light – sun.

C. ***Remind the students that we have discussed human needs, including the things we must take in, but that human waste products are part of the habitat too.***

1. Discuss with the students the different kinds of materials included in the category *"human waste."* Ask the students to name general categories of human waste. *(Body wastes; household wastes; industrial wastes)* Have the students list examples of each type of waste. Categories and examples are:



   a. Body wastes – solid *(feces)*, liquid *(urine and perspiration)*, gas *(carbon dioxide)*
   b. Household wastes – paper, aluminum, steel, glass, plastic, food scraps and other vegetable materials
   c. Industrial wastes – toxic chemicals, gases, carbon dioxide, excess heat, materials as listed for household wastes
   d. Fossil fuel and nuclear wastes – toxic gases *(including NO_x and SO_x)*, excess CO_2, radioactive waste, ash from fossil fuels

2. It has been said that wastes are simply resources out of place. Discuss with the students the concept that nature recycles wastes. All organisms generate waste. For example, plants release oxygen and water vapor to the atmosphere. Additionally, when organisms die, they become organic waste. All these wastes are part of the natural recycling that operates in the earth's ecosystem. However, human activities are much more extensive than those of other organisms, and the wastes we generate are not extensively recycled. Ask the students to give examples of how human wastes in each category above are recycled or could be recycled.
   a. Solid and liquid body waste, and dead organisms – food for other organisms; nitrogen for plant growth; minerals returned to the ecosystem.
   b. Gaseous body waste – CO_2 from animals is essential for plants; O_2 given off by plants is essential for both plants and animals.
   c. Household wastes – many materials can be treated and reprocessed into similar products.
   d. Industrial wastes – many may be useful in other industrial processes.
   e. Fossil fuel and nuclear wastes – We may someday find ways to use more of these, but are not thus far using any of these wastes except fossil fuel ash *(e.g., as a raw material for road building)*.

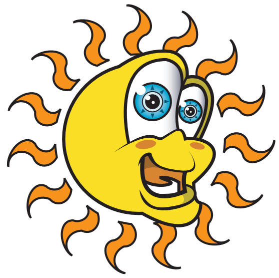
3. Give each student a copy of the student sheet *"Human Waste Management" (page 85)* and have them complete the questions. The answers are as follows: 1) carbon dioxide, urine, feces; 2) paper, yes; 3) metal, glass, plastic, yes; 4) heat, carbon dioxide and other gases.

D. ***Build a school yard "space bubble" using the instructions on the teacher sheet "Build a Space Bubble" (page 86).***

Use it to conduct the activities below. *(Other activities, in cooperation with other teachers, may include physical education, creative writing, and astronomy activities.)*

E. ***Have the students consider some of the problems of developing a human habitat in space.***

1. Ask the students how size will affect the problems of designing a space habitat that has all the requirements for healthy human life. How do size/space limitations relate to the essentials? Here are some examples:



a. We must provide oxygen *(and other inert atmospheric gases)* because there is no atmosphere and not enough room to grow enough plants to provide oxygen.
b. There is limited space for growing/storing food and storing waste.
c. We must store water, but space is limited.

2. Ask the students what physical requirements have to be met for life in space.
   a. We must carefully control temperature.
   b. We must provide light inside. We cannot rely on direct solar energy through the windows because it provides too much heat along with light.
   c. The effects of lack of gravity must be counteracted.
      1. Air has to be pressurized.
      2. People must exercise to prevent muscle deterioration.
      3. Problems in eating, bathing, and using the toilet must be solved.
3. Have the students think about the problems and requirements they have listed and answer the following questions:
   a. In a small space station, what could be recycled? *(water, heat from bodies, lights, and equipment)*
   b. How would things change if the space station were much larger *(multi-roomed)*? *(Answers will vary.)*
   c. What in the space station will require the use of energy? *(pressurization, temperature control, lights, equipment, some of the recycling)*
4. Conduct the activities suggested on the teacher sheet *"Space Habitat Problems"* in the space bubble. Discuss the questions with the students as they complete the activities.

III. *Follow-Up*

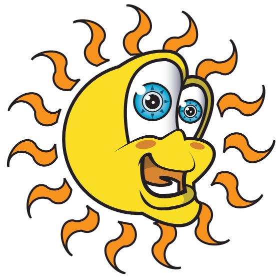
A. ***Have the students name five of the six needs examined in these exercises and write a short explanation of how these needs are met in both earthbound and space habitats.***

B. ***Have each student write a one- to two-page short story about life aboard a space station.***

IV. *Extensions*

A. ***Simulate the work and living area of the space shuttles in your classroom.***

B. ***Have the students write a report on the habitat needs and waste management aspects of a fish bowl.***



C. ***Have the students write a report on the habitat differences they would have to consider if they were making a terrarium for desert plants and another for tropical plants.***

D. ***Have the students research the benefits we have received from space exploration and the preparations for it.*** *(See who makes the longest list.)*
NOTE: A list of resources for information about space exploration appears on the teacher sheet *"Nasa Centers"*.

E. ***Have the students write reports on their choice of the following topics:***
1. The use of robotics in space
2. Plumbing in space
3. Artificial gravity
4. Storing, preparing, and eating food in space
5. Solar energy in a space vehicle

Resources

Alabama Department of Economic and Community Affairs. "Environmental Control for Spacecraft" [LS07], Alabama Energy Education Idea Book for High Schools. Montgomery: ADECA, 1987.

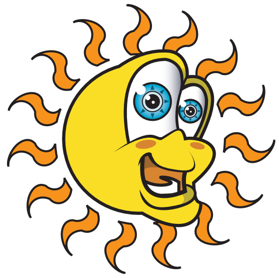
Lujan, B.F., and R. J. White. Human Physiology in Space: A Program for America. Washington, DC: NASA, 1990.

NASA. "Living and Working on the New Frontier." NASA Information Summary. PMS 017-A(KSC).

NASA. "NASA Space Link" *(An Electronic Information System for Educators)*. MSFC 1E988.

NASA. Teacher In Space Teacher's Guide. N.p.: NASA, n.d.

Sharpe, M.R. "Living in Space," Double Science Series. Garden City, NY: Doubleday,1969.



Basic Needs for Human Life

Fill in the blanks below by choosing from the listed words:
food, oxygen, water, heat, air pressure and light.

1. Plants make their own, but we must take in ___________________.

2. Which of the essentials must our bodies take in to supply us with energy?

   ___________________ and ___________________.

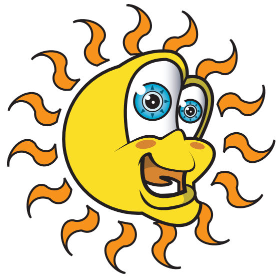
3. Our lungs require ___________________*(two words)* to function.

4. The air we take into our lungs must contain ___________________.

5. All activity of the human body is based on chemical reactions. These reactions require a certain amount of ___________________ to dissolve the chemicals.

6. While some animals rely mainly on their sense of smell to find food, human beings rely mainly on sight. Therefore, for most of us, finding food and water requires ___________________.

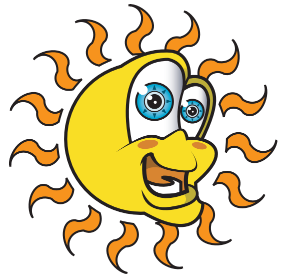
7. It is essential that our bodies maintain temperatures at which normal functions take place. Some of this is provided by burning food *(our fuel)*, but we must also have ___________________ from our environment.



Sources for Basic Human Needs

Match the essentials for human survival with the sources from which we get them. Some needs have more than one source. Some sources provide more than one need.

Needs	Sources
food	animals
oxygen	plants
water	sun
heat	atmosphere
air pressure	streams, lakes, wells
light	



Human Waste Management

Fill in the blanks below by choosing from the listed words:

carbon dioxide, feces, heat, paper, urine, carbon dioxide and other gases, glass, metal, and plastic.

1. Waste products from the human body are: __________________________ *(a gas)*,

__________________________ *(a liquid)* and __________________________ *(a solid)*.

2. When you read a magazine and throw it in the trash, you generate waste in the form of

__________________________. Can it be recycled? ___________ yes ___________no.

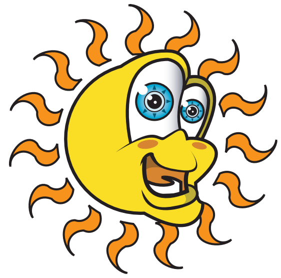
3. Empty soft drink cans are __________________________ waste products, while bottles are either

__________________________ or __________________________ waste products.

Can it be recycled? ___________ yes ___________no.

4. Automobiles generate excess ____ as well as

____ *(several words)*.



Build a Space Bubble

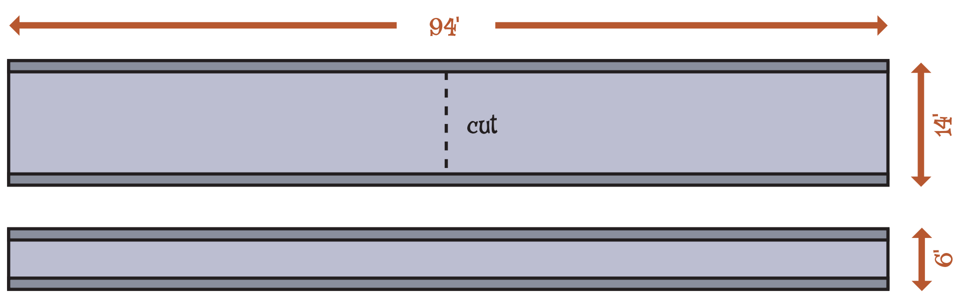
The "bubble" is an envelope-like room, constructed from plastic sheeting, and inflated with a household window fan. It is easy to construct, fairly inexpensive, and provides a wide variety of uses for the classroom teacher or outdoor educator.

Materials: 1 roll of 6-ml polyethylene *(20' wide and 100' long)* – Check with garden centers or large hardware stores, 1-2 rolls of good duct tape, scissors, measuring tape *(or ruler and string)* window fan, a large area for construction.

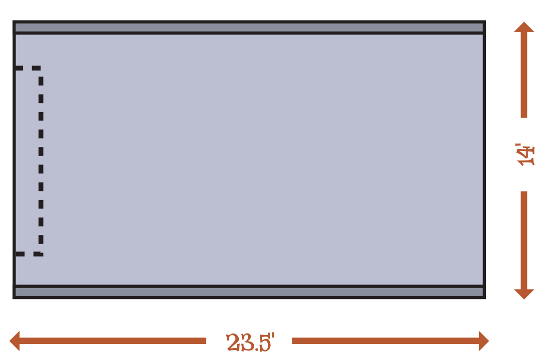
Instructions:

1. Unroll and cut about 6 feet off the roll. You will use this to attach a fan to the bubble.
(Piece will be 6 x 20 feet.)

2. Unroll the remaining plastic. Cut a strip 6-8 feet wide along the entire length; this can be used for a water slide! Then cut the big piece in half crosswise.

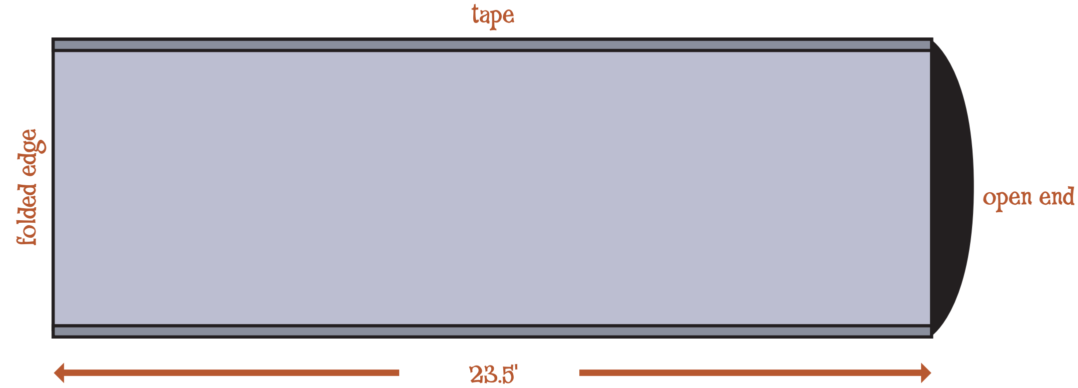


3. Spread out one of the two halves and then fold it in half.



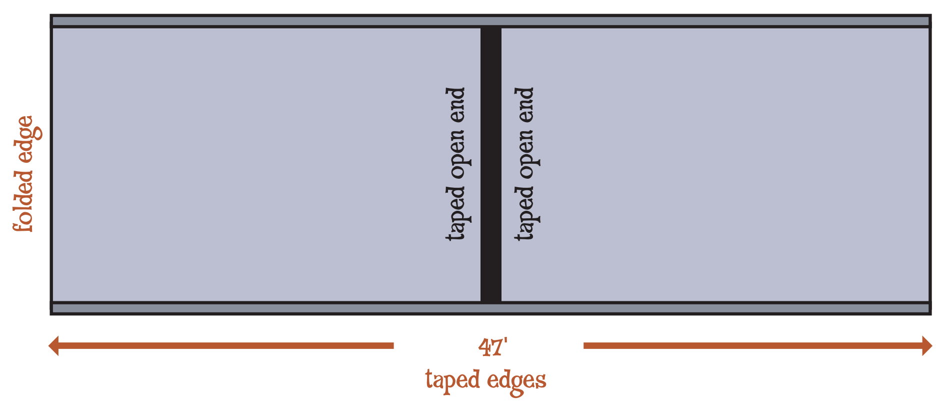
Build a Space Bubble continued

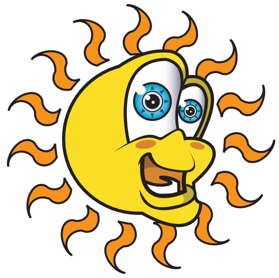
4. Tape along the two long sides, creating a long, narrow envelope. *(When taping, lay the edges next to each other or even overlapped a little, and press firmly so that there are no gaps. It helps to have a hard surface to tape on.)*



5. Repeat steps 3 and 4 *(above)* with the other half of the plastic.

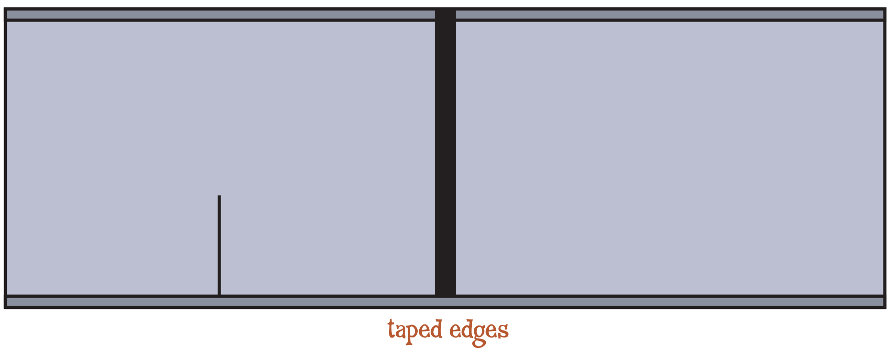
6. Tape the two envelopes together, first on one side and then the other.





Build a Space Bubble continued

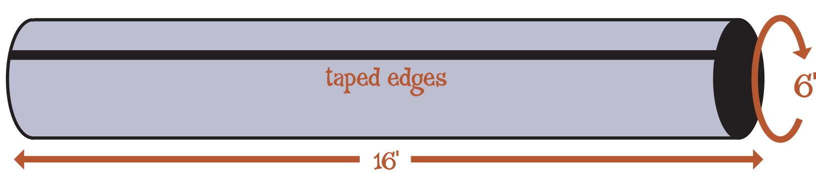
7. For an entrance, start at one of the taped side seams, and cut a slit in one side inward from the side seam about 4 feet. Make the slit about halfway between the corner and the midseam.



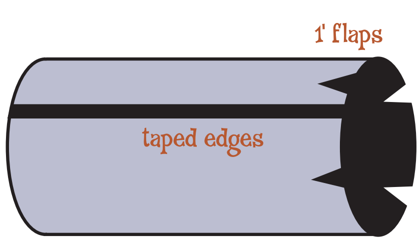
8. Reinforce the edges of the entrance with duct tape.

9. Cut about 4 feet off the piece that you cut for the fan attachment. You will have a piece 4 x 6 feet and one 16 x 6 feet.

10. Make a long tube by taking the longer piece and taping the edges together.

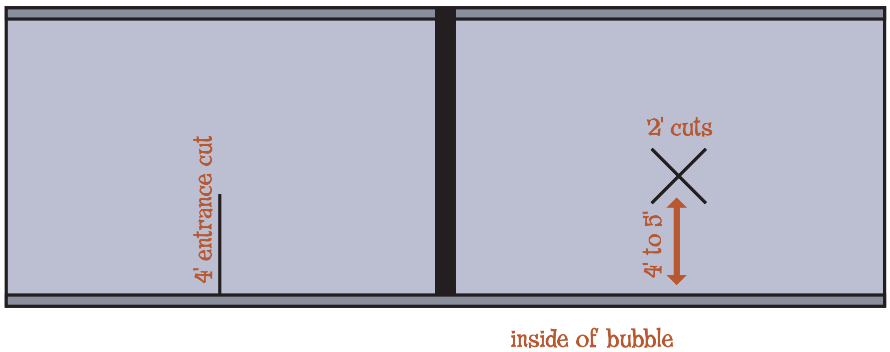


11. Cut one of the ends of the tube so that it has 4 flaps, each about a foot long.

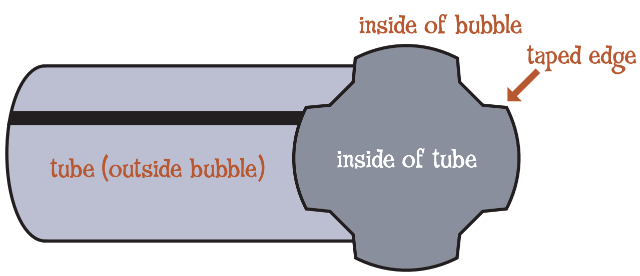


Build a Space Bubble continued

12. On the same side of the bubble as the entrance, cut an X with two 2-foot cuts. Make the cut about 4-5 feet in from the side seam and about halfway between the corner and the midseam.



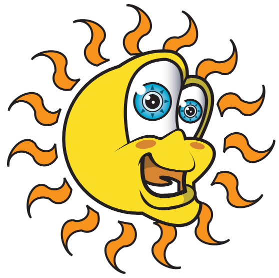
13. Insert the end of the tube with the flaps on it into the X and then tape it from both sides: Pull out the flaps from the X and tape them to the sides of the tube. Tape the tube flaps to the inside wall of the bubble.



14. Turn the bubble so that the entrance and the tube are on the underside. Tape a fan to the tube, making sure that there is an airtight seal around the fan. *(Make sure that the plastic does not cover the fan's air intake.)* To start blowing up the bubble, you may have to lift the corner of the bubble so that the tube is not constricted for the first few minutes. With a good fan, the bubble should be blown up in 45 minutes to an hour.

15. To stop air from escaping from the entrance, tape the 4 x 6-foot left-over piece on the inside, wall so that it hangs over the slit.

16. If you are using the bubble outside, it is a good idea to stake it down by tying rope around a tennis ball in each corner and then staking the rope on the outside. You will have to cut a slit in the tape to put the rope through. Don't use the bubble outside if it is very windy.



Space Habitat Problems

Materials: small and large balloons, hot plate, water squeeze bottles, box of books, roller skates, 2 chairs with rollers, ball, measuring tape *(or string and ruler),* muddy water *(optional)*, coffee filter, jar.

Instructions:

Discuss these questions with the students. Have the students complete the demonstrations as you work through the questions.

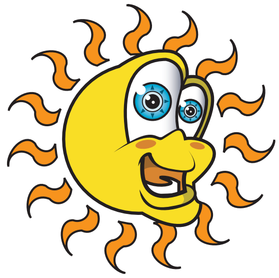
1. ***Problem: Pressurized air for the space habitat***
   a. What gases should be used to fill the space bubble? Why?
   b. What can affect air pressure in an enclosed space? To help get an answer, do this demonstration.
      1. Blow up a small balloon, but not too tightly. Feel how easily it *"gives"* when you press it. This is an indication of the amount of air pressure inside the balloon.
      2. Blow in more air. What happens to the air pressure in the balloon? Why?
      3. Heat the balloon carefully over a hot plate. *(If the balloon bursts, try again with another one.)* What happens to the air pressure in the balloon? Why?
      4. Carefully transfer all the air in the small balloon to a large balloon. How does the air pressure in the large balloon compare with the air pressure caused by the same amount of air in the small balloon?

         Explanation: The actual pressure of the gas inside a closed space *(such as a space vehicle or a balloon)* is directly affected by the quantity of gases and the temperature of the gas *(the more gas and/or the higher the temperature, the higher the air pressure)*, and by the volume of the container *(the greater the volume, the lower the air pressure)*.

