Renewables Are Ready

A Guide to Teaching Renewable Energy in Junior and Senior High School Classrooms



Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

The Union of Concerned Scientists is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions.

The UCS Clean Energy Program examines the benefits and costs of the country's energy use and promotes energy solutions that are sustainable both environmentally and economically.

More information about UCS and the Clean Energy Program is available on the World Wide Web, at *www.ucsusa.org*.

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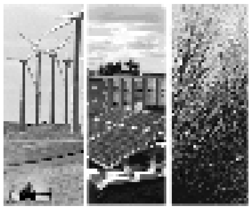

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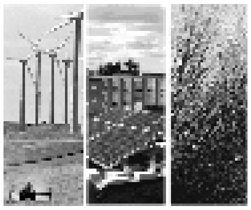


Preface

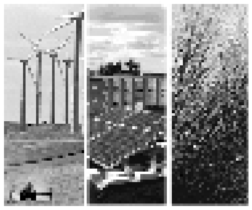
You may remember teaching your students about renewable energy during the oil crises of the 1970s, when interest in energy alternatives was high and the government established federal programs to fund research and development of solar and wind power. In 1980, it seemed as if there might be a solar panel on every roof and windmills in backyards across the country by the turn of the century. But oil prices dropped, and the federal government and much of the American public lost interest in renewables. In 2002, renewable energy sources are scarcely more visible than they were 10 or 20 years ago, since they only make up about six percent of total U.S. energy use. Chances are that most of your current students have never seen a solar car or a modern, working wind machine.

The good news is that interest in the development of renewable energy sources is spreading rapidly once again. Today, as a result of the 2000 California energy crisis and growing concern over global warming, national security and the health effects of poor air quality, renewable energy is gaining the attention of the general public as well as our state and national governments. Fortunately, renewable energy technologies have also been vastly improved in the past two decades. Scientific advances and global market growth have transformed solar, wind, and bioenergy (plants and clean plant wastes) generators from backyard novelties and science fiction fantasies into practical systems capable of fueling our vehicles and heating and lighting our homes, schools, and businesses. Costs have also fallen as the technology has improved. The cost of generating electricity from wind and solar power has decreased by 90 percent over the past 20 years. Renewables are ready to meet America's energy needs today and into the future. They are cleaner and safer than coal, oil, or nuclear power, and their use helps improve public health and energy security, as well as reduce the emissions of carbon dioxide—the primary global warming pollutant. The sooner we make the transition to renewable energy, the more our nation will benefit.

Education is an important first step in making this transition. Renewable energy technologies are ready to be implemented, but increased public confidence, regulatory reforms, and a system of economic incentives for development of these resources are needed to make large-scale use of renewables a reality.

Renewable energy is an ideal topic for middle and high school classrooms. A unit on renewables can be used to teach basic scientific principles: the sun as the source of Earth's energy, conversion of energy from one form to another, or electricity generation. Environmental science teachers can incorporate activities on renewable energy into a unit on the environmental impact of energy use. Social studies teachers can select renewable energy activities that demonstrate how the marketplace and our political system govern the way energy decisions are made.

An understanding of renewable energy will be a crucial part of scientific literacy for the future. When they reach adulthood, many of your current middle and high school students will be commuting from solar energy-powered homes in biomass-fueled cars. Much of the electricity they use at home and in the workplace will come from solar, wind, biomass, and geothermal power. This guide will help you provide your students with an understanding of the technologies and the political and economic systems that will lay a foundation for a clean, sustainable energy future.



Purpose of This Guide

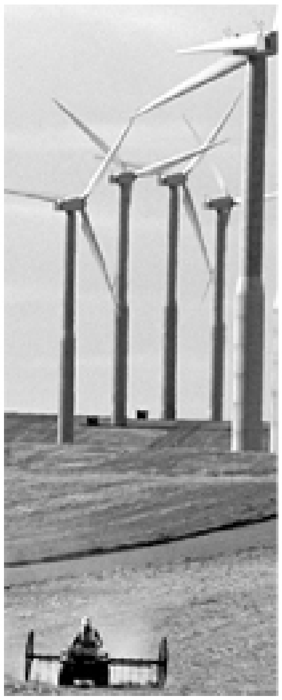
This guide is intended to help you introduce your students to renewable energy technologies and the political and economic conditions necessary for their implementation. It contains a set of classroom activities with detailed instructions, an expanded list of project suggestions, ideas for student-led education and action campaigns, and a bibliography of resources for further investigation.

We have tried to choose activities that are multidisciplinary, investigatory, and fun. Most of these projects emphasize group work and cooperative learning. The activities can be taught independently or as a unit. In either case, we suggest that you use them in the context of a comprehensive unit on energy and energy-related environmental issues. Several good resources on energy and the environment are listed in the bibliography.