2. ***Problem: Recycle the water***
   a. What steps will have to be taken to recycle water in the space habitat?
   b. What would have to be taken out of the water before it could be used for drinking?
   c. Why can't water be filtered in space the same way it is done on earth? *(If desired, pour some muddy water through a coffee filter to demonstrate filtration.)*
   d. What would you have to do to filter water in space?

3. ***Problem: No gravity***
   a. EFFECTS OF ZERO GRAVITY

      This demonstration gives an indication of what happens in zero gravity. Have one student lie flat on the floor with both legs raised vertically. Use a measuring tape to measure the circumference of each ankle. Measure again every 5 minutes for 15 minutes. Discuss the results.



Space Habitat Problems continued

b. Exercise and gravity

Muscles in our bodies retain and increase their strength by working against the force of gravity on earth. In a space habitat, there is no gravity.

1. How can humans prevent loss of muscle tone in space?
2. Would a jump rope be an appropriate piece of equipment for exercise in a space habitat? What would alternatives be?

c. Practical problems

1. Eating in zero gravity

   What would happen in the space habitat if you spilled a glass of water or a spoonful of peas? Eating and drinking must be done from very confining containers. Try drinking from a squeeze bottle while it is standing upright. Your food might be served in tubes like toothpaste tubes so it could be squeezed into your mouth.

2. Moving in zero gravity

   Demonstrate some of the difficulties of zero gravity in the following ways: Have a student try to push a big, heavy box of books *(or a table)* while wearing roller skates. Have two students seated on chairs with rollers throw a ball back and forth while keeping their feet off the floor.

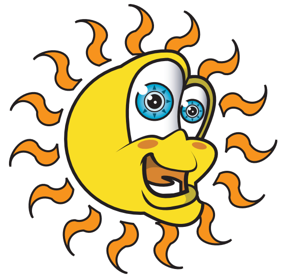
4. *Problem: Psychological effects of too little space*

a. Ask the students to think of situations when they are crowded with too many people around them. What reactions do they have when they are in a crowd of people for a long time?

b. Discuss with the students the following questions.

What do they think would bother them the most about living with the same people for several months with no other place to go? What could be done to prevent this from becoming a serious problem?

c. Ask the students to think about their own bedrooms at home, and draw the following room arrangements. If they share with someone, how do they divide it so that each person has private space? How would they change it if they could? If they do not share a room, have them imagine how they would arrange the room if they could use only half of it for personal space.



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John C. Stennis Space Center
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Technology Utilization Officer: Robert M. Barlow
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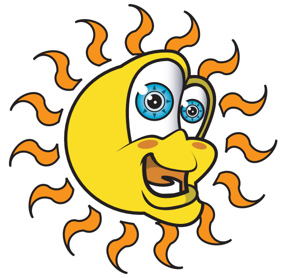
THAR' SHE BLOWS!



SUBJECTS: General Science, Earth Science

TIME: 2 class periods

MATERIALS: record player, paper, pinwheel, 2- or 3-speed electric fan, metric rulers, wire coat hangers, corks, wire cutters, sheets of paper, marker pens, small map tacks, thread spools, small saws or hobby knives, drill or small nails and hammer, scissors, wood dowels or pencils, bathroom cups, large square nuts, pencils with erasers, 3/8" thick balsa, 1/8" thick balsa, wood glue, large map tacks or straight pins, tape, wood or ceramic beads, student sheets

Objectives *The student will do the following:*

1. Demonstrate how the earth's rotation results in global wind patterns.
2. Build and demonstrate the use of wind machine models.
3. Trace the flow of energy from solar heat to mechanical energy in wind machines.

Background Information

Wind is air moving across the earth's surface. Uneven heating of the atmosphere creates the movement of air masses. As the sun heats the surface of the earth, hot air expands and rises, and air from cooler areas flows in to take the place of the heated air. The earth's rotation causes the rising air to move in a certain direction *(called a Coriolis force)*. This effect produces the earth's major wind patterns.

As long as 5,000 years ago, people used wind as a source of energy. Ancient people sailed, using wind energy to move their boats. They also used wind to turn windmills for grinding grain. In the 14th and 15th centuries, wind machines were used for pumping water as well as for grinding grain. Although we still use wind energy today for recreational sailing and for pumping water in some areas, its use has declined as the world has increasingly relied on fossil fuels for energy. However, fossil fuels are nonrenewable resources and their use produces undesirable environmental effects. Wind is one possible alternative – a nonpolluting, inexhaustible energy source.

Terms

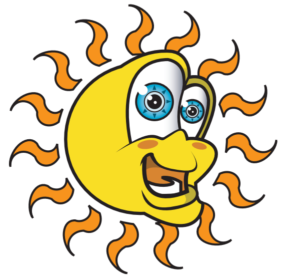
blade: a flat or concave projection from a rotor shaft; a rotor shaft plus its blades make up a propeller.

convection: the natural movement within a fluid caused by unequal heating; warm air rises and cool air sinks.

Coriolis force: rotational force of the earth which affects global wind patterns.

rotor: the rotating part of an electrical or mechanical device; transfers mechanical energy from its source *(such as wind or flowing water or steam)* to the device.

wind: moving air masses; especially, natural air movement parallel to the surface of the earth.



Procedure

I. *Setting the stage*

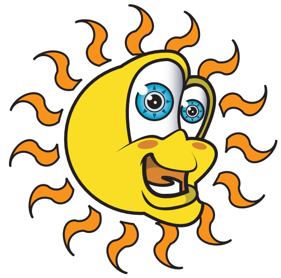
A. ***Have your students brainstorm a list of ways that we capture and use wind energy.*** *(Answers might include windmills, sails, gliders, kites and balloons.)*

B. ***Remind the students of convection.*** Ask them to give examples of convection they have observed at home or school. *(Good examples include a room being warmer near the ceiling; breezes created by opening a window at both top and bottom to cool a room; and rooms on the lower floor of a building being cooler than those on upper floors.)* How does convection relate to the uses of wind the students listed above?

II. *Activities*

A. ***Have the students conduct a simple demonstration to aid their understanding of convective air currents and Coriolis forces.***

1. Share with the students the following introductory information:
   When the sun heats the atmosphere, the gas molecules in the air gain energy, move faster, spread out, and rise higher. As a mass of warmed air rises, it is replaced by cooler, heavier air. A beach on a hot summer day heats much more quickly than the water in the ocean. As a result the breeze will blow from the sea toward the beach during the day. However, at night the sand cools off much more quickly than the water so the breeze blows from the beach toward the sea at night. Unequal heating also causes global winds. The hot air at the equator rises and is replaced by cooler air from the poles. Because of this convective movement of air, we would expect most winds to be northerly and southerly. However, most global winds, travel east or west. The rotation of the earth on its axis explains this.
2. Have the students use a turntable to illustrate the effect of the earth's rotation on its winds.
   a. Have the students cut a square of paper to cover the top of a turntable. Instruct them to make a hole in the center of the paper and fit the paper onto the turntable, mark the circumference, remove the paper, and cut it to the size of the turntable.
   b. Have the students do the following:
      1. Measure one-third the distance from the edge of the paper to the hole in the center, and place an "*X*" there. Label it 60°N.
      2. Measure one-third the remaining distance to the hole, and make another "*X*". Label it 30°N.
      3. Use a compass and a colored marker to draw circles at 60° and 30°.
      4. Put the paper back on the turntable.



c. Instruct the first student to brace his/her wrist with one hand and hold a marker on the 30°N latitude line of the paper on the turntable. Have the second student slowly and steadily rotate the turntable counterclockwise at least one full rotation. Have the students do the same thing again, this time holding the pencil at the 60°N latitude line.
NOTE: The student will have to adjust the pressure of the marker on the paper so that he/she does not stop the motion of the turntable.

d. Now instruct the student with the marker to try to move it on the paper in a straight line from the center to the 60° line while the second student continues to turn the turntable slowly counterclockwise. Have several pairs of students try this.

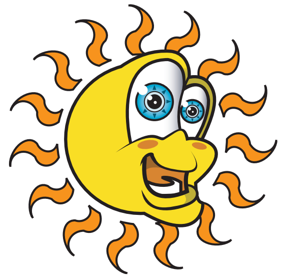
e. Since the surface air currents move over the earth toward the poles from 30°N to 60°N, have several pairs of students try moving the marker point on the paper in a straight line from 30°N latitude to 60°N latitude while the turntable moves counterclockwise.

B. *Have the students build models of wind machines.*

1. Show the students a pinwheel. Have several students blow on it to rotate it. Relate this to wind machines. Point out the blades and the rotating structure to which they are attached. These are analogous to the propeller of a wind machine.
2. Divide the students into three groups. The students in different groups will build models of different kinds of simple wind machines. Give each group copies of a different student sheet: *"Making a Helix Rotor" (page 97), "Making a Savonius Rotor" (page 98),* or *"Making a Conventional Wind Machine" (page 99).*
   NOTE: The conventional wind machine model is more complex and requires more time.
3. Provide the materials listed on the student sheets. Have the groups construct the wind machine models according to the instructions on the student sheets.
4. When the wind machine models are constructed, have the students demonstrate the use of each machine. Use a large room fan with slow and fast speeds to provide the *"wind." (You can take the students outside for the demonstration if there is a steady wind blowing.)*
5. Have the students count the number of times each machine turns at a slow fan speed in a given amount of time *(10, 15, or 30 seconds)*. Discuss how to tell which wind machine did the best job of harnessing the wind.

C. *Have the students trace the energy conversions in the models.*

(For example, begin with solar heat – the energy that causes the development of convection currents – and trace it to the wind's kinetic energy and then to mechanical energy.) Use the models above to illustrate mechanical energy derived from the wind. Explain that we can produce electrical energy by using wind to turn turbines attached to electrical generators.



III. *Follow-Up*

A. *Have the students write a paragraph explaining why winds occur.*

B. *Have the students name four ways we can convert wind energy into usable energy.*

(grinding, pumping, producing electricity, sailing)

IV. *Extensions*

A. *Have the students look at a climate map of the U.S. and suggest locations which might be appropriate for wind energy use.*

Have them research the average wind speeds and frequency in the areas they have selected. Ask them to find out the minimum average speed for economically feasible wind-powered generation of electricity. For detailed information on wind, contact the AMERICAN WIND ENERGY ASSOCIATION, 777 North Capitol Street, NE, Suite 805, Washington, DC 20002.

B. *Have the students research power plants that use wind energy to produce electricity.*

Resources

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CA: Visual Purple, 1974.

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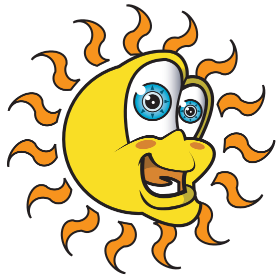
McLean, VA: The Mitre Corporation, 1975.

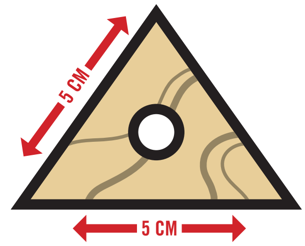
Konigsberg, J. THE MONTANA RENEWABLE ENERGY HANDBOOK.
Helena, MT: Department of Natural Resources and Conservation, 1981.

Oak Ridge Associated Universities. "WIND ENERGY."
Oak Ridge, TN: DOE, n.d. *(Address: Technical Information Center, DOE, P. O. Box 62, Oak Ridge, TN 37830.)*



Making a Helix Rotor

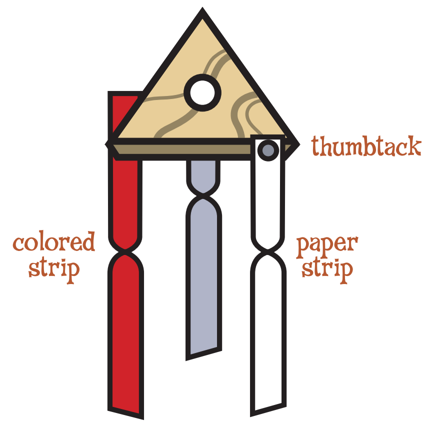
Materials: piece of 3/8" thick balsa wood, sheet of paper, wire coat hanger, wire cutters, 2 corks, 6 small map tacks, 2 empty thread spools, marker pen, small saw or hobby knife, drill *(or small nail and hammer)*



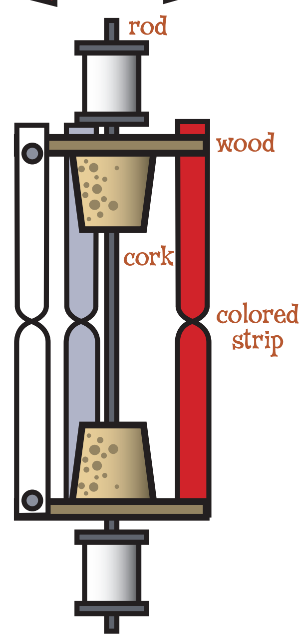
1. Cut 2 triangles, measuring 5 cm on each side, from the 3/8" balsa. Make a hole in the center of each triangle, as shown. Use a small nail and a hammer or use a drill. The hole should be slightly larger than the thickness of the wire coat hanger.

2. Cut a straight length of coat hanger to measure about 12".

3. Force each cork onto an end of the wire, moving each to about 2" from the end of the wire.

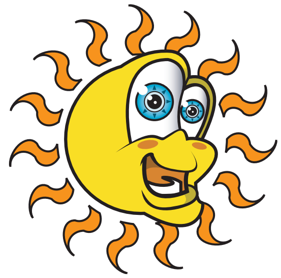


4. Cut 3 paper strips *(1/2" wide)* from the top or bottom of a sheet of paper. The strips will be 8" x 1/2". Use a marker to color one of the paper strips. Then use small map tacks to attach the 3 paper strips to one of the triangles, as shown.



5. Put both balsa triangles on the wire, outside the corks. Position the corks to determine the proper gap between the triangles. Twist each paper strip once and tack each to the second triangle.

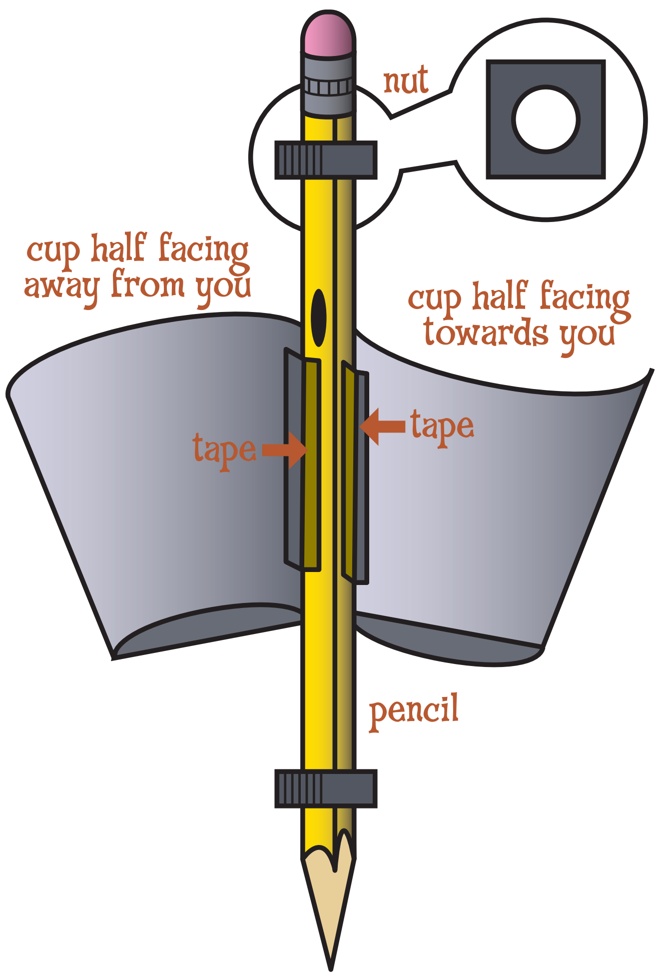
6. Put a thread spool on each end of the wire. When you hold the helix rotor in the wind, hold it by these spools so that the rotor can spin freely. Hold the rotor vertically in the wind.

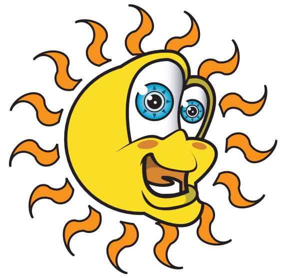


Making a Savonius Rotor

Materials: bathroom cup, wood dowel or pencil, marker pen, 2 large square nuts *(to fit dowel or pencil loosely)*, scissors, tape.

1. Cut a bathroom cup in half vertically and tape each half to the pencil or dowel, as shown.
2. Use a marker *(or a strip of tape)* to make a stripe down the outside of one of the cup halves.
3. Fit a large square nut over each end of the dowel or pencil.
4. Hold the nuts and position the rotor vertically in the wind.

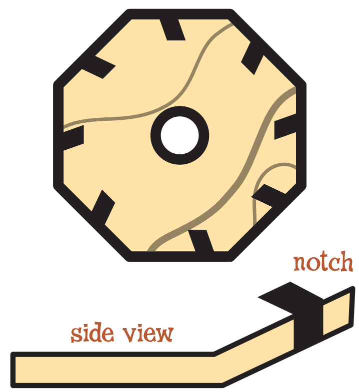


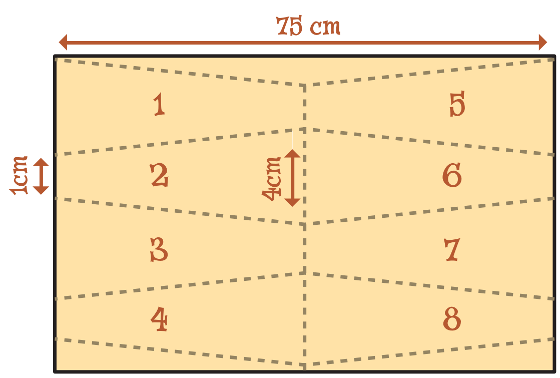


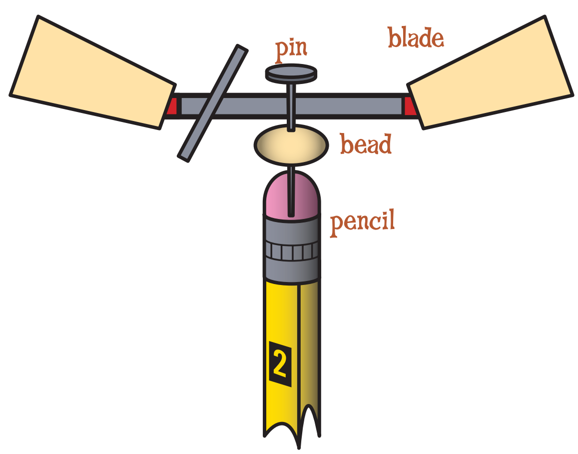
Making a Conventional Wind Machine

Materials: pencil with eraser, 5-cm square of 3/8" balsa, 12 cm x 15 cm piece of 1/8" balsa, hobby knife or small saw, metric ruler, tape, wood glue, large map tack or straight pin, marker pen, wood or ceramic bead.

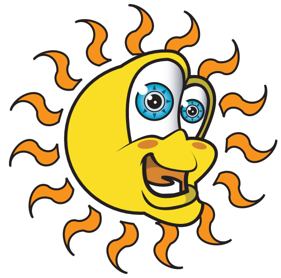
1. Cut the corners from the square of 3/8" balsa to make an octagon. This will be the hub of your wind machine's propeller.
2. Use the ruler to determine the center of the hub. Push the map tack or straight pin through the center. Turn the hub on the pin until it spins freely. Remove the pin until after you have finished building the propeller.
3. Use a hobby knife to cut grooves in each of the octagon's edges. The grooves are where you will insert the blades. Cut them at an angle, as shown. Make them 1/2 to 1 cm deep.
4. Divide the rectangle of 1/8" balsa in half. Use a pencil and a metric ruler; mark the wood so that you have 7.5 cm halves. Use the pencil and ruler to mark off 8 blades, each 1 cm wide on the narrow end and 4 cm wide on the other end, as shown. Use the hobby knife to cut out the blades.
5. Use a marker to color 1 propeller blade.
6. Insert and glue the propeller blades into the grooves you cut in the hub. Let the glue dry.
7. Reinsert the pin through the hub. Put a small wood or ceramic bead on the pin and push the pin down into the top of the eraser.
8. Hold the model by the pencil, so that the propeller is vertical, and allow the propeller to spin in the wind.







OLD MACDONALD MADE SOME FUEL



SUBJECTS: Life Science, General Science

TIME: 4 class periods
(including record keeping over 2 weeks)

MATERIALS: transparencies, overhead projector, one-quart canning jars *(or large beakers)*, dried baking yeast, sugar, hot water, paper towels, rubber bands, heavy duty plastic bags, shovel, fresh manure, large buckets *(preferably, with volume measurements)*, duct tape, grease pencils, water, thermometers, large cardboard box, study lamp with 40-W bulb, *(optional)* gas collection bottles, tapers, matches, student sheets

Objectives *The student will do the following:*

1. Define biomass and name at least 10 sources of biomass.
2. Describe fermentation and the production of ethanol.
3. Describe the production of methane.
4. List advantages and disadvantages of using biomass rather than fossil fuels.