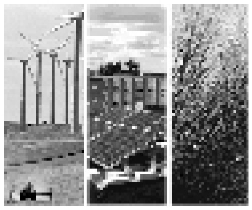
Our objectives in this guide are to help you teach students:

- the difference between renewable and nonrenewable energy sources
- to identify and distinguish between different forms of renewable energy
- to understand the pros and cons of different renewable energy sources
- to identify a wide variety of applications for renewable energy
- the basic scientific and technical principles behind large-scale applications of renewable energy
- to identify some political, social, and economic incentives that would accelerate the implementation of renewable energy in the United States
- how to take actions that will accelerate the development of renewables

Because renewable energy is a broad topic that covers many disciplines, it presents an ideal opportunity for team teaching. We encourage science, social studies, English, and art teachers to work together in planning a comprehensive unit on renewables.



Activities



What Is Renewable Energy?

In this activity, students will learn about renewable energy sources and will distinguish them from nonrenewable sources.

The students will be asked to come up with a definition of energy, then to think about the different sources of energy, to divide those sources into renewable and nonrenewable categories, and to consider how renewables are currently used. At the end of the activity, students are asked to envision a "renewable future."

OBJECTIVES:
- to understand the concept of energy
- to establish a base of knowledge about renewable energy that students can use in additional activities on renewable energy
- to establish a common definition for "renewable energy" that will allow students to distinguish between renewable and nonrenewable energy sources
- to familiarize students with some of the applications of renewable energy

GRADES: 6–9; can be the basis for a shorter discussion for older students

SUBJECTS: science, social studies

TIME: 45 minutes

MATERIALS: overhead projector and transparency made from chart of U.S. Energy Consumption 2001 (pg. 8); alternatively, you can draw the chart on the blackboard or give a copy of it to each student

PREPARATION: You may want to announce the topic of energy in advance and encourage students to look for newspaper or magazine pictures related to energy use or energy sources to post in the classroom.

PROCEDURE:

1. Ask students what they think of when they hear the word "energy." Write down their answers. (Many students will likely think first about their own personal energy; e.g., "I don't have much energy today.")

2. As a class, come up with a definition for the word "energy" and the term "energy source." Standard definitions are:

   - energy—the ability to do work, or the cause of all activity
   - energy source—something that can be tapped to provide heat, chemical, mechanical, nuclear, or radiant energy

3. Have the students list as many energy sources as they can. Write this list on the blackboard. Among scientists and energy professionals, a standard list of current energy sources would include:

biomass (plant matter)	nuclear
coal	oil
geothermal	solar
hydro (rivers)	wave or tidal
natural gas	wind

Your students may come up with some variations on this list or additions to it that are also acceptable:

animal energy	food	propane
batteries	gasoline	water
charcoal	human energy	wood

4. Tell the class that their list of energy sources can be placed into two categories: renewable and nonrenewable. Show them the following definitions:

- renewable—energy sources that are replaced by natural processes at a rate comparable to their use
- nonrenewable—energy sources that are limited and can eventually run out; these sources of energy cannot be replaced on a timespan of human significance

5. Ask the students to use these definitions to decide which of their energy sources are renewable and which are nonrenewable.

6. Ask students to guess how much of the energy we use in the United States comes from renewable energy sources. Then project the transparency of the U.S. energy supply. It shows that most of our energy comes from oil, coal, and natural gas, which are nonrenewable. Explain that these three energy sources are known as fossil fuels and define the term. The energy stored in fossil fuels comes from the solar energy that was captured in plants millions of years ago, but the formation of fossil fuels is too slow to permit replacement for human use.

7. You may wish to provide students with some of the following information:

The major categories of renewable energy sources are solar, wind, hydro, and biomass (plant matter).

Worldwide, wood is the largest source of biomass for nonfood energy, but other sources are also used, including municipal wastes and crop wastes. Crops such as sugar cane are used to make alcohol for transportation fuel. In many developing countries, wood is the most important energy source.

Global resources of geothermal energy (the heat contained below Earth's surface) are so immense that they are usually considered to be renewable. But this classification is not strictly correct, since the heat stored in any given volume of rock or underground water is depletable. In addition, the most easily accessed geothermal resources—natural hot springs and geysers—will not last for more than a few decades if exploited for energy on a large scale.