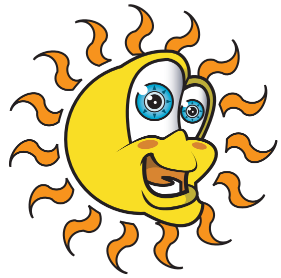
Background Information

The process of photosynthesis in plants stores 40 trillion watts of solar energy in organic matter each year. As the use of nonrenewable fossil fuels continues to result in environmental and supply concerns, organic matter may provide a significant energy alternative. Green plants continually convert solar energy to the chemical bonds in organic matter – a renewable energy resource. This energy source can be used in two basic ways: burned directly as a fuel *(as in specially adapted electric generating plants)* or used to produce transportable fuel, such as ethanol, methanol, and methane. Any solid material of animal or vegetable origin from which energy can be extracted is called biomass.

Plants with high concentrations of carbohydrates *(sugars or starches)* can be harvested for their total organic content rather than just for the vegetables or other limited products they provide. Carbohydrates from such plants can be broken down by enzymes into simple sugars. We can ferment simple sugars under anaerobic *(without oxygen)* conditions to produce ethanol and carbon dioxide. *(We already use some ethanol as fuel.)*

When organic wastes from both plants and animals are stored in anaerobic conditions, the decomposer bacteria use the organic matter as food and produce methane gas. If only half the one-and-a-half billion tons of organic waste produced by the United States *(U.S.)* each year were collected and processed, we could produce methane gas equivalent to half our current natural gas production. A few electric generating plants in the U.S. already use methane gas, piped in from extensive landfill areas, as a fuel to produce electricity.

There are three chief advantages of using biomass instead of fossil fuels for energy. First, biomass is renewable. Second, using organic wastes for energy makes use of something we would otherwise have to dispose of. Third, using biomass energy is often less environmentally damaging than obtaining fossil fuels and burning them. There are, however, drawbacks. Biomass is not renewable if the plant materials are not grown at a rate matching the rate of use. Biomass contains less energy per unit of weight or volume than fossil fuels *(in which energy is highly concentrated)*. Some forms of biomass energy have thus far been more expensive than conventional fossil fuels. Finally, some biofuels or ways of using biomass have environmental effects that are as undesirable as those of fossil fuels.



Terms

aerobic: describes organisms that must have free oxygen for respiration to live.

anaerobic: describes organisms that are able to live and gain energy without oxygen.

biomass: all solid material of animal or vegetable origin from which energy can be extracted.

ethanol: a form of alcohol derived from fermentation of sugar and grain crops and used as fuel; structural formula is CH_3CH_2OH.

fermentation: the breakdown of complex molecules by microbes into ethanol and carbon dioxide.

methane: a colorless, odorless gas formed by the anaerobic decomposition of biomass; formula is CH_4; can be burned as a fuel.

methanol: a form of alcohol produced from a variety of materials *(including wood)* and used as fuel; formula is CH_3OH.

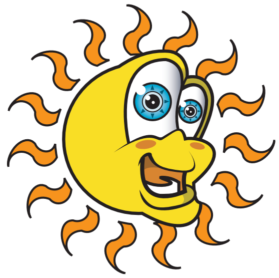
organic wastes: discarded or unwanted materials of living or once-living origin such as animal wastes, crop residues, agricultural product residues, and food scraps; composed of carbon-based substances.

Procedure

I. *Setting the stage*

A. *Ask the students how they would define "biomass."* *("Bio" indicates living or once-living.)* Make sure the students understand that the term *"biomass"* refers specifically to the use of materials from plant or animal sources as energy resources.

B. *Ask what normally happens to organic materials when they are no longer a part of the organism that produced them.*
(They decay or are eaten; their energy is transferred to the organisms which decay or eat them.)
NOTE: This may lead to a brief review of food chains. Make the point that solar energy, used in photosynthesis to make carbohydrates, is transferred from one organism to another. If humans use organic materials as biomass fuel, they are stepping into the food chain and using the energy for other purposes.



C. ***Have the students brainstorm a list of materials that could serve as biomass.***

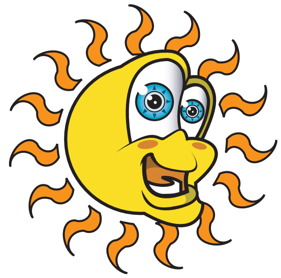
Some materials such as firewood are very familiar to them. In some places in the world dried dung is a common fuel. Some students may be familiar with beeswax candles or lamps that burn whale or plant oils.

II. *Activities*

In these activities, the students will demonstrate the production of two fuels from solid organic wastes. Such fuels are sometimes called biofuels. First, the students will investigate the fermentation of sugar to produce ethanol. Second, they will demonstrate the production of methane from manure.

A. ***Have the students produce ethanol by the yeast fermentation of sugar.***

1. Introduce fermentation to the class.
    a. Share the following information:
    Fermentation is a biochemical process in which microorganisms convert simple sugars into ethanol and carbon dioxide. The microbes release carbon dioxide as a gas. Ethanol can be blended with gasoline *(to make "gasohol")* or used by itself as a fuel. For ethanol production, we can ferment sugar-rich crops such as corn, wheat, sugar cane, potatoes, and beets and/or organic by-products and wastes. Large carbohydrate molecules such as starches and cellulose are treated to break them down into simple sugars, which are then mixed in a warm, water-based mash. Yeasts then ferment the organic mixture.
    b. Show the students a transparency made from the teacher sheet *"Commercial Fermentation Process" (page 106)*. Discuss the information with the students.
    NOTE: Point out that none of the by-products are wasted.
2. Have the students complete the demonstration.
    a. Divide the students into groups of two to four students each. Dispense to each group a one-quart canning jar or large glass beaker. Then have the students combine *(in order):*
    2 cups water *(hand hot from the tap)*
    2 tablespoons white sugar
    1 teaspoon dried baking yeast.
    b. Have them loosely cover the jar and leave it in a dark place. *(You might provide paper towels and rubber bands for covering the jar.)*
    c. Have the students record the smell and appearance of the mixture every day for a week, including the end of the class period the first day.
    d. Discuss the results with the students. The mixture should smell like bread the first day. In following days, it should smell progressively more like beer or wine. It should get progressively cloudier as the yeasts multiply. The mixture should have a "*head*" of carbon dioxide bubbles on the top of the solution for the first day or two. At the end of the week, the solution may be relatively clear and the head on the top may be completely gone. The ethanol produced by the yeast during fermentation actually kills the yeast eventually when its concentration reaches lethal levels.



e. Show the students the transparency again and relate the classroom demonstration to the industrial processes in the diagram.

f. Ask the students to list some common food products produced by fermentation.

B. *Have the students produce methane by the anaerobic decompositon of animal waste.*

1. Introduce the topic to the students. Show the students a transparency made from the teacher sheet *"Basic Steps from Biomass to Gas" (page 107)*.
2. Have the students generate methane from manure.

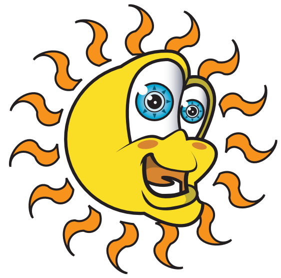
a. Prepare in advance for the production of methane.
Obtain a supply of fresh *(green)* animal manure adequate to provide two cups for each group of students. It may contain small amounts of straw or hay without creating a problem. Remove any sticks or other things that could punch a hole in the plastic bag. The manure can be handled best by placing it in a container *(such as a garbage bag)* that can be securely closed, and then putting the bag in a large can or bucket. The manure should be high enough in water content so that it is highly viscous *(semi-liquid)*. Add water to it if it is too dry. Local farms, stockyards and large animal treatment facilities are sources of manure. Cow manure is preferable; sheep, horse, hog, or chicken manure is a satisfactory alternative.

NOTE: Check with the students to see if they have access to cow manure. You may be able to make arrangements with one of them for bringing it to the classroom.

b. Divide the students into groups of about four students each. Give each group a copy of the student sheet *"Methane from Manure" (page 108)*. Give each student a copy of the student sheet *"Data Sheet: Methane from Manure" (page 110)*.

c. Supply each group with the materials listed on the student sheet. Have them proceed according to the given instructions.

1. Caution the students about the need for care in handling the material and in preparing the bags for gas collection. Methane will escape if there are holes in the bags or if they are not properly closed and secured. Use thick bags that will hold two to three gallons.
2. Before the students put the wastes into the bags, they must label the bags and test them for air leaks by inflating them with air and submerging them in water.
NOTE: Grease pencil-writing on duct tape makes a good label and is waterproof.
Apply it before inflating and submerging the bag to check for air leaks.
3. Have the students estimate the volume of material placed in the bags, following the directions on the student sheet. Provide a large bucket or other container *(preferably with volume measurements)* for each group. If necessary, provide each group with a container to catch the displaced water and a beaker or other graduated container to measure the volume of the displaced water.



d. Have the students incubate their biomass digesters for five to ten days.

1. Have the students place the bags in various locations, recording the temperatures and locations on the data sheets. Some suggested locations are: incubators or warming chambers, under an inverted cardboard box with a lamp with a 40-watt bulb to supply heat, on a sunny window ledge, in a shaded part of the classroom, or in a portable cooler with a few ice cubes *(which should be replaced each day as the ice melts)*.
2. Bags placed in the warmer environments may fill with gas in a few days and should be evaluated then. The others may be evaluated at the same time. Those in cooler environments will take much longer and may not generate methane at all if the temperature is sufficiently low. Have the students make daily observations for five to ten days and record them on the student sheet.

e. *(Optional)* Demonstrate collecting and testing the gas.

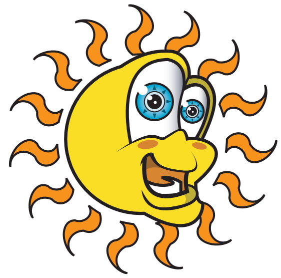
1. With the help of a student, submerge a gas-filled bag in a sink or large tub filled with water and puncture a hole in the double plastic bags with a sharp instrument. Allow the gas to bubble into submerged, water-filled gas collection bottles. You may need to collect the gas from several bags.
2. After filling several bottles, test a few of them by bringing a long taper near the mouths of the bottles. Have the students compare the flame to that produced by burning natural gas *(e.g., in a gas range)*. Compare the clean burning of methane and natural gas to the characteristics of kerosene or another lower-grade fuel.

III. *Follow-Up*

A. ***Have the students list 10 types of biomass.***

B. ***Have the students discuss the advantages and disadvantages of using biomass and biofuels instead of fossil fuels.*** *(Use the background information to guide the discussion.)*

C. ***Have the students write a paragraph and draw simple diagrams describing the use of biomass for ethanol and for methane production.***



IV. *Extensions*

A. *Have the students survey local gas stations to see how many sell gasohol.*

Have them write to their state government *(and those of other states)* to find out how widely gasohol is used.

B. *Have the students report on other types of biomass energy now being used such as wood.*

C. *Have them debate the use of crops for biomass when there are people in the world who need crops for food.*

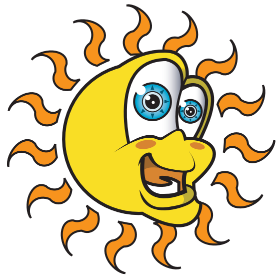
Divide the students into two groups.

Resources

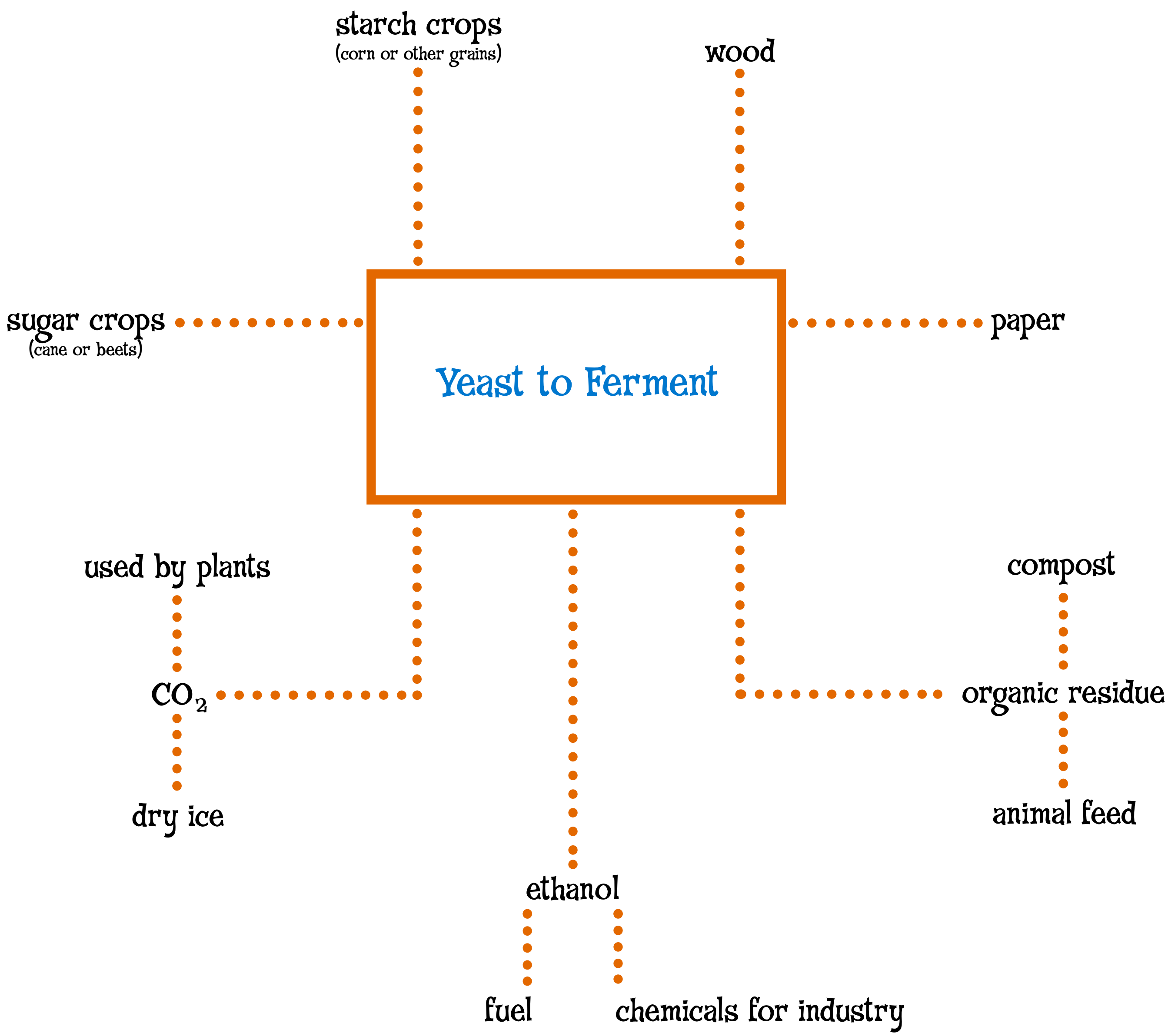
House, D. THE COMPLETE BIOGAS HANDBOOK.
N.p.: N.p., 1978.

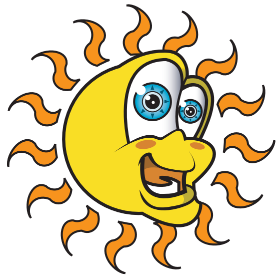
Konigsberg, J. MONTANA RENEWABLE ENERGY HANDBOOK
Helena, MT: Department of Natural Resources and Conservation, 1980.

United States Department of Energy. FUEL FROM FARMS.
(Address: Technical Information Center, DOE, P.O. Box 62, Oak Ridge, TN 37830, Attn: Fuel From Farms.)

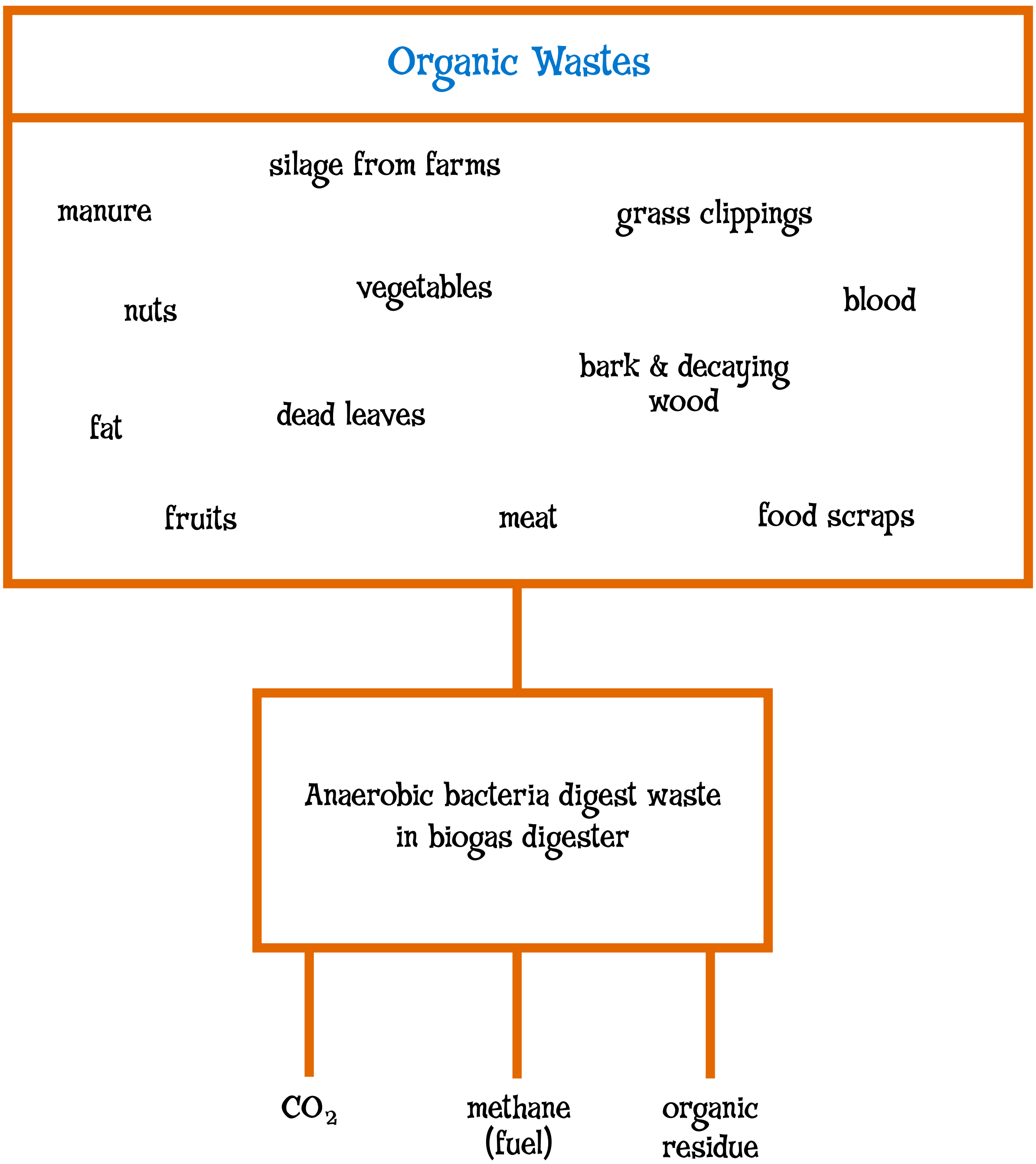


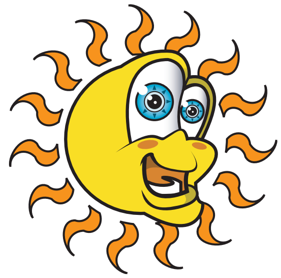
Commercial Fermentation Process





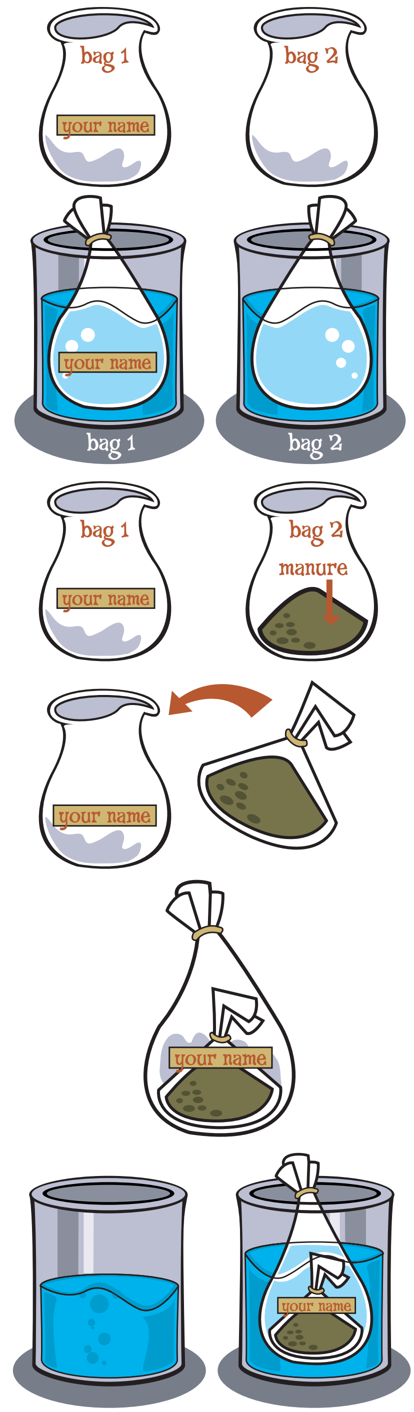
Basic Steps from Biomass to Gas





Methane from Manure

Materials: 2 heavyweight plastic bags with closures, duct tape, grease pencil, large bucket *(with volume measurements),* water, 0.5 L *(about 2 cups)* fresh manure and a thermometer.