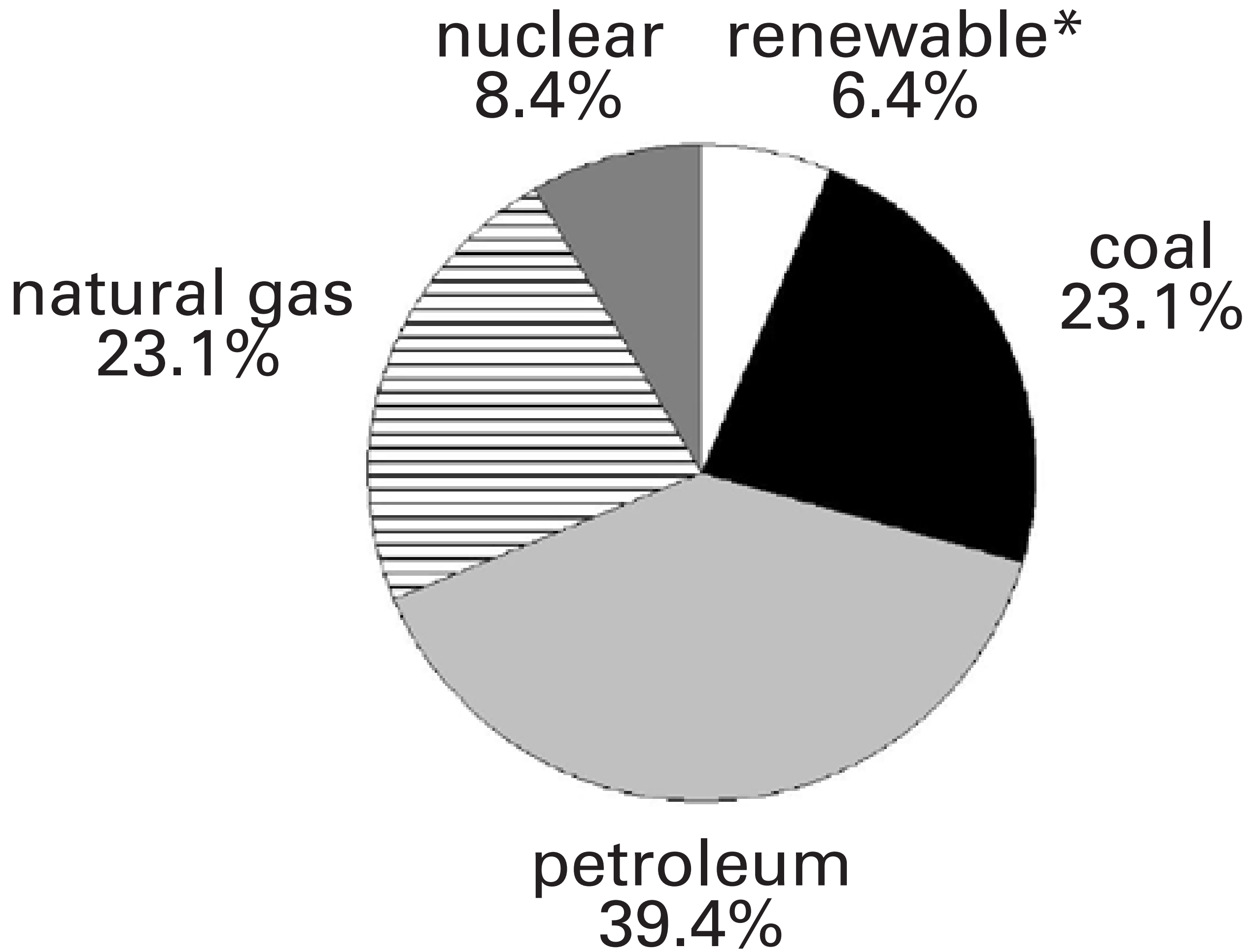
Estimates vary widely as to how long fossil fuels—oil, coal, and natural gas—will last. These estimates depend on assumptions about how much fossil fuel remains in the ground, how fast it will be used, and how much money and effort will be spent to recover it. However, most estimates agree that, if present rates of consumption continue, proven oil and natural gas reserves will run out in this century, while coal reserves will last more than 200 years. Once they are used, these energy sources cannot be replaced. Long before we actually run out of coal, oil, or gas, however, the environmental and social consequences of extracting, processing, transporting, and burning fossil fuels may become intolerable. In addition, it will not be economically viable to extract all of our fossil fuels, as renewable resources will eventually become competitive. You may want to discuss these consequences with your students.

In contrast to fossil fuels, renewable sources of energy produce little or no pollution or hazardous waste and pose few risks to public safety. Furthermore, they are an entirely domestic resource.

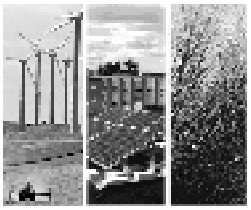
8. Ask students to list as many current uses of renewable energy sources as they can. Answers can range from small devices like solar-powered calculators to large-scale production of electricity from hydroelectric dams to occasional uses like wood for cooking on camping trips and wind for sailboats.