1. Prepare your bags.

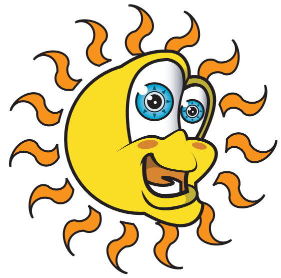
- **a.** On one plastic bag *(bag 1)*, place an 8-cm strip of duct tape. With a grease pencil, write your initials or name on the tape.
- **b.** Blow air into both bags *(1 and 2)*. Close each bag tightly. Look closely for air leaks after placing the bags in water. Use only bags without leaks! Dry the bags.

2. Prepare the biogas digester.

- **a.** Place about two cups (0.5 L) manure in bag 2.
- **b.** Handle all plastic bags with care! Do not punch holes in them.
- **c.** Squeeze *all* the air out of bag 2 *(containing the waste)*.
- **d.** Close bag 2 by twisting the top tightly down about 8-10 cm only. Leave room for the gas to inflate the bag.
- **e.** Loop the twisted part of bag 2 over and tie it carefully. Let no air in!
- **f.** Place bag 2 *(with the waste)* in bag 1 *(with the label)*, removing all of the air in bag 1 and closing it as you did for bag 2.

3. Estimate the volume of your double bag and its contents.

- **a.** Submerge the closed double bag in water.
- **b.** Measure the water it displaces.
- **c.** Record this volume on the data sheet.
- **d.** Dry off the bag.



Methane from Manure continued

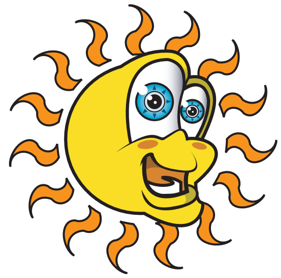
4. Place the bag in a room temperature, a cool, or a warm classroom location, as directed by your teacher. Record the location of your bag on the duct tape, using a grease pencil.

5. Be sure you have recorded the bag identification, its location, the temperature of the location, and the starting date on the data sheet.

6. Observe your bag every day. On the observation chart, record any changes or absence of changes for 5 to 10 days *(or until some of the bags in the classroom seem to be nearly full of gas)*.

7. To find the estimated final volume of the bag, submerge the closed bag in water. Measure the displaced water. Record the volume. Calculate the volume of gas in your bag *(final volume minus starting volume)*.

bag inflates



Data Sheet: Methane from Manure

Bag I.D.	Location	Temp.	Initial Volume	Start Date	Final Volume	Final Date	Volume Change (gas produced)

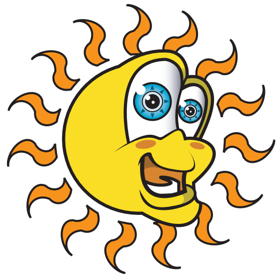
Date	Observations

Results:

1. Compare the amount of gas produced by your generator with that produced by others in your class. Which generators seemed to produce the most methane? The least?

2. What factors *(variables)* seem to influence the production of gas?

IF THE SUN DIDN'T SHINE...



SUBJECTS: Life Science, General Science Earth Science

TIME: 5 class periods

MATERIALS: transparencies, overhead projector, globe, flashlight, 2 small houseplants or pots of vegetable seedlings, filmstrip projector, prism, 6" flower pots, potting soil, corn seeds, metric rulers, 5 large cardboard boxes, cellophane *(red, blue, yellow, green and clear)*, tape, several green leaves, ethanol, beaker, hot plate or bunsen burner, piece of cheese cloth, 2 pieces of white poster board, scissors, student sheet

Objectives *The student will do the following:*

1. Explain how the sun affects all life on earth.
2. Identify the electromagnetic spectrum, including the visible light spectrum.
3. Conduct experiments showing some of the effects of light on plants.
4. Relate the earth's tilt and rotation to the varying amounts of solar energy available at different locations and different times of the year.

Background Information

The sun is the source of the energy that sustains life on earth, providing heat and light. Through the process of photosynthesis green plants convert this light energy into the chemical energy *(food)* that keeps them alive. Photosynthesis gives off oxygen, which most living things must have to survive. The sun's warmth keeps our planet habitable and solar heat energy drives the climate and weather systems that distribute heat and fresh water over the earth's surface. Solar energy even powers the cycles of vital elements such as nitrogen in our environment.

The sun is a huge thermonuclear fusion reactor, giving off a number of different energy rays in all directions in space. A minute fraction of this energy falls on the earth. Of the energy falling on the earth, somewhat less than half is reflected back into space by atmospheric clouds and dust and the earth's surface. The remainder *(about half)* of the sun's rays affect the earth. Only a tiny portion of this energy *(far less than one percent of the radiant energy falling on the earth)* is captured by green plants. Almost all of the energy affecting the earth is converted to heat energy; it is re-radiated out into space after warming the atmosphere and surface, evaporating water, and causing wind and waves.

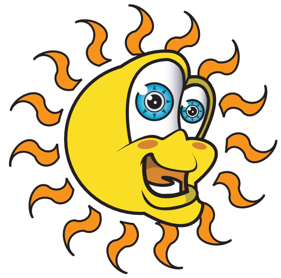
Terms

electromagnetic spectrum: the sequence of electromagnetic waves ranging from cosmic rays *(shortest wavelength)* to radio waves *(longest wavelength)*; the visible light spectrum is a very small part of it.

photosynthesis: the process by which green plants capture light energy from the sun and convert it to chemical energy; the process by which green plants combine carbon dioxide and water using light energy to make carbohydrates *(food)*.

radiation: the flow of energy across space via electromagnetic waves, such as visible light.

solar radiation: energy emitted by the sun and traveling in waves.



Procedure

I. *Setting the stage*

Ask the students to imagine what would happen to the earth and the life on it if the sun stopped shining. Have them explain their answers.
NOTE: Students should list effects in two general categories: 1) physical effects on the earth itself, such as decreased temperature, winds, precipitation, and so forth; and 2) biological effects, including effects related to the interdependence of plants and animals.

II. *Activities*

A. *Introduce the students to the essential role of the sun in life on earth.*

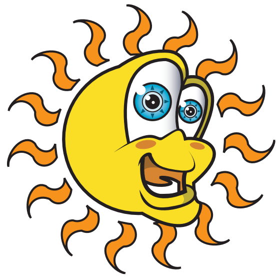
1. Share the background information with the students. Review photosynthesis briefly.
2. Have the students amend their list of the effects of the sun's ceasing to shine.

B. *Have the students examine the electromagnetic spectrum and the energy the earth receives from the sun.*

1. Use a transparency made from the teacher sheet *"Solar Spectrum" (page 117)* to show the students the electromagnetic spectrum and where solar energy fits into it. Discuss the spectrum with them, pointing out the major features on the transparency.
   NOTE: Clarify that infrared rays convert to heat energy when they strike matter and that ultraviolet rays are the component of sunlight responsible for tanning our skin. Ultraviolet light is harmful to us; the ozone layer high in our atmosphere protects us from most of these damaging rays.
2. Give each student a copy of the student sheet *"Spectacular Spectrum Facts" (page 118)*.
   a. Leave the transparency up for them to consult as they answer the questions on the student sheet.
   b. When the students have completed the questions, discuss the answers with them. The answers are as follows: 1) infrared, visible light, ultraviolet; 2) visible light; 3) infrared; 4) x-rays; 5) ultraviolet; 6) infrared, green plants; 7) light; 8) light, photosynthesis; 9) infrared; 10) red, orange, yellow, green, blue, violet; 11) violet, red; 12) infrared, visible light.

C. *Demonstrate the visible light spectrum for the students.*

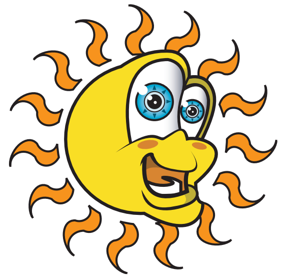
1. Shine the light from a filmstrip projector through a triangular glass prism onto a white screen. *(If you do not have a projector, use strong sunlight at a window.)*
2. Ask the students to describe their observations. In what order do the colors appear? Explain that each color is a different wavelength and that each, therefore, has a different amount of energy. The prism refracts or bends the rays differently because of their differing energy.



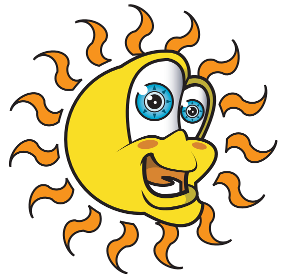
3. Ask the students how this demonstration relates to rainbows. *(Water droplets act as prisms, making the visible spectrum in sunlight separately visible to us.)*
4. Discuss with the students why humans see color. *(We see color because the retinas of our eyes are capable of receiving all the different wavelengths of visible light. Our brains then attach meaning to the signals transmitted from our eyes, and we "see" an incredible variety of colors, shades and tones. The color we see are the wavelengths reflected by the things we are looking at. The other wavelengths are absorbed. For example, a blue shirt looks blue because it reflects certain wavelengths [blue light] to our eyes and absorbs red, orange, yellow, green, and violet light.)*

D. ***Have the students investigate the importance of sunlight to living organisms.***

1. Discuss with the students why sunlight is important to all living organisms. Be sure to include the following terms in the discussion:
   a. Photosynthesis *(conversion of light energy into chemical energy)*
   b. Plants *(produce energy/food from sunlight, water and carbon dioxide)*
   c. Animals *(consumers obtain energy directly from plants or indirectly, by eating other animals that eat plants).*
   NOTE: Make sure the students understand that all living organisms *(with a few bacterial exceptions)* get energy from sunlight, either directly or indirectly. You might use some simple food chains to illustrate this.
2. Demonstrate the effects of differing amounts of sunlight on plants of the same species.
   a. Obtain two small houseplants of the same species and size *(Wandering Jew works well)* or plant two identical pots each with four corn or bush bean seeds *(sprouted potatoes also work well).* Maintain both specimens under the same good conditions for about two weeks.
   b. After about two weeks, when the seedlings have emerged and the first leaves are well developed, begin the experiment. Put one pot in a sunny window and the other pot in a area of deep shadow *(under a table or desk, where it is shaded but gets some reflected light.)*
   NOTE: If using seedlings, remove some so that there are only two in each pot.
   c. Keep the soil in all the pots moist but not wet. Check the plants before you water.
   d. Have the students record their observations at the end of one week and again at the end of the second week. Have them observe the plants' sizes, colors, leaf and stem differences, and other characteristics.
   e. Discuss the results with the students. The dark-grown seedlings or houseplants will be long, thin, and pale, with long stems between small leaves. *(These characteristics are known as etiolation.)* They might also lean towards the light. *(This is phototropism.)* Ask the students why plants do this. *(It is a survival mechanism; the plant grows toward the light as quickly as possible.)* Now your students are able to diagnose a common houseplant problem – long, thin stems, smaller-than-normal leaves, and leaning toward the light means that plants are not getting enough light.



3. Have the students investigate the effect of different wavelengths of visible light on green plants.
   a. Gather the following materials:
      five 6" plastic pots, package of corn seeds *(at least 50),* potting soil, 5 cardboard boxes *(large enough to completely contain one 6" pot with a 6-8" plant, open on top, and with a few holes cut around base to allow air circulation),* 5 pieces of cellophane *(green, red, yellow, blue, clear)*
   b. Plant 10 corn seeds in each of the pots *(filled with equal quantities of soil.)* Water the soil well, but do not soak it.
   c. When most seedlings have emerged, have the students carefully measure and record the height of each seedling in each pot. Have them calculate the average height of the seedlings in each pot.
   d. Place one pot in each box and cover the box top completely with one of the five different colors of cellophane.
   e. Put the pots in a location where they all get equal light. Water when the soil becomes slightly dry to the touch. Keep the moisture as equal as possible in all five pots.
   f. At the end of two weeks, have the students measure and record the heights of all the seedlings in each pot, again calculating average heights for each pot's seedlings.
   g. Post on the board the average heights for each pot before and after the colored light treatment. Have each student make a bar graph showing the growth of the seedlings. Discuss the results as a class. Which color produced the best growth and why? Which produced the least growth and why?
      NOTE: Remind the students that the colored cellophane blocks the wavelengths of the color we see and admits the other wavelengths. The fact that plants are green but photosynthesis requires red and violet wavelengths of light is sometimes confusing to students. Remind the students that the plants are green because green wavelengths of light are reflected by the plants' chlorophyll, not absorbed and used. The plants absorb mostly the red and violet light; they absorb lesser amounts of the others. Sometimes we can see these other colors in plants that are normally green. Yellow and orange pigments, for example, become visible when leaves die and the chlorophyll breaks down .
4. *(Optional)* Demonstrate the wavelengths of light that chlorophyll absorbs and the wavelengths it transmits.
   a. Gather the following materials:
      several green leaves *(torn into small pieces)*, ethanol, beaker, hot plate, piece of cheese cloth *(for a coarse filter),* prism, rectangular glass container *(clear)*, light source *(such as a filmstrip projector),* 2 pieces of white poster board.
   b. Boil the leaves and ethanol together in the beaker until the alcohol is deep green. *(This extracts the chlorophyll from the leaves.)*
   c. Pour the green alcohol into the rectangular glass container through a coarse filter *(cheese cloth)* to remove leaf bits.
   d. Cut a narrow vertical strip out of the middle of one piece of posterboard.



e. Put the posterboard with the slit cut in it in front of the projector. Have a student hold the prism in front of the slit. Have a student hold the second piece of posterboard in front of the prism.

f. Adjust the positions of the light, slit poster board, prism, and second piece of poster board so a visible light spectrum appears on the second poster board. The students will see the entire spectrum *(all colors)*. Have them record the colors they see.

g. Now put the container with the extracted chlorophyll into the line-up between the prism and the second poster board. Shine the light again and adjust the positions until a spectrum appears on the second poster board. Have the students record the colors that appear.

h. Discuss the results with the students.

E. *Discuss with the students the factors that determine the amount of solar radiation reaching the earth's surface.*

The amount given off by the sun is constant, but the amount reaching the surface of our planet varies for a number of reasons.

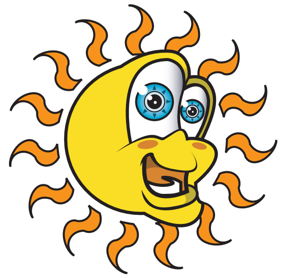
1. Have the students brainstorm a list of things that affect the amount of solar radiation received at any location. Write the list on the board. *(Be sure to include latitude, altitude, topography, cloud cover, air pollution, time of day and season.)*
2. Review with the students how the earth's tilt and its rotation around the sun affect the amounts of solar energy that different locations receive. Show them a transparency made from the teacher sheet *"Solar Energy Varies with the Season and the Place."* Use a globe and a flashlight to illustrate the points in the text on the transparency.
3. Discuss the ways that seasons and latitudes affect plants and animals. Have them list ways that living things are adapted to their habitats, particularly from the standpoints of available solar energy. Point out that the temperatures of various climates are due to the availability of solar heat energy and that the length of daylight hours and intensity of sunlight has many effects on plant growth and flowering and on animal behavior.

   NOTE: It may be helpful to list organisms typical of various biomes, such as tropical rain forests, polar regions or temperate grasslands.

III. *Follow-Up*

A. *Have the students write futuristic poems, essays, short stories, or news reports about what would happen if the earth no longer received energy from the sun.*

Let the students think up their own scenarios in which this might happen. For example, a student might write that our atmosphere has become too polluted by human and/or volcanic activity for solar energy to pass through. Another student might write that a giant asteroid has moved between our planet and the sun, blocking the sun's rays. Tell the students to incorporate information learned in the preceding activities.



B. ***Let the students share their work with the class.***

C. ***(Optional) Coordinate this writing activity with your school's Language Arts Department.***

IV. *Extensions*

A. ***Have the students further investigate the effect of day length on plant growth and flowering.***
One species that may be of interest is the poinsettia *(Euphorbia pulcherrirna)*. Growers of this popular houseplant must carefully manipulate hours of dark/light to cause the coloration of the bracts.

B. ***Have the students design an experiment to demonstrate the phenomenon of phototropism (in which plants grow toward the light).***

C. ***Have the students research chlorophyll and other plant pigments.***
Some might make charts showing the series of events that results in the fall colors of deciduous trees.

Resources

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Miller, G.T., Jr. Living in the Environment.
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Solar Energy Handbook 1978.
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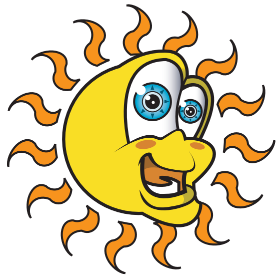
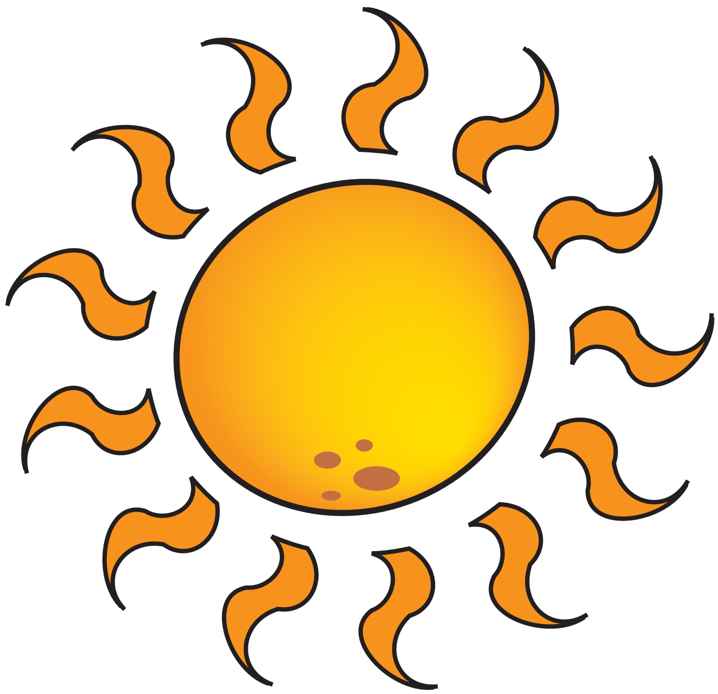
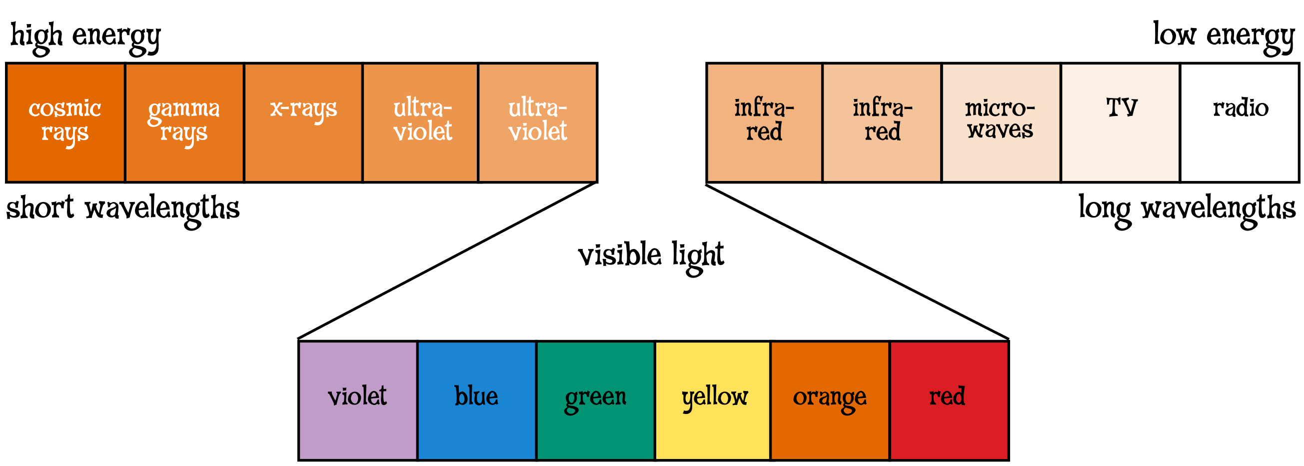
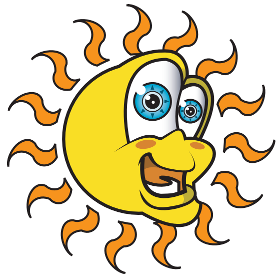


Solar Spectrum

Most of the solar rays reaching the earth's surface fall in the part of the spectrum ranging from near infrared *(heat)* waves through visible light and near ultraviolet rays.







Spectacular Spectrum Facts

1. Name the three kinds of rays that make up most of the solar energy reaching the surface of the earth.

__________________________ , __________________________ and __________________________ .

2. The human eye sees only one kind of ray. What is it? __________________________ .

3. Without solar energy, the earth's surface temperature would be hundreds of degrees below zero. What kind of ray keeps the earth from being too cold for any known life form? __________________________ .

4. Which have more energy – microwaves or X-rays? __________________________ .

5. A suntan is your body's response to skin damage from sunlight. An increase in the pigment occurs when special skin cells react to damaging solar rays. What kind of ray produces this response?

__________________________ .

6. All living things must have liquid water. That is the first reason there would be no life on a cold earth. What kind of ray makes the earth warm enough for water to exist in a liquid state? _______________________ .
The second reason there would not be life in a world without solar energy involves light. What kind of living thing depends *directly* on light energy to survive? __________________________ .

7. Which have more energy – light rays or radio waves? __________________________ .

8. Every living thing must have food – the source of the energy and nutrients necessary to maintain life. Every food chain begins with a green plant. Where do green plants get the energy they store in the food they make? __________________________ . What is the name of the process by which plants do this? __________________________ .

9. Wind results when masses of air gain different amounts of heat. Wind causes much of our weather and create ocean waves. What kind of rays convert to heat energy and cause wind? __________________________ .

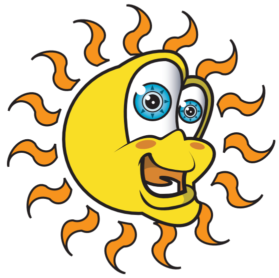
10. What are the colors of the visible light spectrum? ____

____

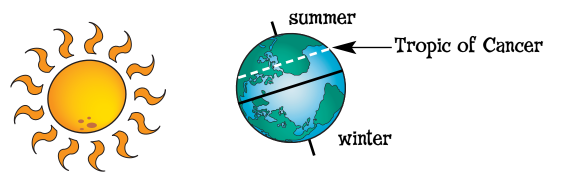
11. Which color has the highest energy? __________________________ .
Which color has the lowest energy? __________________________ .

12. Name two kinds of rays that people have learned to make very useful in modern lives.

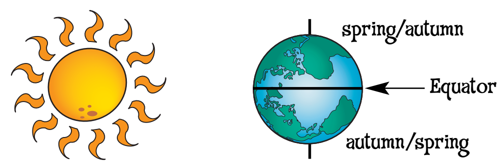
__________________________ and __________________________ .



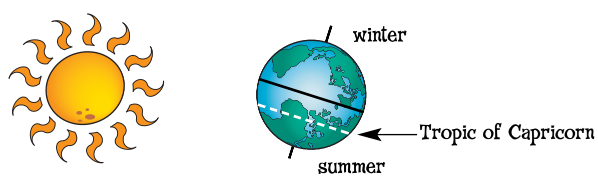
Solar Energy Varies with the Season and the Place



The amount of radiant energy given off by the sun is fairly constant year-round, but the amount of energy received varies at different seasons and places. The earth rotates on its axis, completing one turn every 24 hours. The side of the earth facing the sun receives sunshine. The side facing away from the sun is in darkness. The axis is tilted 23.5° from the plane of orbit. For this reason, the number of daylight hours at any given location changes as the earth orbits around the sun. The earth completes one orbit in one year.



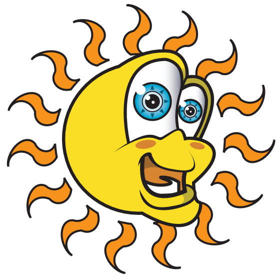
The number of hours of sunshine affects the amount of energy received from the sun. Also, the amount of energy that reaches the earth depends on the angle at which the sun's rays strike the earth. Rays that strike the earth at an angle of about 90° pass through the least amount of atmosphere. These rays lose the least energy and transfer the most heat to the earth.



The sun's rays are most direct in the tropics, near the equator. The tropics extend from the Tropic of Cancer *(23.5°N)* to the Tropic of Capricorn *(23.5°S)*. In this part of the world, the average temperature is warm year-round. When the sun's rays reach the Arctic or Antarctic Circles, the rays are at very low angles. These rays are distributed over a large area because they have a low angle and they pass through the deepest layer of atmosphere. Therefore, the smallest amount of radiant energy reaches the earth at the North and South Poles.

Polar regions remain cold even when they receive 24 hours of sunshine. The ice cover reflects much of the radiant energy and the rays strike at such a low angle that little heat is retained. The areas between the polar regions and the tropic zone are called temperate zones.

A Little SUNSHINE IN YOUR LIFE



SUBJECTS: General Science, Home Economics

TIME: 4-5 class periods

MATERIALS: large beaker or jar, sheet of black plastic, thermometer, stopwatch, hand lens, black paper, mirror, fruit, knives, hole punch, 8 sheets of plastic window screen *(available from hardware or variety store)*, 4 sheets of cardboard, string, masking tape, 3 large *(1-gal.)* glass jars, tea bags, sugar *(optional)*, paper cups, food *(as specified)*, 3 mirrors, 3 large cardboard boxes, 3 small cardboard boxes, black nontoxic paint, paint brushes, newspaper, 3 heat-proof dishes with glass covers, 1 heavy bowl, shovels, clear plastic at least 3 feet square, rocks or bricks, potted plants

Objectives *The student will do the following:*

1. Demonstrate several practical uses of solar energy.
2. Debate the advantages and disadvantages of using solar energy.
3. Formulate and write an opinion on solar energy's viability as a major U.S. energy source in the near future.

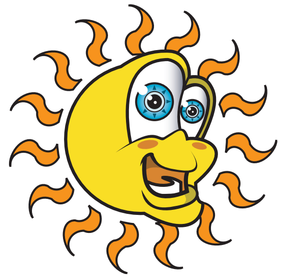
Background Information

Each day the amount of solar energy striking the earth is more than the energy potential in 22 million barrels of oil. Solar energy has many advantages in addition to its vast supply. It is available every day locally. It is not subject to political control, as are foreign oil supplies. It cannot be depleted. It does not require transportation. It is safe. It does not pollute the environment. It is free.

The history of designed use of solar energy dates back to the ancient Greek and Roman civilizations. The Greeks had created fuel problems by ravaging forests for fuel to use for healing and cooking. They also used trees to fuel smelting operations and to build houses and ships. By the 5th century B.C., Greece was almost totally barren of trees. Modern excavations indicate that the Greeks oriented their homes toward the southern horizon and even designed entire cities to gain access to winter sunlight.

Early Romans also used architectural concepts to design their homes. They used solar energy to heat the water in their public baths. They were the first to use glasses as a solar heat trap in structures similar to modern greenhouses, where they developed the science of producing fruits and flowers year-round. After the fall of Rome, greenhouses and the use of glass were lost to Europeans until the Middle Ages. Collecting solar heat for horticulture was revived in the 16th century.

Today people use solar energy in many ways, some of which work without highly developed technology. Some solar energy applications for direct drying, heating and evaporation are demonstrated simply and easily. They are the forerunners of wider industrial and home use of solar energy. When solar energy becomes a priority, we will develop the technology to increase the efficient collection, concentration and storage of solar energy.



Terms

concentrator: a device that concentrates the sun's rays on an absorber surface which is significantly smaller than the overall concentrator area.

dehydration: to cause to lose, or become relatively free of, water, as in the drying of foods to preserve them or to reduce bulk and weight.

desalinization: the removal of salt from seawater to produce fresh water.

distillation: the process of driving off gas or vapor from liquids or solids by heat and condensing the product for purification.

evaporation: the process by which a liquid is converted into a vapor.

solar collector: a device that collects solar radiation and converts it to heat energy.

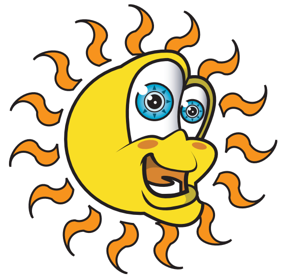
solar reflector: a device used for reflecting sunlight onto a specific point or area.

Procedure

I. *Setting the stage*

A. *Discuss with the students how they, their families, and/or their homes use solar energy today.*

1. To help get the discussion started, ask the students the following questions:
   a. What does sunshine most obviously provide? *(light by which we see)*
   b. What else does sunshine provide? For example, what happens to the students when they stand in the sun? *(They get hot and dry as the heat energy of the sun increases the temperature around them and moisture evaporates.)*
2. Point out to the students that heat, drying and light are the three things for which we all use solar energy in our daily lives.
3. Have the students brainstorm about everyday places and situations where people use solar energy. Have them state why they use it. Some examples might be greenhouses *(heat, light)*, south-facing windows *(heat)*, open drapes on sunny winter days *(heat)*, dark-colored roofs *(heat)*, outdoor clotheslines *(drying)* and skylights and windows *(light)*.

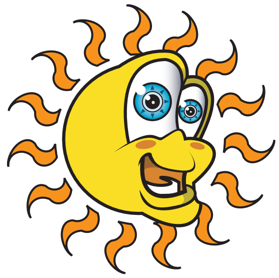


B. ***Discuss with the students the advantages of using solar energy as opposed to using fuels.*** *(Solar energy is free, nonpolluting and in unlimited supply.)* What are some disadvantages? *(The sun does not shine all the time; solar energy is hard to collect and store.)*

C. ***Distinguish between Solar Collectors, Concentrators and Reflectors.***

Many common uses of solar energy employ one of these ways of putting *"sunpower"* to work for us. Share the following information with the students:

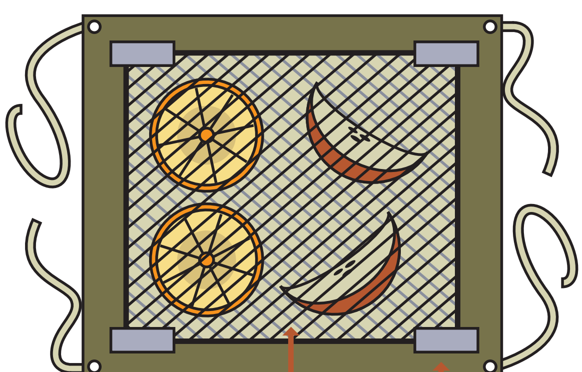
1. SOLAR COLLECTORS gather the sun's energy and store it as heat. A solar collector generally has a dark-colored surface covered by plastic or glass. Sunlight passes through the glass or plastic to the material beneath which absorbs the heat energy and the plastic or glass traps it. To demonstrate collection of solar energy, perform the following exercises:
   a. Cover a large beaker or jar of water with black plastic, and place it directly in the sun for one hour. Have the students measure and record the temperature of the water before and after the hour. The water absorbs heat energy.
   b. Measure and record the temperature inside your car before you park it in full sun and close its windows. Leave a thermometer in the car in a place where the students can read it from outside but which is not in direct sun. Have them read the temperature after you car has been parked for a while. (*Be sure that you and your students exercise all the necessary caution in the parking area.)* The air and materials inside the car absorb heat energy.
2. SOLAR CONCENTRATORS concentrate the sun's energy by focusing that energy on one spot or area. They bend the rays of solar energy. The most common concentrator is a magnifying glass.
   NOTE: A device called a Fresnel lens is made specifically for concentrating solar energy.
   To demonstrate solar concentration, do the following exercises:
   a. Use a magnifying glass to focus the smallest possible circle of sunlight onto a sheet of lightweight black construction paper.
      CAUTION: Protect the students and yourself from burns.
      Have the students use the stopwatch to time how long it takes to produce smoke from the area of focused sunlight.
   b. Now, cover the magnifying glass lens with a piece of black paper that has a 3-cm hole in the middle, and repeat the experiment. How much difference in time is there, and why?
3. SOLAR REFLECTORS reflect solar energy; like solar concentrators, they allow us to focus solar energy on a given spot. The most common reflector is, of course, a mirror. Some solar energy systems use special mirrors to help make the most use of solar energy even though the sun appears to move across the sky. *(The angle at which the sun's rays strike a fixed object changes throughout the day.)* Curved mirrors help direct the rays onto a point of collection. Examples of this include a solar furnace in France *(where a giant, curved wall of mirrors directs sunlight onto an elevated boiler)* and the Solar I solar power tower in California *(where the boiler for a steam power plant stands on a tower in the middle of a huge field of upturned mirrors focused on the boiler). (Can the students think of any everyday applications of solar reflectors?)*



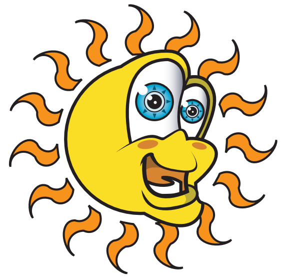
II. *Activities*

A. *Have the students build a food dehydrator.*

1. Share with the students the following introductory information:
   People have used solar energy to preserve food for thousands of years. Water in food helps create good conditions for spoiling. The sun can be used to dry foods because the heat energy evaporates most of the water. Dehydrated fruits, vegetables, and meats not only keep well because of their lack of moisture, but are easy to store and to carry from place to place. Their weights and volumes are reduced but their nutritive value is not.
2. Have the students build solar food dehydrators. Divide them into four groups, each of which will dry a different fruit.
   a. Give each group: 1 flat piece of cardboard cut out like a picture frame with a 2-inch edge *(cardboard: approximately 2 feet by 1 1/2 feet)*, 2 pieces of plastic screening *(cut to slightly smaller than the cardboard)*, string, hole punch, masking tape, small quantity of fruit *(several apples or peaches, sliced VERY thin; or several SMALL purple plums, cut in half and pitted; or 1/4 lb. seedless grapes)*
   b. The procedure for building the dehydrator is as follows:
      1. Tape one piece of screening firmly to the cardboard frame, centering it over the open part of the frame.
      2. Punch holes in each corner of the cardboard, reinforce the holes with tape, and attach strings as shown in the illustration below.



      3. Place the fruit in a SINGLE LAYER on top of the screening, place the second piece of screening over the fruit and firmly tape the edges of the screening to the cardboard.
   c. Have the students hang the dehydrators outside in a sunny spot.
      NOTE: Bring the dehydrators in every night. On damp or rainy days, keep them inside hanging in an area with free air circulation. Drying may take 2 or 3 weeks to complete.



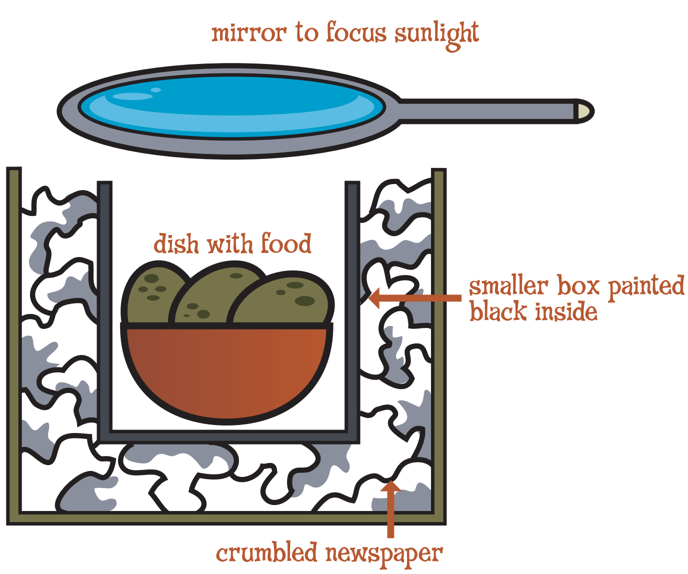
B. *Have the students investigate the merits of "sun tea."*

Ask the students how they make tea at home. Share with the students that several years ago, a major tea company had an ad campaign touting sun tea – tea *"brewed"* by the heat of the sun rather then by heat from gas or electricity. The students will compare the taste of sun tea, regularly *"brewed" (and then cooled)* tea, and tea brewed in cold water.

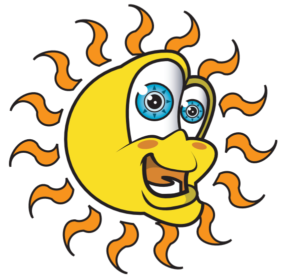
1. Prepare three batches of each in one-gallon glass jars. *(Use the same number of tea bags for each.)* Put the bags in one jar and fill it with cold water. Place it in a dark corner or in a refrigerator. Put the bags in the second jar, fill it with boiling water, and allow it to steep. Put the bags in the third jar and place it in the direct sun. Allow the jars to sit undisturbed for about four hours.
2. If desired, sweeten each gallon of tea the same way. Distribute small paper cups to the students and have a blind taste test of the three teas. Have the students record the results.
   NOTE: Make sure they are all at the same temperature and are not diluted with ice.
3. Have the students tabulate and discuss the results.

C. *Have the students use solar energy for cooking.*

1. Share the following introductory information with the students:
   Using the heat energy of the sun to cook food has some real advantages. There is no fire hazard because there is no fire; no smoke pollutes the air and there are no ashes to clean up. Sometimes campers use simple solar cookers. If modern technology were applied to solar cooking, it could become more than just a camper's back-up. A solar oven, using the absorption of heat by a dark surface and insulation to retain heat to cook food, is the demonstration in this exercise.
2. Divide the class into three groups and provide each group with the following supplies: 2 cardboard boxes *(one bigger than the other)*, newspaper, flat black paint and a paint brush, a large hand-held mirror, a flat heat-proof dish with cover, thinly sliced potatoes, apples, and/or hot dogs.
3. Have the students construct the oven as shown in the diagram below.



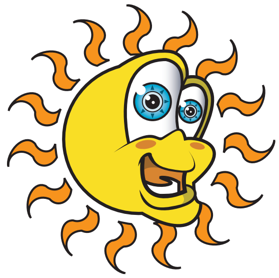
Have the students paint the inside of the smaller box black and allow it to dry. They will then place the small box inside the large box, filling the space between the two boxes with firmly crumpled newspaper to act as insulation.



4. On a very sunny day, have the students use their solar ovens.
   a. Place thinly sliced food one layer thick in the dish, cover the dish, and place it in the bottom of the small box. Set the oven where the dish will receive full sun.
   b. Have the students take turns focusing sunlight on the food using the mirror.
   NOTE: The longer the mirror is held without moving, the better.
   c. When the food is cooked, have the students sample their solar cooking.
5. Discuss situations in which solar cookers are practical. In many places in the world where people still cook over fires, there is a drastic shortage of wood for burning. In many of these places, the land has been stripped of trees and shrubs, contributing to desertification. Sub-Saharan Africa is a prime example. Solar cookers would be very helpful in many instances, but they have been resisted where they have been introduced. Talk with the students about how difficult it is to change habits, traditions and ways of life. Point out that proper training in using new technologies is essential.

D. *Have the students demonstrate water distillation using solar energy.*

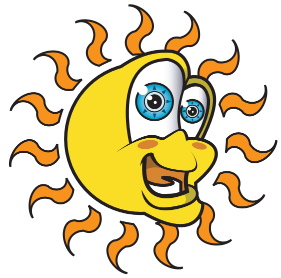
1. Share with the students the following introductory information:
Water is an abundant resource that we take for granted. While the same amount of water has been present on earth for a long time, shortages of fresh water have increased dramatically. This is due to three major factors: 1) the enormous and increasing use and pollution of water by industry and by irrigation farming in dry areas; 2) the increase in the world's population; 3) rapidly growing populations in areas of the world where natural water supplies are already scarce, such as the Middle East. Using the almost limitless supply of seawater to produce fresh water is one possible solution. However, desalinization of seawater by fossil fuel-powered distillation plants is much too expensive in terms of both money and non-renewable resources to be practical on a large scale. Solar energy has some real possibilities in this area. A simple solar still demonstrates how distilled *(clean)* water can be obtained from water that contains impurities.
2. Have the students construct a solar still.
   a. In this device, sunlight passes through plastic that covers a hole in the ground. The sun light is absorbed by the material beneath the plastic *(water, earth, plants)*. The heat evaporates the moisture, which then condenses on the bottom of the cooler plastic above. The condensed, distilled water runs clown the plastic and drops into a container.
   b. This demonstration is to be done as a class project. Gather the following items: shovels for digging, clear plastic sheet *(a shower curtain will do),* ceramic bowl, rocks or bricks, several small, potted annual plants or large seedlings *(optional)*.
   Choose an open, sunny area with soil that is easily dug.
   NOTE: Get your principal's approval before digging.