9. Now tell the class to take a mental trip into the future. It is 50 years from now. Half of all the energy we use in the United States comes from renewables: sun, wind, water, biomass, earth heat (geothermal). Ask students to think of some inventions that have made this possible. How are houses, offices, and schools heated and lighted? Where does the energy used to run factories come from? What do people use for transportation? Have students write down their ideas or draw pictures. (Alternatively, you can use this as a homework assignment.) Collect these pictures and ideas. Tell students you will come back to them at the end of the unit on renewables, so that students can evaluate their ideas in light of new information.

U.S. Energy Consumption 2001



Source: Monthly Energy Review, USDOE, April 2002
* wind, solar, hydro, geothermal, bioenergy, landfill gas



Where Do You Get Your Energy?

In this activity, students will trace their personal energy supply to its sources.

OBJECTIVES:
- to examine the many different ways students use energy
- to understand how that energy is produced and transmitted to students' homes, vehicles, and schools
- to determine how much of the energy students use comes from renewable sources
- to get students to think more broadly about the subject of energy and their use of energy

GRADES: 6–12

SUBJECTS: social studies, science

TIME: two 45-minute class periods, at least a week apart

PROCEDURE:

Day 1

1. Tell students that they are going to participate in an activity to discover where and how they get the energy they use.

2. Ask students to list all the ways they use energy in their daily lives. You can either do this as a class, in small groups, or with each student writing out his or her own list. Make the lists as comprehensive as possible. You should probably restrict the list to students' direct use of energy (e.g., to power their televisions, school buses), rather than including such indirect uses as providing energy for the factory that manufactures the jeans they wear.

3. Group the lists by energy source used (e.g., wood for wood stoves, sunlight for calculators, natural gas for home heating, oil/gasoline for cars). For those energy uses that run on electricity, place them in a category titled "electricity."

4. Ask the students if they can trace any of the other materials used for energy back to their original sources. Write the answers on a chart. For example, if students have wood stoves, how do they get the wood and where does it come from? Where do they get the gasoline for their cars? They should trace the energy as far back toward its origin as they can: Where does the gas station get its gasoline? Where does the school get its electricity?

5. When students are unable to trace a particular energy use back to its source, place a question mark on the chart. So, if they do not know where the gas station gets its gasoline, your chart would look as follows:

Car ← gas ← gas station ← ?

6. Then assign individual students or groups of students to find answers to replace the question marks. Tell them that their job is to trace the energy back to its source and that they will be asked to report back to the full class. A group of students can go to local gas stations to see if they can find out where the gasoline is shipped from, where it is refined, and so on. Several students should work together on the subject of electricity. They should find out what energy sources their local utility uses to supply electricity, where the power plants are located, and how much electricity comes from each energy source.

Day 2

1. After students have had time to complete their homework assignments, have them report back to the class.

2. As the students present their information, add to the chart that traces the various energy uses back to their sources.

3. After all the students have presented their reports, look over the chart and identify any ways in which students use renewable energy sources.

Optional follow-up activities

1. Science classes can study the various processes power plants use to generate electricity.

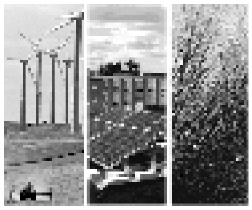
2. Invite a representative of the utility company to visit the class to discuss how the company obtains and distributes its electricity.

3. Invite a representative of the local natural gas company to visit the class to discuss the transmission of natural gas by pipeline.

4. Visit an electricity-generating plant.

5. Have students draw pictures or bring in photographs from magazines illustrating all their uses of renewable energy. Create a bulletin board.

6. Electric appliances have a label or plate that lists how much power they require (usually in watts or amps). Have students go through their houses and record all electric appliance power requirements. Then help the students rank their uses of power from their largest use of electricity to their smallest (e.g., refrigerators use more electricity than televisions). How much power would they need to run all the appliances in their houses simultaneously for an hour? How much would it cost to do this?



Renew-A-Bean

This activity introduces students to the difference between renewable and nonrenewable resources. It shows students that nonrenewable sources will be exhausted over time. Moreover, it shows that conservation measures—ways of using less energy—along with increased use of renewables can slow the depletion of fossil fuels. Through the activity, students will gain an increased understanding of:

- the eventual depletion of fossil fuel resources
- the effect of changing rates of energy use on the future
- the need to conserve as well as the need to develop renewable resources

This activity will also give students an opportunity to practice charting and graphing skills, and working with percentages.