1. Have the students dig a hole about three feet in diameter and one-and-a-half feet deep. Carefully remove the sod first and pile the soil to one side, so that you can replant the grass when the demonstration is over.
2. If the soil is dry, have the students pour a gallon of water carefully around the sides and bottom of the hole.
3. Place the bowl in the center of the bottom of the hole, making sure it is stable and will not tip over.
   (Optional: To add another source of moisture, put several well-watered potted plants upright around the bowl.)
4. Cover the hole completely with one layer of clear plastic. Use bricks or rocks to seal the edges against the surface of the ground as tightly as possible.
5. Place a small rock in the center of the plastic directly over the bowl in the hole so that the condensed water will drip into the bowl.
   NOTE: In very hot weather place a small cloth between the rock and the plastic to prevent the rock from melting the plastic and/or breaking it.
6. After 24 hours, have the students uncover the hole carefully and remove the bowl. Have them measure the amount of water collected, noting its appearance.
   (Optional: After an hour or two in the sun, water will begin to condense on the plastic and drip into the bowl. If the plastic seals the hole well, the distillation process will continue even at night, but at about half the rate. The demonstration could continue for several days, with the amount of water being recorded each day. The students should also note the cloud cover. Separate collections for day and night periods could also be made.)
7. After the demonstration is done, have the students fill the hole completely and carefully. Replant the grass if possible.
8. Discuss with the students some situations in which they might use this technique themselves. In what kinds of places in the world might this be most useful?

E. *Have the students compare using a clothes dryer and hanging clothes out to dry (using a "solar clothes dryer").*

1. Have the students determine the cost of drying clothes in an electric or gas clothes dryer. Appliance stores or the local utility company will tell them how many kilowatt hours of electricity an electric clothes dryer uses and the utility company will tell them the cost per kilowatt hour. *(They can obtain the information for gas also.)*
2. Have them discuss the trade-offs we make when we use clothes dryers and the advantages and disadvantages of both methods. *(Drying clothes outside does not use nonrenewable resources and does not pollute the environment or form hazardous waste. On the other hand, it is not as convenient as using a clothes dryer, and it cannot be done at night or on rainy days.)*



III. *Follow-Up*

A. *Have the students debate the use of solar energy.*

1. Divide the class into two groups; one will stress the advantages of solar energy and the other will stress the disadvantages. Give the class time to prepare lists of advantages or disadvantages and to develop arguments to back up their claims.
2. Have each side present its arguments.
3. Have each student write down the advantages and disadvantages that would be the most important to him/her if he/she had to make a decision about whether to put more money and technology into making solar energy a major energy source for our country.

B. *Have each student write a one-page position paper on whether or not he/she thinks solar energy is a viable energy option for the United States in the near future (e.g., 20 years).*

IV. *Extensions*

Have the students research and report on topics selected from the following:

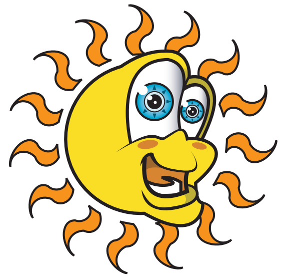
A. *The history of solar energy*

1. Greek and Roman use of solar energy – solar designed cities *(e.g., the Greek cities Olynthus, Priene, and Delos; the Roman cities of Pompeii and Herculaneum)*; Roman baths and hot rooms
2. Solar reflectors or parabolic mirrors and early *(10th century)* motors
3. Renaissance revival of solar energy use – e.g., Leonardo da Vinci's plans for industrial applications of solar energy
4. Augustin Mouchot – French scientist who, in the 1870s, invented several solar appliances, including a solar still, engine, pump, cooker, and ice maker

B. *Futuristic applications of solar energy*

1. Solar energy applications in space *(e.g., space stations)*
2. Solar energy applications in industry, including solar furnaces and food dehydrators
3. Fractional distillation of petroleum *(how solar energy could be used to separate crude oil into petroleum products)*
4. Solar energy and desalinization of seawater *(compare the cost per gallon using traditional energy sources and using solar distillation)*

3. Possible solar-powered weapons and their uses



Resources

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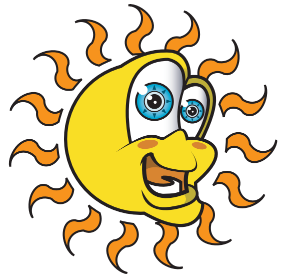
SUNSHINE FOR WARMTH



SUBJECTS: General Science, Physical Science

TIME: 4-5 class periods

MATERIALS: 4 large cardboard boxes *(same size)*, aluminum foil, glue or rubber cement, strong plastic wrap or vinyl *(clear)*, rubberbands, silver duct tape, 4 small dowels, fine sandpaper, flat black paint, paint brush, scissors or linoleum knives, 8 soft drink cans, compass, 4 thermometers, support stand, 200-watt lamp with reflector and clamp, clock, newspaper, large polystyrene cup with lid, tape *(or modeling clay)*, student sheets

Objectives ***The student will do the following:***

1. Differentiate between active and passive solar energy systems.
2. Build a model of a passive solar water heater.
3. Compare how efficiently different types of materials insulate.

Background Information

The sun provides an inexhaustible, nonpolluting and free source of energy for the earth. People take advantage of the heating energy of the sun in many simple ways. For example, some shelters and buildings are situated so the sun warms them on cold winter days. Some buildings have windows placed to allow maximum winter sun and minimum summer sun. Opening insulated curtains to let in solar heat during the day and closing them at night to retain it is a simple, but effective, strategy.

Using solar energy much more systematically becomes more important as people try to find renewable sources of energy. We have the technology to collect, temporarily store, and then use solar energy effectively. However, we need to develop even more efficient ways of doing this.

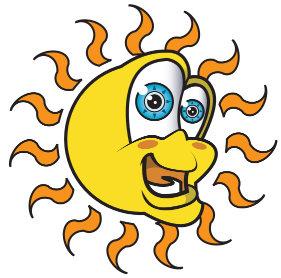
Solar energy systems are classified as either active or passive systems. Active solar heating systems use electricity to operate pumps and fans which move heated liquid or air from a collector to a storage area and then to where it is used. Passive solar heating systems use the heat energy of the sun directly or rely on basic properties of heat *(hot air or water rises; cold air or water sinks)* to transfer heat from one area to another.

Terms

active solar energy system: a solar energy system that requires external mechanical power to move solar heat energy for storage and/or use; compare *passive solar energy system*.

insulation: a material with a high resistance to heat flow.

passive solar energy system: an assembly of natural and architectural components that converts solar energy into usable or storable heat energy without external mechanical power; compare *active solar energy system*.



Procedure

I. *Setting the stage*

A. *Begin a discussion of solar energy with the students by asking the following questions:*

1. What is solar energy? *(radiant energy given off by the sun)*
2. What forms of solar energy are most familiar to us? *(heat and light)*
3. What are the major advantages of solar energy? *(nonpolluting, unlimited, free, available in almost every part of the world)*

B. *Discuss solar energy use with the students.*

1. Have the students brainstorm a list of ways they personally use solar energy and other ways they have seen or heard that solar energy can be used. Write their list on the board. *(Accept all reasonable answers.)*
2. When the list is finished, discuss it with them. Point out to them that two different kinds of solar energy use are listed. First is direct personal use of solar energy for vision, for getting warm on a cold day, or other simple uses. Second is the use of some technology by which we utilize solar energy *(such as a solar water heater)*.

II. *Activities*

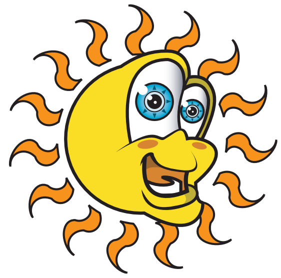
A. *Share with the students the following introductory information:*

There are two kinds of solar energy technologies – active and passive. Their names give you some idea of the difference in the ways they work.

ACTIVE SOLAR ENERGY SYSTEMS use external mechanical power to distribute collected solar heat to where it is needed. The systems often transfer heat from one substance to another. For example, in one type of active solar water heater, a fluid circulates in a closed loop, collecting heat from the sun. Water circulates around pipes containing the heated fluid, picking up the heat. Pumps and other electrical devices make this system work and carry the heat to its destination.

PASSIVE SOLAR ENERGY SYSTEMS do not use any energy source other than solar heat. Their structures allow them to collect and make use of solar energy. They rely on gravity and/or the tendency of hot water or air to rise. For example, the simplest solar water heating systems are passive. A water storage tank, painted black, absorbs solar energy though a large slanted glass or plastic window positioned to get maximum exposure to the sun. As people draw hot water from the tank for use, more water flows into the tank to be heated by solar energy.

1. Have the students list the advantages and disadvantages of both active and passive solar energy systems.
2. Tell the students they will build a model of a passive solar energy system – a small water heater.

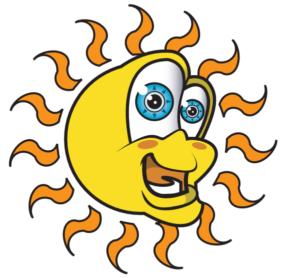


B. *Have the students build a passive solar water heater model.*

1. Prepare the soft drink cans ahead of time. Rough the surface of the cans slightly with fine sand paper. Paint them with two coats of flat black paint.
2. This activity directs the students to build and *"operate"* a passive solar water heater. Divide the class into four groups and provide each group with the following supplies: cardboard box, aluminum foil, scissors or linoleum knife, strong plastic wrap or vinyl *(clear),* empty soft drink can *(lightly sanded and painted flat black)* thermometer, glue or rubber cement, silver duct tape, rubber band, copy of the student sheet *"Build a Solar Water Heater Model" (page 134).*
3. Have the students build a solar water heater model according to the directions given on the student sheet.
4. Have the four student groups operate the solar water heater models as directed on the student sheet. Designate two groups to measure and record only the beginning and ending temperatures of the water and two groups to measure and record the temperature every 10 minutes for 40 minutes.
5. Discuss the results with the class. Why did the temperature change? Was there a difference in the temperature change between the frequently checked models and those checked at the beginning and end of the experiment? Why?

C. *Have the students investigate the effectiveness of insulation.*

1. Share with the students the following introductory information:
   To use any heating system efficiently, especially solar heating systems, we must prevent the loss of heat as much as possible. Insulation is essential to the ability of any structure to retain heat. Insulation is particularly important in solar energy systems because the collected energy is free; supplemental energy to replace *"lost"* solar heat is not free. Not having effective insulation defeats the purpose of a solar energy system.
2. Have the students test the insulating abilities of three common materials.
   NOTE: Unless you have more than one lamp available, you will have to perform the experiment as a demonstration, using student assistants. Involve as many students as possible.
3. Gather the following materials: 200-watt lamp with reflector *(clamped to a support stand)*, 4 empty aluminum cans with 1 hole in top, aluminum foil, newspaper, tape or modeling clay, polystyrene cup with lid *(big enough to completely contain a can)*, 4 thermometers, copies of the student sheet *"Effectiveness of Insulation" (page 135).*
4. Test the materials according to the following procedure:
   a. Fill each can with equal amounts of lukewarm water. *(Measure it to be sure.)*
   b. Arrange the cans in front of the lamp, making sure they are all the same distance from the lamp. Put a thermometer into each can. Use a piece of tape or modeling clay to hold it upright so it can be read without removing it. Measure the initial water temperature in each can. Have each student record the beginning temperature on his/her data sheet.



c. Turn on the light and leave it on *(without moving the cans)* for 20 minutes. During this time assemble the insulating materials: aluminum foil, thick layer of newspaper taped securely in a size to fit around a can, and a large polystyrene cup with a lid.

d. After 20 minutes, read the water temperature in each can. Have the students record these figures on their data sheets. Turn off the light, and do the following as quickly and carefully as possible:

   1. Cover two of the cans *(including the tops)*, with different insulating materials. Put the third can inside the large polystyrene cup. Do not cover the fourth can at all. **NOTE:** Make sure the bottoms of the coverings are very flat so the cans will not fall over.
   2. Make a small hole through the top insulation of each can into its opening so the thermometer will go back into the water. Hold the thermometers in place with pieces of tape or clay, so the students may take readings without removing them from the cans.

e. Have the students read and record the temperature of the water in each can every two minutes for 20 minutes. Have each student graph the cooling of the water. *(Show them how to mark each of the four lines differently so that they are distinguishable.)*

5. Discuss the results with the students.

III. *Follow-Up*

A. *Have the students identify all the insulating materials used in the solar water heater model and the insulation investigation.*

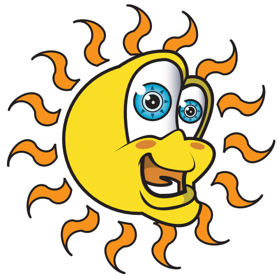
B. *Have the students brainstorm ideas for adding insulation to the solar water heater model.*

Where could it be added, when, and why? What kind would they use?

NOTE: Every part of the construction could be insulated all the time with the exception of the *"window"* of plastic facing the sun. Only when the sun goes down, or on a very cloudy and cold day, should they insulate this part.

C. *Ask the students what would have happened to the temperature of the water in the cans if they had been insulated with the different materials before they were under the lamp.*

(Any insulation would have slowed the increase in temperature. The more efficient the insulation, the less the temperature of the water would have increased.)



IV. *Extensions*

A. *Hold a "Cool Contest."*

Have the students design and make containers that will keep ice cubes from melting. The containers must be made by the students, not purchased products. They should not be larger than 25 cm in length or width. Give each student an ice cube *(make equal cubes by freezing identical amounts of water in 3-oz. paper cups)*. The student with the largest piece of ice remaining at the end of the day wins.

B. *Have the students identify the properties of water that contribute to its usefulness in solar energy systems.*

Why is water used for heat storage in solar heating systems? One property is its high specific heat, i.e., the unusual ability of water to store heat energy and release it slowly. Discuss with the students why this is important in solar heating. Have the students research the specific heat of water and other substances.

Resources

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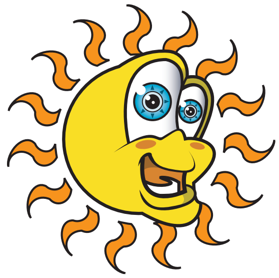
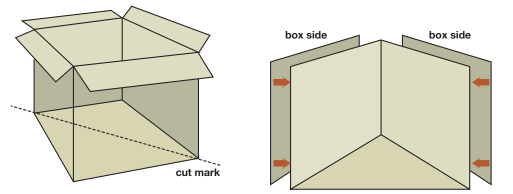
Norton, T.W. Solar Energy Experiments for High School and College Students.
Emmaus, PA: Rodale, 1977.

U.S. Department of Energy. "Science Activities in Energy: Solar Activities." N.p.: DOE, n.d.
(Address: Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.)



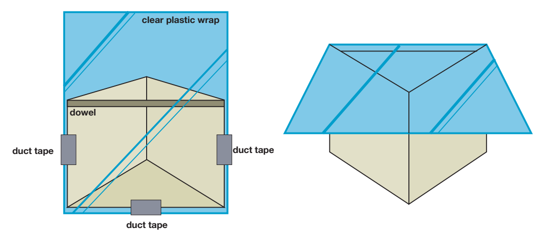
Build a Solar Water Heater Model

1. Cut the cardboard box in half diagonally. Cut off the top flaps. Cut the left-over half's 2 sides off and glue or rubber cement them to the outside of your box half. This adds strength and insulation.



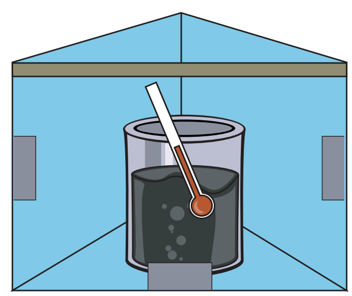
2. Glue aluminum foil shiny side out to the inside *(sides and bottom)* of the box. Secure a small dowel across the top of the opening *(from corner to corner)* with silver duct tape to serve as a brace.

3. Cut a piece of clear plastic or vinyl large enough to tape to the underside of the box and to cover the opening and the top of the box.



4. Tape the plastic wrap securely to the underside of the box. This plastic serves as both the cover and the *"door"* for the heater. When you use the solar heater, pull the plastic up over the top of the box and tape it tightly in place.

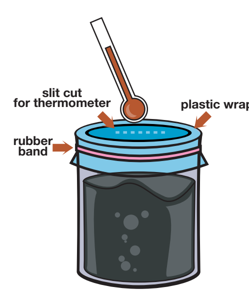
5. Fill the can with tap water. Measure and record the initial temperature of the water. Cover the top of the can with plastic wrap and secure it with a rubber band. Make a small slit in the plastic, insert the thermometer, and leave it in the water except when you are reading it.

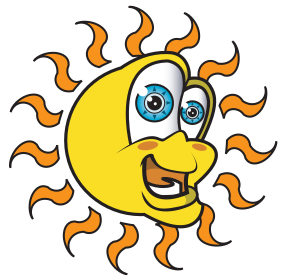


6. Set up the model solar water heater outside so the opening of the box faces the sun; make sure it is not shaded. The direction the box must face will vary depending on the time of day.

7. Place the water-filled can inside the box and seal the box with the clear plastic cover.

8. Check the changes in water temperature as directed by your teacher. Two groups will measure and record the temperature every 10 minutes for 40 minutes. The other two groups will measure and record the temperature only at the beginning and the end of 40 minutes.





Effectiveness of Insulation

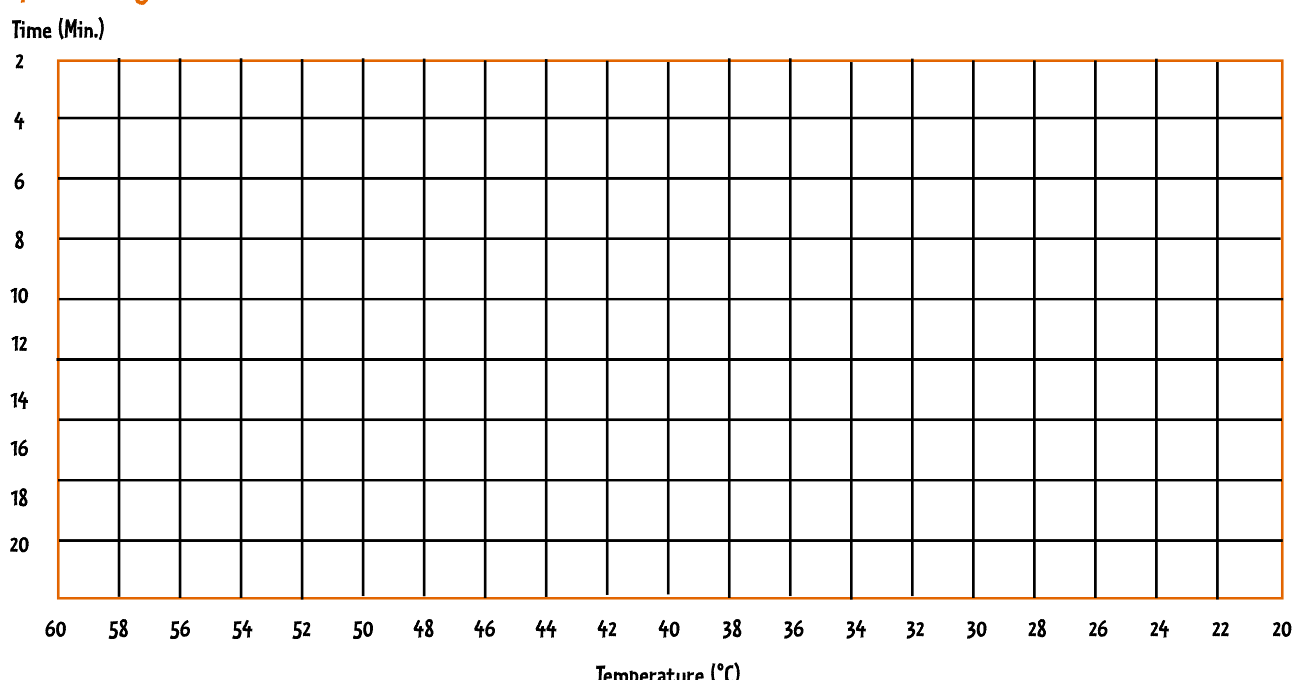
Data Table: Warming

	Can #1	Can #2	Can #3	Can #4
Beginning temp. (°C)				
Temp. after 20 min. (°C)				
Temp. difference (°C)				

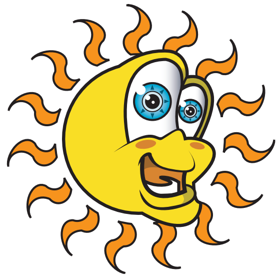
Data Table: Cooling

Can	Insulation	Temperature (°C) after elapsed time (min.)										Temp. difference (°C)
		2	4	6	8	10	12	14	16	18	20	
#1	Foil											
#2	Newspaper											
#3	Styrofoam											
#4	(None)											

Graph: Cooling



PHOTOVOLTAIC PHUN



SUBJECTS: General Science, Physical Science

TIME: 4 class periods

MATERIALS: solar cells, solder, small soldering iron, thin gauge wire, red and black alligator clips, light emitting diodes, cardboard, scissors or razor knife, transparencies, overhead projector, student sheet

Objectives *The student will do the following:*

1. Discuss the advantages and disadvantages of solar energy.
2. Demonstrate the production of electricity by solar cells.
3. Match present users of photovoltaic power with the devices they use.
4. Design a solar electric wilderness house.