Note: *The numbers used in this game are approximate and do not reflect actual depletion rates. The actual figures are difficult to estimate. The intent is only to simulate depletion of nonrenewable resources.*

GRADES: 7–12

Note: *The difficulty of this activity can be adjusted for different grade levels. Junior high teachers may want to end the activity with step 6, or continue subsequent rounds with each group using the same variation.*

SUBJECTS: math, science, social studies

TIME: one to two 45-minute class periods

MATERIALS: Divide students into groups of five. Each group will need:

- a paper bag containing 100 beans (or poker chips, or different colored pieces of paper): 94 of one color, six of another color
- extra beans of both colors: 10 of first color, 40 of second color
- five copies of the student handout
- extra graph paper

PREPARATION: Fill each bag with 94 beans of one color, six beans of another. This represents the ratio of nonrenewable to renewable energy use in the United States today. Mix the beans well.

PROCEDURE:

1. If you have not done the "What Is Renewable Energy?" activity, review with students the difference between renewable and nonrenewable resources and what those resources are. Ask them how much of each type of resource they think we are using in the United States today. Do they think the world will use more or less energy in coming years?

2. Discuss rates of energy use. Ask students whether they use the same amount of energy all day, or if the amount of energy they use varies at different times. Does energy use vary with the season? Do today's students use more or less energy than their parents did when they were in school? Explain how increases and decreases in energy use each year can be expressed in percentages.

3. Tell the students that they will participate in a game called "Renew-A-Bean." Explain that the beans in the paper bag represent nonrenewable and renewable resources. They will draw beans from the paper bag in order to simulate energy use over time. The class will play the game twice.

4. Divide the class into groups of five. In the games, students in each group will take turns drawing a given number of beans from the bag. When they pick a "nonrenewable" bean, they should set it aside—it is "used up." When they pick a "renewable" bean, they should return it to the bag. Each drawing represents one decade.

5. Distribute bags. In the first game, have students in each group take turns drawing 10 beans per decade out of the bag. Have them record the number of renewable and nonrenewable beans they drew on their student data sheet. Groups should stop picking beans when all the nonrenewable beans are "used up."

6. Ask groups how many decades it took to "run out" of nonrenewable energy. When the nonrenewable energy ran out, was there enough energy to meet the next decade's energy needs (10 beans)? Graph energy use over time. (Sample graph provided on pg. 14.) Ask students how they could make the energy supply last longer. They should come up with two answers—use less energy (conservation) and use more renewables.

7. In the next game, give each group a different variation to simulate. You can use the variations and charts on the teacher information sheet (pg. 14) to tell students how many beans to pick each year, or you can have students make up variations and calculate the numbers on their own. Some groups should increase the rate of energy use, some should conserve energy, and others should increase the percentage of renewable beans in their mix. Have each group chart and graph their results.

8. At the end of the second game, list the different variations on the blackboard. Ask the class to guess which variation produced the longest-lasting energy supply. Then, have one student from each group copy its chart of results on the board.

FOLLOW-UP:

1. When did each group run out of energy? How did this relate to how quickly they used energy? Which groups ran out of energy first?

2. Have students look at their graphs. During which decade did each group start using more renewables than nonrenewables? How is this represented on the graph? Which kind of energy will people probably use more of in the future?

3. Introduce the concept of "sustainable use." A sustainable rate of energy use ensures that there will always be enough energy for the next year's needs. Ask groups when, if ever, their energy use was sustainable during the game. (For

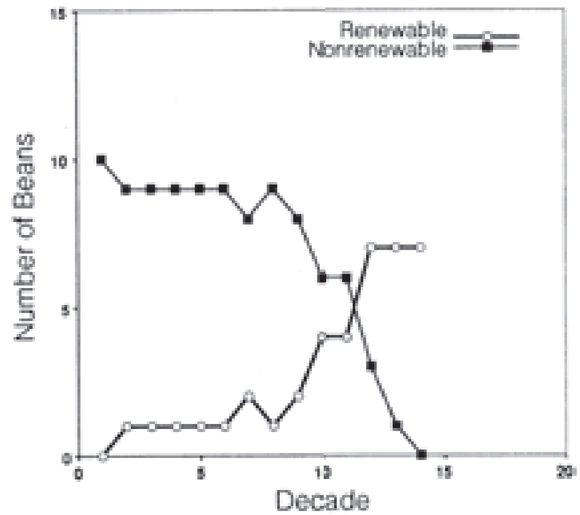
the purpose of the game, energy use is sustainable when the number of "renewable" beans in the mix is equal to a constant consumption rate, or is growing at the same rate as or faster than a growing energy consumption rate.)

4. Ask students if they think energy use can keep increasing indefinitely. Why or why not? If students answer that the rate of energy use can keep increasing because renewable energy will never run out, discuss limits on the growth of renewable sources of energy (e.g., available land for biomass crops and wind turbines, water sources for hydro).

5. Ask students what they think the ratio of renewable to nonrenewable energy use in the United States is in the current year (see "What Is Renewable Energy?" activity for 2001 figures). Ask how they think the rate at which we use energy changes each year. Is our current use of energy sustainable? What do we need to do to make it sustainable?

This activity was adapted from *Conserve and Renew: An Energy Education Package for Grades 4–6,* Sonoma State University, 1990.

Game 1: Draw 10 beans per decade until there are no "nonrenewable" beans left. Pool data, take average, and draw graph.

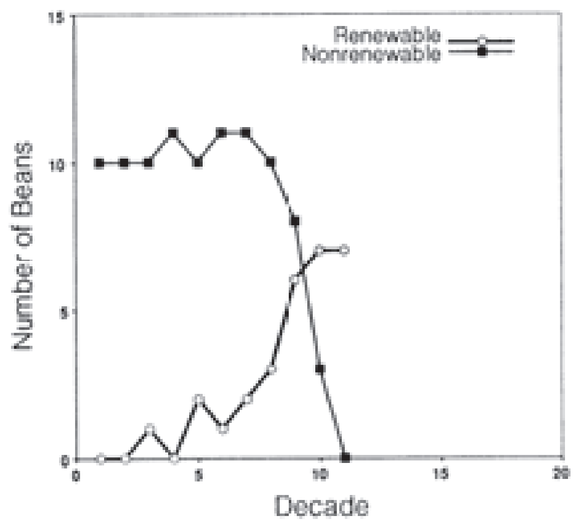


Game 2:

Variation 1: Energy consumption increases by four percent per decade. Compute number of beans to draw each decade (round to the nearest whole number), or use chart below. Graph results.

Decade	1	2	3	4	5	6	7	8	9	10
# of Beans to Draw	10	10	11	11	12	12	13	13	14	14

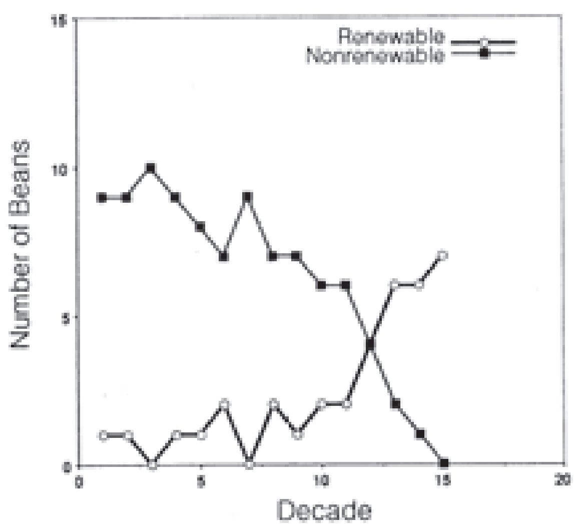
Decade	11	12
# of Beans to Draw	15	16



Variation 2: Energy consumption decreases by two percent per decade. Compute number of beans to draw each decade (round to the nearest whole number), or use chart below. Graph results.

Decade	1	2	3	4	5	6	7	8	9	10
# of Beans to Draw	10	10	10	10	9	9	9	9	9	8

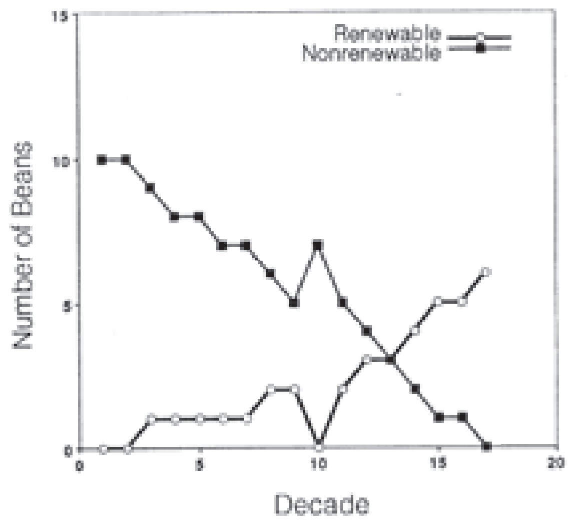
Decade	11	12	13	14
# of Beans to Draw	8	8	8	8



Variation 3: Energy consumption decreases by four percent per decade. Compute number beans to draw (round to the nearest whole number), or use chart below. Graph results.