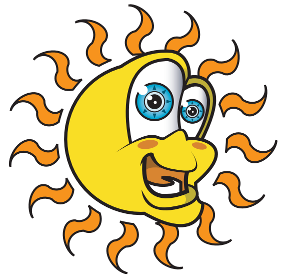
Background Information

Sunlight offers a clean, dependable source of energy for the future. Current technology has focused on two major ways of using solar energy: 1) use of solar heat energy directly or indirectly and 2) direct conversion of solar light energy into electrical energy. Photovoltaic *(solar)* cells convert light into electricity.

When photons *(packets of light energy)* strike atoms of certain elements *(such as silicon)*, the photons knock the outermost electrons of the atoms loose. The loose electrons then tend to *"flow"* from one location to another. A photovoltaic cell is made up of microscopically thin layers of pure silicon which are impregnated with small amounts of boron, phosphorus, or other semi-metallic elements. When sunlight strikes the cell, the cell's structure enhances the flow of electrons into electrical wiring. The resulting electrical current from solar cells is direct current *(DC)*, like the electricity from a battery. In the United States *(U.S.)*, electricity from utilities is alternating current *(AC)*. Electrical devices differ as to whether they use AC or DC. Using solar electricity *(DC)* to power common U.S. appliances necessitates an inverter to change the current to AC.

A solar cell about four square inches *(100 cm^2)* in area produces approximately one watt of electricity in full sun. To produce enough energy to run electrical equipment, solar cells are connected together on a rigid plate called a module. Modules are connected in panels and panels are connected in arrays. The array assembly is what is seen on roofs, facing the maximum sun exposure.

Photovoltaic electrical energy has a number of advantages. Solar cells are made of common materials. They have no moving parts. They are reliable, quiet, and require no maintenance. They use no fuel, are not dependent on conventional power plants, and produce no pollution as they operate. However, there are a number of disadvantages to their use. These include costs of rechargeable storage batteries and inverters, hazardous waste from solar cell manufacture, and inefficient energy conversion. As we develop more efficient technology and the economic and environmental costs of nonrenewable fuels continue to increase, photovoltaic energy will certainly become a common part of our energy future. Many facilities and individuals already use solar electricity. Where it is too expensive to run power lines or where batteries are not practical, solar cells supply power. Facilities in remote locations, villages in developing countries, and mobile users *(like recreational vehicles and train cars)* depend on solar cells for the electricity to run appliances, light, and communication devices.



Terms

photon: a tiny bundle of light energy from the sun.

photovoltaic: pertaining to electricity *("voltaic")* generated from light *("photo")*.

Procedure

I. *Setting the stage*

A. *Have the students make a list on the board of the advantages and disadvantages of solar energy.*

(Advantages of solar energy: free, inexhaustible, nonpolluting, available everywhere on earth, not controlled by a few countries. Disadvantages of solar energy: not available when the sun does not shine and the technology to capture and store it is limited.)

B. *Discuss with the students some of the ways people use solar energy.*

(Make sure they recognize both direct use and electrical energy production; see the background information.)

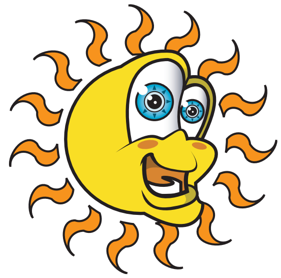
II. *Activities*

NOTE: Obtain solar cells and LEDs ahead of time if you do not already have them on hand. Check first with local electronics outlets, such as Radio Shack stores. If you must mail order them from scientific suppliers, two addresses follow:

EDMUND SCIENTIFIC COMPANY
101 East Gloucester Pike
Barrington, NJ 08007-1380
(609) 573-6250
or (609) 547-3488

CAROLINA BIOLOGICAL SUPPLY
2700 York Road
Burlington, NC 27215
(919) 584-0381
(toll free for orders only) 800-334-5551
(NC customers call) 800-632-1231

Each of these suppliers offers a variety of solar cells. The most economical *(by far)* are the "grab bags" of manufacturers' seconds. These are, however, irregular sizes and shapes *(affecting electrical output)* and are sold by weight rather than number of cells. The most durable cells are those that are encased or coated for protection; these are much more expensive. You may also purchase solar cells from manufacturers and electronics suppliers. Check your library for these contacts.

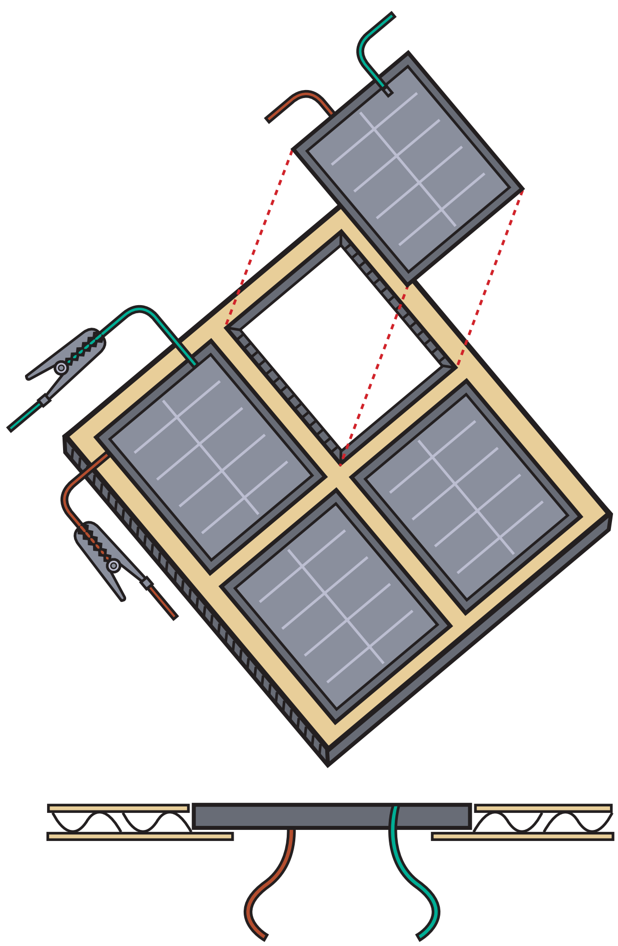


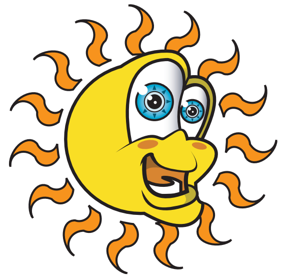
A. *Prepare the solar cells for use.*

You may have the students do this, but to save class time *(and perhaps to protect the fragile cells)*, you may chose to do this yourself.

1. Since silicon solar cells are fragile, handle them carefully to prevent breaking. Use a small soldering iron *(less than 50 watts)* and carefully solder 6-inch pieces of thin wire to the negative and positive sides of each cell. The front of the cell is negative and the back is positive.
2. Solder a red alligator clip to the positive lead wire and a black clip to the negative wire on each cell. These leads will enable the students to connect the cells in different ways. Prepare at least four cells for each small group of students. *(Decide how many groups you will have.)*
3. Make a mounting for each group of four cells using a square or a strip of heavy, double-faced corrugated cardboard. Cut holes all the way through the cardboard, trimming the front and back sides of the cardboard differently to form ledges on which to mount the cells. Be sure to cut away the back of the cardboard to prevent overheating. Label each cell using letters or numbers. You have made a photovoltaic *(PV)* cell module.

   NOTE: The cells can be arranged two-by-two as illustrated or end-to-end in a narrow strip of cardboard.





B. ***Have the students investigate the production of electricity by solar cells.***

NOTE: Do this activity on a sunny day. If possible, take the students outside; otherwise, have them perform these tests at a sunny window or with lamps.

1. Divide the students into small groups. Give each group a solar cell module and light emitting diode.
2. Have each group demonstrate that solar cells produce electricity, using the light emitting diode *(LED)*. First, have them connect the LED to the negative *(front)* and positive *(back)* leads of one cell. The LED uses a very small current, but one small *(2 x 4 cm, e.g.)* cell may not light the LED. Have them try connecting two, three, then four cells to the LED. It will produce light when the solar cells produce enough current.

C. ***Show the students a transparency made from the teacher sheet "Photovoltaic Phacts" (page 142).***

Discuss the information with them, augmenting it with additional facts from the background information.

D. ***Give each student a copy of the student sheet "Who's Using Solar Electricity?".***

Have them match the users with the photovoltaic-powered devices. The answers are as follows: 1.c., 2.h., 3.a., 4.g., 5.f., 6.e., 7.b., 8.i., 9.j., 10.d.

E. ***Show the students a transparency made from the teacher sheet "A Solar Electric Home".***

Go over the information with them, relating it to the activity in which they tested the solar cells.

NOTE: If this activity follows others that deal with solar energy, relate it to the basics of heating with solar energy and cooling by preventing unwanted solar heat gain.

III. *Follow-Up*

Have the students design solar-powered housing.

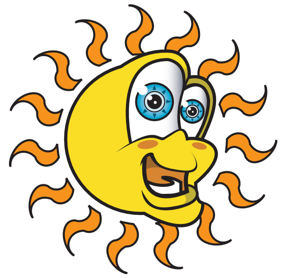
A. ***Divide the class into small groups and tell them that each group is to design a wilderness house for year-round living in hilly, forested country.***

Point out that it is too expensive to have electricity brought in by wire, so they will have to rely on solar energy.

B. ***Each student group has two tasks:***

1. Decide and list what factors will have to be taken into account in order to design an efficient solar house with the essential modern conveniences.

   NOTE: Considerations include the use of both solar light and heat energy; positioning of solar cells; types of essential appliances; room for solar cells, storage batteries and other equipment; and landscaping to allow maximum exposure of the cells to the sun.



C. ***Have each group present its design to the class.***

IV. *Extensions*

A. ***Have the students investigate the performance and costs of photovoltaic electricity.***

1. Contact solar energy companies for information on the performance and cost of various types of solar cells and rechargeable batteries.
2. Using the information from the companies, determine how much the equipment costs that will ensure a 1000-watt output 24 hours a day.
   NOTE: Students may ask the companies this directly, noting the list of equipment each recommends and both the initial and maintenance costs.

B. ***Set up a simple circuit to recharge a rechargeable battery using the output from the solar cell modules.***

C. ***Find out from local solar energy advocates if there are any solar electric homes in your area.***
If so, contact the owners and ask if you and some of your students could visit and videotape the home. Have the students make and edit the videotape. Show it to your classes.

Resources

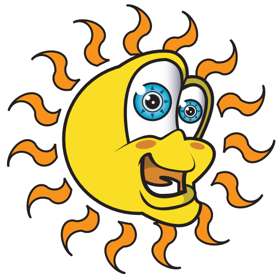
ALABAMA PHOTOVOLTAIC EDUCATION INSTRUCTION MANUAL.
Huntsville, AL: UAH Johnson Research Center, 1990.

Maywick, P. D., and E. N. Stirewalt. A GUIDE TO THE PHOTOVOLTAIC REVOLUTION.
Emmaus, PA: Rodale, 1985.

PHOTOVOLTAICS DEMONSTRATOR CONSTRUCTION MANUAL.
Huntsville, AL: UAH Johnson Research Center, 1990.

Tennessee Valley Authority. "ELECTRICITY FROM THE SUN: PHOTOVOLTAICS" *(factsheet)*.
N.p.: TVA, 1992.

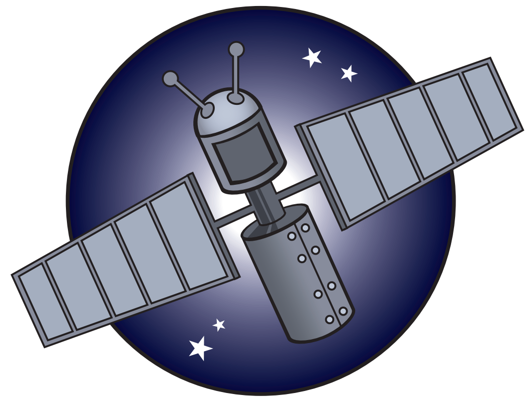
Tennessee Valley Authority. THE ENERGY SOURCEBOOK – HIGH SCHOOL UNIT.
2nd ed. N.p.: TVA, 1990.



Photovoltaic Phacts

Solar cells were invented in the late 1950s.

The first major user of solar cells was the U.S. Space Program. *(The "wings" on satellites have thousands of solar cells and power the satellite.)*

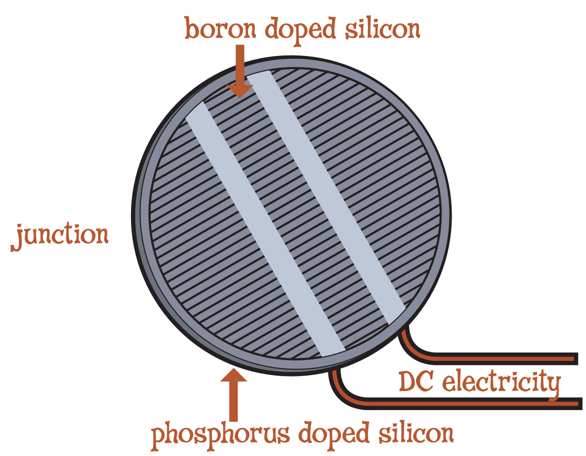


Solar cells are *"cousins"* of transistors and computer chips.

Solar cells are made mostly of silicon.

When light energy strikes the silicon atoms, some of their outermost electrons jump free. Because many photons of light energy strike many atoms at one time, and because of the way the solar cell is made, these free electrons flow into the wires attached to the solar cell. If the wires join the solar cell to something that uses electricity, this makes a circuit. The electricity will flow through the circuit.

A single solar cell makes only a tiny amount of electricity. Generally, 100 cm^2 of cell surface make about 1 watt of electricity in full sun. *(Less surface means less electricity; more surface means more. Less than full sun means less electricity.)*



Solar cells make DC electricity, like batteries.

Solar cells are sometimes the best source of electricity for locations far away from electric lines, for things that are mobile electrical units *(for which batteries are not a good option)*, and for items that use very small amounts of electricity.

Solar cells do not work at night. They work best in full sun. Some are made especially to work using light from inside lighting devices.

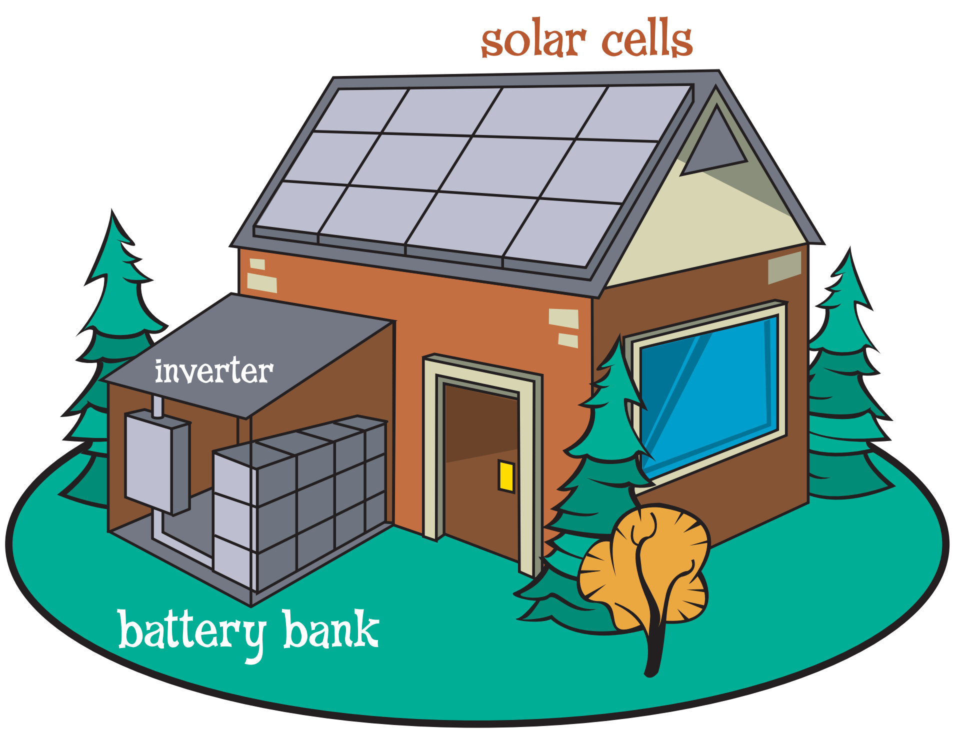
Photovoltaic Phacts continued

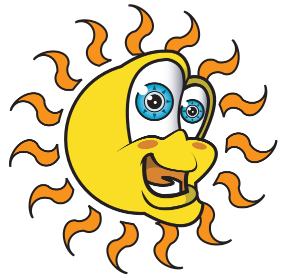
Over 6000 U.S. homes are powered by banks of solar cells, which are usually mounted on the roof.

Solar cells have been used to power experimental cars.

Using solar cells does not produce pollution.

As of 1990, electricity from solar cells was only 25 percent more expensive than electricity from most U.S. power companies.





Who's Using Solar Electricity?

Write the letter of the device powered by solar electricity next to the number of its user.

Users

_____________ 1. backpackers, hunters, and other other vacationers

_____________ 2. rancher

_____________ 3. mountain or desert village in a developing country

_____________ 4. NASA

_____________ 5. homeowner

_____________ 6. U.S. Coast Guard

_____________ 7. math student

_____________ 8. highway department

_____________ 9. farmer

_____________ 10. jungle station doctor

Photovoltaic-Powered Devices

a. communication devices *(telephone, radio)*

b. calculator

c. wilderness lodge lights and appliances

d. refrigerator for medicine

e. lighted buoys

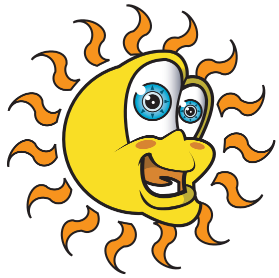
f. yard lighting

g. satellites

h. electric fencing

i. lighted highway signs

j. remote water pump for irrigation



A Solar Electric Home

Powering a home's electric appliances with solar cells requires enough solar cells to produce the needed amount of current.

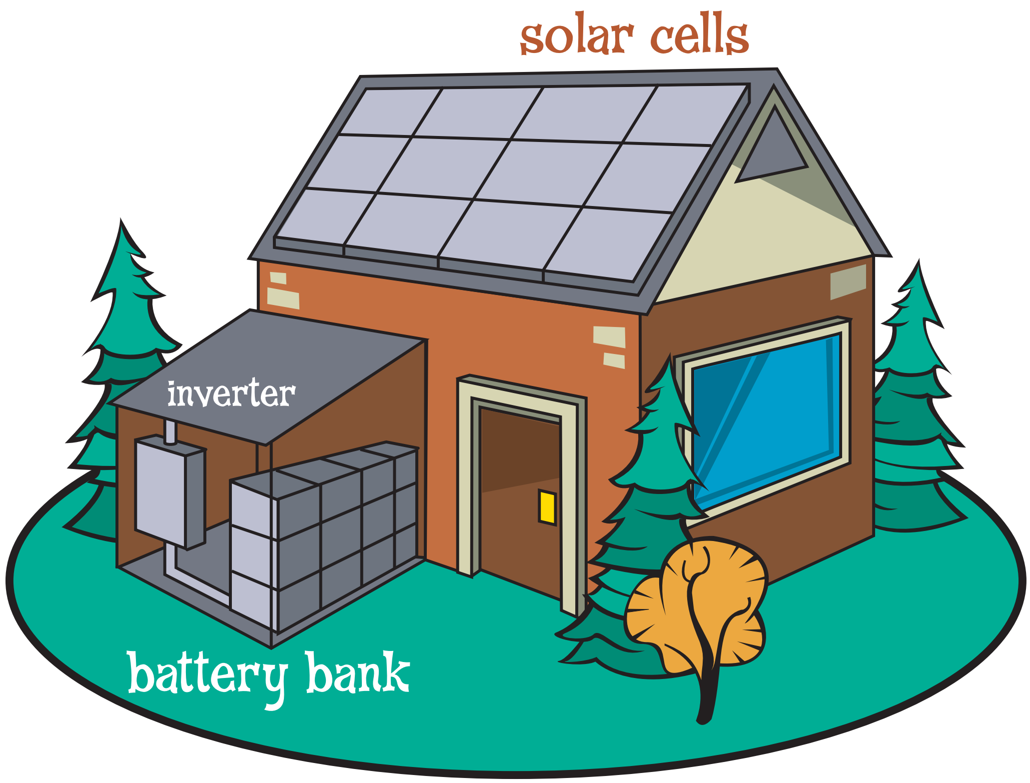
The system must include a bank of large-capacity, rechargeable batteries for times when the sun is not shining enough. These are located outside the house for safety.