Decade	1	2	3	4	5	6	7	8	9	10
# of Beans to Draw	10	10	10	9	9	8	8	8	7	7

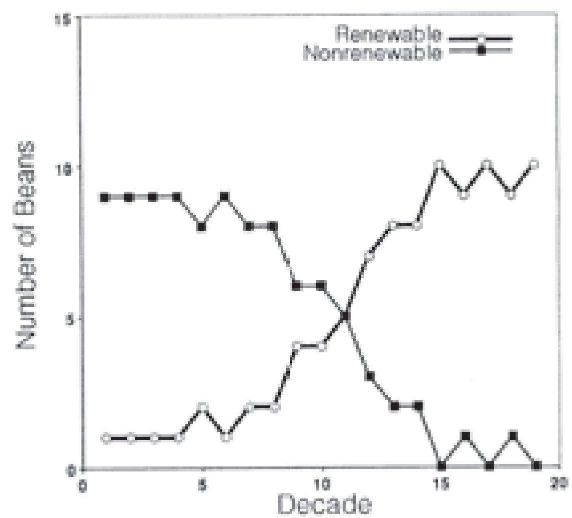
Decade	11	12	13	14	15	16	17
# of Beans to Draw	7	7	6	6	6	6	6



Variation 4: Renewables increase by six percent per decade; energy use remains constant. Compute the number of renewables to add per decade (round to nearest whole number), or use chart below. Graph results.

Decade	1	2	3	4	5	6	7	8	9	10
# of Beans to Add	0	0	1	0	1	0	1	1	0	1

Decade	11	12	13	14	15	16	17	18	19
# of Beans to Add	1	1	0	1	1	1	1	1	1

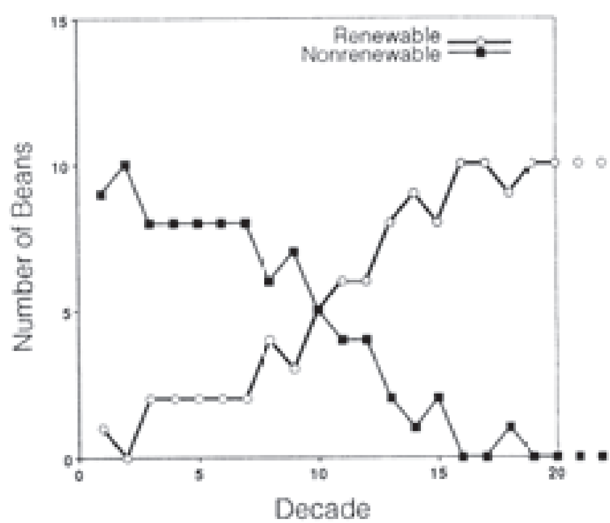


Variation 5: Renewables increase by 10 percent per decade; energy use remains constant. Compute the number of renewables to add per decade, or use the chart below. Graph results.

Decade	1	2	3	4	5	6	7	8	9	10
# of Beans to Add	0	1	0	1	1	1	1	2	1	1

Decade	11	12	13	14	15	16	17	18	19	20
# of Beans to Add	2	2	2	2	3	2	3	3	4	4

Decade	21	22
# of Beans to Add	4	5



Renew-A-Bean

STUDENT HANDOUT

Take turns drawing beans from your group's bag at the rate assigned by your teacher. Each drawing represents one decade of energy use. If you draw a "nonrenewable" bean, set it aside (but do not throw it out). If you draw a "renewable" bean, return it to the bag *after* you have completed your drawing for the decade. Record how many renewable and nonrenewable beans you draw each decade on the chart below, then graph your results.

DECADE **NUMBER OF BEANS DRAWN**

DECADE	Round 1 renewable	Round 1 nonrenewable	Round 2 renewable	Round 2 nonrenewable
1				
2				
3				
4				
5				
6				
7				
8				
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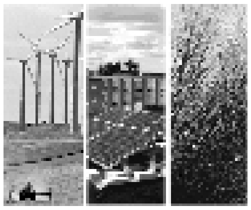


Solar Water Heater

In a solar water heater, water passes through a collector, usually on a roof, where it is heated by the sun. In order to attain the highest temperature possible, the collector is painted black and insulated. Solar collectors can also be used to heat homes and buildings, and power industrial processes.

This experiment shows how sunlight can be used to heat water. Students will build a thermosiphoning water heater, modeled after home solar water heaters.

GRADES: 7–12

SUBJECT: science

TIME: one 45-minute class period to build the water heater; two to three hours to heat the water

MATERIALS: Divide the class into groups of four or five. Each group will need:

- a shallow rectangular cardboard box (without flaps), at least 45 x 30 cm, no higher than 10 cm
- approximately three meters of plastic tubing, approximately 2 mm thick and 1.2 cm in diameter
- black paint and brush
- a bucket that holds at least two gallons of water
- two thermometers
- food coloring
- plastic wrap, Plexiglas, or glass that is the same size as or larger than the box
- aluminum foil
- extra cardboard
- tape
- a sunny day

PROCEDURE:

1. Ask students how energy from the sun gets to Earth. Ask about the difference between heat and light energy. Review the basics of solar energy collection, such as the storage, reflection, insulation, and heat absorption of materials with different colors and densities.