The system must have a device called an inverter to change DC electricity from the cells and batteries to AC, which is what regular appliances use. A homeowner could purchase devices that run on DC but these are of limited variety.

The cells must be oriented *(faced)* and angled to receive the most sunlight.

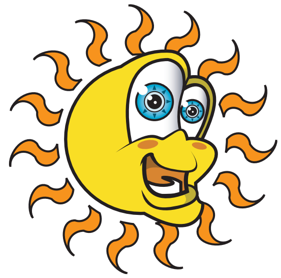
The cells must not be shaded.

Solar electricity systems are often combined with other solar energy-using design elements, such as passive solar heating and cooling. Photovoltaic systems are not suitable for most electric heating and air-conditioning systems.



fact sheet

PERSPECTIVE ON ENERGY USE



The economies of all industrialized nations, the lifestyles of most of the world's population, the tools with which we explore our universe, and even the transmission of our principal cultures all depend on a cheap, abundant and convenient supply of energy. That energy has been readily available since the beginning of the industrial revolution, and it is something that we have come to take for granted. But the fossil fuels, which account for the large majority of the energy we use, are finite resources and they will eventually be exhausted. Although that depletion is still several centuries in the future, the exponential increase in our use of fossil fuels has had an environmental impact which makes an immediate reconsideration of our energy priorities essential.

Past and Present

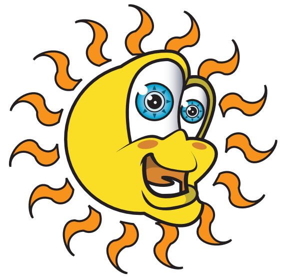
For millennia people built economies, cultures and political entities using the energy in their own muscles and the muscles of domesticated animals, the wind, water power and biomass – all renewable resources. These energy sources were more than enough to power the civilizations which developed writing, mathematics, philosophy, medicine and art. Cities of hundreds of thousands of people were sustained without fossil fuels. Empires were extended across continents with no more sophisticated form of transportation than the legs of legionnaires or the backs of steppe ponies.

The world underwent a fundamental change in the eighteenth century, as the industrial revolution multiplied our dependence on energy, and brought fossil fuels – first coal, then oil – into prominence. All aspects of our economies, our political systems, and even our cultures adopted new technologies that required enormous amounts of fossil energy. The sources of fossil energy that appeared limitless at the beginning of the industrial revolution are now seen to be finite. And the demand for them grows at an ever increasing pace as the world's population grows and more and more of our societies become industrialized.

Energy Choices

As more developing nations try to secure the obvious material benefits of industrialization for their people, the strain on the world's fuel resources becomes greater. This competition of limitless wants and limited resources imposes difficult choices, increased industrialization provides jobs and material well-being. But it also depletes non-renewable resources and has environmental impact. The choice that seems *"right"* changes as the observer's point-of-view changes. A developed country may make decisions based on future environmental impact while a poor country must base its decisions on the need to feed its people immediately.

Just as countries have different priorities in their energy choices, so do individuals. To some, the additional expense of energy-efficient appliances is well worth it for the energy – and money – which will be saved in the long term. Some people are willing to forego the convenience of driving their cars for the energy and cost savings of public transportation. Some are willing to spend the time and money to make their homes more energy-efficient. And some can't be bothered to do anything at all.



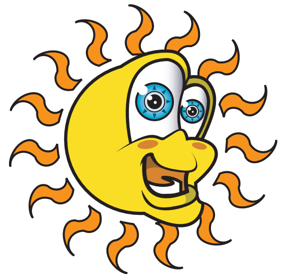
Energy choices are not simple. All involve trade-offs in cost, convenience, performance, comfort, environmental protection and many other factors. One important change is that we are beginning to realize that all energy decisions require choice. In the recent past we took for granted that we would have an unlimited supply of energy at our fingertips, and seldom considered any of the consequences.

Environmental Considerations

All significant present sources of energy have some impact on the environment. One of the choices which must be made in selecting energy sources involves weighing the relative environmental impact of each. Burning fossil fuels produces carbon, dioxide, nitrous oxides, and sulfur dioxide. And although new technologies continually reduce the output of these gases, some emissions are inevitable. Hydropower changes the ecology of the river which is dammed and floods acreage which might have been valuable farmland or animal habitat. Nuclear power entails some risk of reactor accidents, and creates nuclear waste which must be disposed of. The only way to eliminate environmental impact is to eliminate energy use, because even pre-industrial animal power created its own kind of pollution. People will not sit in the dark and freeze in order to avoid using any energy at all; but they may well decide that they have to be less profligate in their future energy use in order to enhance the quality of our environment.

fact sheet

ENERGY CONSERVATION



Energy conservation means reducing energy consumption by using energy more efficiently, by eliminating some uses of energy or by decreasing the frequency or duration of energy use. Energy conservation will help make our finite supply of fossil fuels *(coal, oil, and natural gas)* last longer. It will also reduce the need for new or expanded energy-producing facilities – including coal mines and oil and gas fields, refineries, fossil- and nuclear-fueled generating plants, and hydroelectric dams. By reducing the need for these facilities, energy conservation can help reduce the environmental impact they may cause. It can also help control the prices consumers pay for energy, by eliminating the significant expense new facilities require. New technologies and new habits are helping to conserve energy now. Additional technological advances – and increased awareness of the need and ways to conserve – will help save even more in the future.

Energy Conservation and Changing Technologies

New technologies are helping to conserve energy in many ways. Refrigerators built after 1990 use much less electricity than those built 10 or 15 years earlier. The average gas mileage of a new car today is twice as much as that of new cars 20 years ago. Compact fluorescent light bulbs use about a quarter of the energy needed by conventional incandescent bulbs and they often last 10 to 15 times longer.

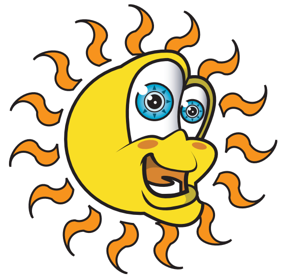
In the future more efficient generators, transformers and transmission lines will enable us to use a greater percentage of the electricity produced in generating plants. Airliners will use much less fuel for every passenger mile. And more industries will follow the example of the innovators who find energy from unexpected sources, like those who now convert old tires to carbon black using the tires themselves as fuel for the process.

Not all of the changing technologies are new, however. Some are a change back to former, more energy efficient ways of doing things. In agriculture reduced tillage and a trend away from chemical fertilizers, herbicides and insecticides is helping cut the use of heavy equipment, which reduces energy use.

Energy Conservation Construction and Indoor Spaces

The indoor spaces in which we spend most of our time use energy for heating, cooling and lighting. Some simple efficiency measures can reduce this energy consumption significantly without affecting our comfort, productivity or convenience. Heating alone accounts for between half and two-thirds of the energy used in most American homes. And much of the warmth leaks out through poorly insulated walls or around inadequately weather-stripped doors and windows.

Constructing new homes and commercial buildings with adequate insulation and weather stripping can save tremendous amounts of energy. So can adding weather stripping or additional insulation to older structures. Turning the thermostat up in the summer and down in the winter can be an important energy conservation technique. Adding deciduous trees to the south of a structure and evergreens to the north can also result in significant energy savings. The deciduous trees on the south shade the building in summer, then drop their leaves to let the sun add warmth in winter. The evergreens protect the building from cold north winds in winter.



Energy Conservation and Consumer Choice

Conserving energy can only come as a result of deliberate choice on the part of the people who use energy: consumers. All energy is, ultimately, used by individual consumers, either directly *(in the gasoline they burn in their cars or the electricity used to light their homes)* or indirectly *(in the energy which goes into the products and services they use)*.

Most of the choices will require balancing various needs and considerations. Cost, convenience, performance, and energy savings will have to be evaluated and consumers will have to decide the relative importance of each. For example, several cars now offer fuel economy which is more than twice the average. But they are all small, and offer relatively low levels of performance. If everyone chose to forego size and performance and bought one of these more efficient cars, the energy used for automobiles in this country would be cut in half immediately.

Compact fluorescent light bulbs could reduce the energy used in many lighting applications by about 75 percent. But the bulbs can cost more than 10 times as much as conventional incandescent bulbs. They last more than 10 times longer, and save many times their purchase price in electricity, but many people do not want to spend the additional initial price.

There are many other trade-offs and considerations, all of which depend on the priorities and value judgments established by consumers. The trend is toward greater energy consciousness and a willingness to pay more or perhaps accept less performance or comfort to save energy. But we aren't likely to see a time when rock fans will pass up a concert to conserve the kilowatt hours of the lights and sound system or shoppers will eliminate trips to the mall to save gas.

Recycling and Energy Conservation

Recycling is a simple way to save energy. It also saves natural resources, reduces pollution, and helps slow the rate at which we are filling up our limited landfill space. Most aluminum cans are now recycled, at an energy savings of 95 percent over that required to smelt aluminum from bauxite ore. The potential additional energy savings from more extensive recycling of steel and paper is more than half a billion barrels of oil and $750-million in disposal costs each year. And energy savings can also be made by recycling glass and plastic.

Attitudes and Energy Conservation

The most important factor in conserving energy is people's attitudes. Many potential energy-saving products and techniques are widely known and readily available. But, unfortunately, they are underutilized. Using public transportation instead of private cars could save billions of barrels of oil each year. Yet many commuter buses and trains run at far less than their capacity in cities whose roads are choked with cars carrying just one person. Turning the thermostat down in winter or turning the lights off when leaving a room could save vast amounts of energy if everyone did it, but too few do. The United States has about five percent of the world's population, but is responsible for about a third of global energy use. Increasing energy conservation awareness, and re-ordering individual priorities will be needed if we are going to bring our consumption more into line with worldwide norms.

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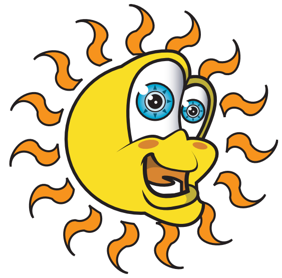
ALTERNATIVE ENERGY STRATEGIES



A number of alternatives to conventional fossil fuels, hydropower, and nuclear energy are in use or under study today. To be feasible, these alternative energy strategies must produce energy on a large enough scale to be economically viable. In addition, it is important that the energy be in a transportable form and that it be environmentally compatible.

In addition to alternative sources such as the sun, wind, geothermal energy and biomass, new energy strategies include advanced technologies which make better use of existing fossil fuel supplies.

Solar Energy

Every day the earth receives more than 10,000 times more energy from the sun than people use in all of their energy-consuming activities. Of course not all of this energy is available to power vehicles, light cities, and run appliances. Most is used to fuel our weather cycles, grow the plants which are the bases of our food chains on land and sea, provide the light of our days and the warmth which makes life possible on our planet, and to originate almost every other source of energy on earth. Utilizing just a small fraction of the energy the sun delivers to earth could provide for our energy needs indefinitely, and do so without pollution.

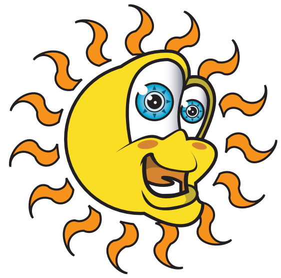
Although many proponents of solar energy call solar energy *"free,"* there is cost involved, as there is for all energy sources. The sunshine is, of course, free. But in that sense so are coal, oil, water power and uranium. No one paid to have them created. The cost is in getting to them, extracting their energy and delivering it to its ultimate consumers. A river flows at no dollar cost, but the dam needed to convert that flow to electricity costs many millions of dollars, and the power lines which take the electricity to cities, farms, and factories cost millions more. And there are ongoing costs required to operate and maintain the facilities and to distribute the energy produced. Sunlight is free, but the technology and machinery needed to capture and distribute it are not.

But, even at a cost, solar energy is a very appealing alternative to present energy sources. Whether in passive systems or in large-scale or photovoltaic active systems, it has the advantages of being virtually limitless, inexhaustible and clean. Solar energy is covered in more detail on a separate factsheet.

Biomass

All plant material on earth is the result of solar energy converted to organic form by photosynthesis, and all animal matter derives from the plant material at the bottom of its food chain. This plant and animal material is biomass, and it is the basis of much of the energy we use.

Fossil fuels – oil, natural gas and coal – were created by enormous amounts of biomass altered by geological and chemical forces over great periods of time. Oil, gas, and coal were ferns and animals hundreds of millions of years ago. They collected in enormous quantities during the Carboniferous and Permian eras and were converted to fuel in the eons since then. Our supply of fossil fuels is finite, and we are using them millions of times faster than they can form. But there are sources of biomass energy which are renewable.



Biomass – specifically trees and some other plant matter – was probably our first fuel. It is still one of the most important. In many developing countries, wood is a primary energy source for cooking and heating. It is also making something of a comeback in the United States, at least for heating, with the renewed popularity of wood-burning stoves.

Biomass is also being examined for industrial and power generating applications. Today many municipalities burn biomass from garbage as an energy source. And experiments indicate that trees may become an economically feasible fuel in the future, as their cost per unit of energy produced comes down.

Biomass has one very important attribute as an alternative fuel source. It eliminates much of its own pollution. The trees grown to fuel a biomass-powered generating plant could consume as much carbon dioxide as the plant releases into the atmosphere.

Geothermal Energy

Geothermal energy is heat from the mantle of the earth. It reaches the surface in areas where the earth's crust is thinnest or especially permeable. The heat of geothermal energy is captured in the form of steam, which is used to drive turbine generators. In the future geothermal fields without convenient hot springs or geysers may be tapped by pumping water down to the heated rocks below, and recovering it as steam. Geothermal plants are now producing electricity in some locations, most notably Iceland.

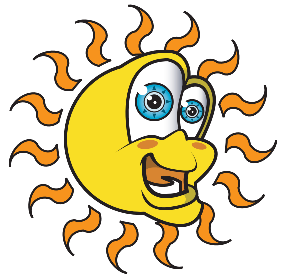
Wind

Wind, which is created by differences in temperature in areas of the earth's atmosphere and by the earth's rotation, has been used as an energy source for centuries. The windmills which powered grinders, pumps, and saws long ago have evolved into the energy sources for pumps on farms and ranches all over the world. Their modern descendants, the windmill generators, sit in rows on wind farms in areas with steady, relatively strong winds. Coming improvements in windmill design, to help capture even the faintest breezes, may help make this clean energy source more cost effective.

New Fossil Fuel Technologies

Fossil fuels are virtually finite. Although small amounts are still being created, these are infinitesimal compared to the rate at which current supplies are being depleted. That inescapable fact, and pollution are the two areas of fossil fuel study receiving most emphasis right now.

The limited supply of fossil fuels is being dealt with in several ways. One is continued exploration to discover additional resources. Another is the more efficient extraction of those resources. New techniques may make it economically feasible to extract the oil from oil shale, which has 50 times more oil than today's proven reserves. New technology may also open oil and natural gas trapped in porous rock for development.



New methods are also enabling drillers to extract more oil from each well. Conventional wells leave 40 to 80 percent of the oil in the ground, but enhanced recovery through catalytic cracking, acidification and rock fracturing bring much more oil to the surface.

Additionally, new technologies are being applied to coal. Fluidized bed combustion improves coal’s efficiency and reduces sulfur and nitrogen oxide emissions. Both gasification and liquification of coal are also under study to determine if a more usable form of this abundant resource might be developed.

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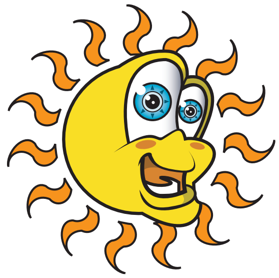
SOLAR ENERGY



The sun is the source of almost all the earth's energy. Fossil fuels originated as biomass grown with the sun's energy and subsequently convened to coal, oil and gas by geological and chemical action. Wind derives much of its impetus from the sun's heating of the earth's atmosphere. All biomass is ultimately dependent on photosynthesis to convert solar energy into carbohydrates. Even hydropower is driven by the sun which gives it potential energy by evaporating moisture into the atmosphere, to be converted to kinetic energy as it falls as rain and flows downhill in streams and rivers.

Only geothermal energy *(fueled by the internal heat of the earth's core and mantle)*, nuclear energy *(derived from the so-called "weak force" which binds atoms together)*, and some of the kinetic energy produced by the earth's rotation, exist independent of the sun. Most scientists today agree that these forces have their origins in the period of frequent collisions of planetesimals which formed the earth just over four-and-a-half billion years ago.

Because of its virtually ubiquitous and inexhaustible nature, solar energy is an extremely attractive alternative energy source. Its attractiveness is enhanced by the fact that solar energy is virtually nonpolluting. The only environmental hazards of solar energy come from the manufacture of the solar collection, generation, and distribution devices. In some cases, there is no environmental down-side risk at all.

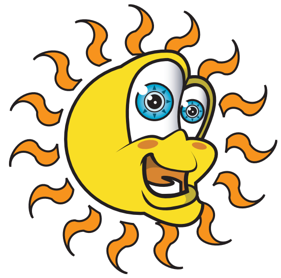
Pre-historic people used passive solar energy systems in that they chose winter dwellings with south facing openings to take advantage of the sun's warmth. Many early civilizations, including the Romans, Greeks and Near Eastern and Asian cultures designed and aligned their buildings to take advantage of the sun's *"free"* energy.

But although these passive uses of solar energy have virtually no environmental impact, and no on-going expense after initial construction, the greatest potential for solar energy is in active systems used to produce electricity.

Passive Solar Energy System

Using the sun's energy to warm a space or heat water does not require any complex technology. In the simplest form, openings through which the sun's energy can pass *(like windows)* are aligned toward the sun, to allow solar energy to enter the space; *"collectors"* inside the space *(like the stone floors of caves or the marble or terrazzo floors of Roman villas)* capture the heat and release it gradually after the sun has set.

Today's passive solar designs use dark colors to trap heat, buildings constructed to permit convection currents to warm the entire building, and water-filled collector pipes *(or drums)* to capture solar energy. Although these systems can be effective, they are not yet efficient in dollars and cents. Although the solar energy which is collected is free, the systems which collect it, and structures built to take maximum advantage of it, are still more expensive than conventional energy sources. This is especially true since present-day solar technology requires a complete conventional back-up system in addition to the solar



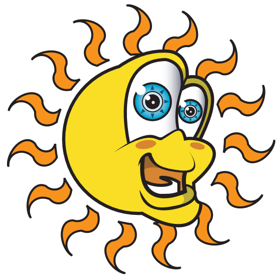
Large-Scale Active Solar Energy Systems

The use of solar energy to generate electricity in large quantities is still in the experimental stage. Present technology involves the use of a large field of heliostats *(mirrors)* which focus the sun's energy on boilers. The boilers generate steam used to drive turbines which, in turn, drive generators. The systems are not yet commercially feasible, since the true cost of the electricity produced *(which includes the initial cost of the collection and production facility)* is much higher than that of conventional energy sources. As further experimentation brings the cost down, or when consumers decide that they are willing to pay substantially more for energy which has virtually no environmental impact, large-scale solar power production may become practical.

Photovoltaic Cells

Photovoltaic cells convert solar energy directly into electricity. Similar cells were first developed in 1895. Photovoltaic cells have been used in solar-powered calculators and in satellites and other space equipment. Each cell produces a minute amount of electricity, and to develop usable quantities they are joined into solar panels *(made up of many cells)* and solar arrays *(made up of many panels)*. To maximize electric output, the cells, panels and arrays must be aligned to capture the most possible sunlight. Photovoltaic cells have been used to power experimental automobiles and in some individual households and other applications, but the present cost and efficiency preclude widespread use.

GLOSSARY



aerobic: describes organisms that must have free oxygen for respiration to live.

anaerobic: describes organisms that are able to live and gain energy without oxygen.

active solar energy system: a solar energy system that requires external mechanical power to move solar heat energy for storage and/or use; compare *passive solar energy system*.

biomass: all solid material of animal or vegetable origin from which energy can be extracted.

blade: a flat or concave projection from a rotor shaft; a rotor shaft plus its blades make up a propeller.

closed system: a system that requires nothing from outside itself to sustain itself and releases nothing to the outside.

concentrator: a device that concentrates the sun's rays on an absorber surface which is significantly smaller than the overall concentrator area.

convection: the natural movement within a fluid caused by unequal heating *(warm air rises and cool air sinks)*.

Coriolis force: rotational force of the earth which affects global wind patterns.

dehydration: to cause to lose, or become relatively free of, water, as in the drying of foods to preserve them or to reduce bulk and weight.

desalinization: the removal of salt from seawater to produce fresh water.

distillation: the process of driving off gas or vapor from liquids or solids by heat and condensing the product for purification.

ecosystem: a self-regulating community of living organisms interacting with each other and with their environment.

electromagnetic spectrum: the sequence of electromagnetic waves ranging from cosmic rays *(shortest wavelength)* to radio waves *(longest wavelength)*; the visible light spectrum is a very small part of it.

environment: all the physical and organic factors that surround and affect living organisms.

ethanol: a form of alcohol derived from fermentation of sugar and grain crops and used as fuel; structural formula is CH_3CH_2OH.