2. Tell students about solar thermal systems. Ask them how they think a system for heating water might work and look. Describe a solar hot water heater and a solar thermal power plant. Describe developments in modern technology.

3. Review how thermosiphoning works. Explain how differences in water temperature can cause differences in pressure. Explain how this pressure difference can be used to siphon water.

4. Distribute the handout "How to Build a Solar Water Heater" (pg. 19). Supervise student construction, helping if problems arise.

5. Ask students to measure the temperature of the water periodically during the three to four hours it is heating. Also ask them to write down the temperatures inside the heater.

FOLLOW-UP:

1. Ask students to name the ways heat was collected and transferred to the water in this activity. Ask them for ways to improve the efficiency of the solar heater.

2. Write the temperatures that students measured on the board. Ask students to draw conclusions about them. You may want to average the temperature readings of the different groups.

3. Ask them how a system would be designed to heat water enough to create steam for electricity. What fluids could be used in place of water?

4. Ask students what limitations sunlight might place on solar thermal system use. Factors to discuss are amount of sunlight, cloudiness, angle of sun, seasonal differences, and location.

5. Assign independent science research projects on solar thermal systems. Some possible topics are:

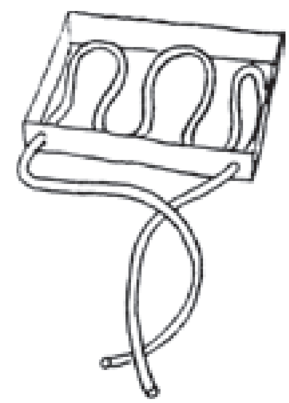
   - solar water heaters
   - solar thermal generating plants (parabolic trough, central receiving tower, or parabolic dish collectors)
   - recent developments in either of the above

How to Build a Solar Water Heater

STUDENT HANDOUT

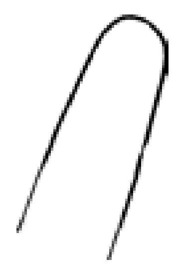
1. Poke two holes in the box at opposite ends of one side. Make them the size of the tubing you will use. Glue aluminum foil on the inside of the box and paint the foil black.

2. Insert tubing through one hole and curl it around the bottom of the box. Poke the tubing out the hole at the other end. Leave roughly equal amounts of tubing sticking out of both ends of the box.



3. Paint the tubing inside the box completely black.

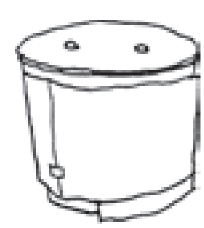
4. If the tubing does not stay at the bottom of the box, pin it down. Do this by bending a paper clip around the tubing and sticking its ends through the bottom of the box. Bend the clip ends on the other side, clamping the tubing down.



5. Tape a thermometer to the bottom of the box.

6. Cover the box with plastic wrap, glass, or Plexiglas. Tape it on so that it is airtight. If you use plastic wrap, stretch it so that there are no wrinkles.

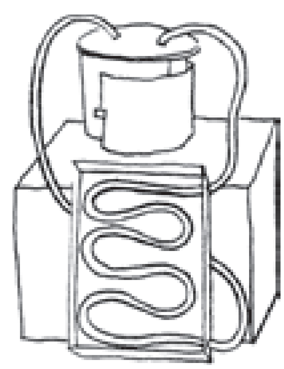
7. If the buckets you use do not have tops, make tops out of cardboard. Insulate the buckets by taping sheets of newspaper around them. Poke two holes in the top of one of the buckets for the tubing. This is your experiment bucket. The other bucket will be your control.



How to Build a Solar Water Heater

STUDENT HANDOUT

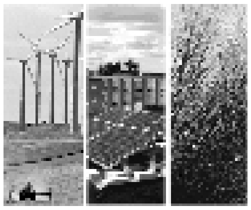
8. Fill both buckets with water. Insert tubing in your experiment bucket. Make sure that one end of the tubing is near the top, the other at the bottom. You may need to cut off some excess tubing to do this.



9. Prop up the box at a slant so that it is facing the sunlight (its shadow should be directly behind it). Place the experiment bucket on some support (books or another box will work), so that it is *completely* above the level of the collector. Arrange the control bucket at the same level.

10. Suck on one end of the tubing in the control bucket to fill the water pipe with water. Make sure there is no air in the pipe when you insert it back in the water.

11. Leave the solar heater and control bucket out in the sun for 3-4 hours and measure the temperature of the water periodically, as well as the temperature inside the heater.



Solar Box Cooker

In this activity, students build a solar box cooker from simple materials. The solar cooker represents a simple technology that is beginning to be used in less developed countries. Many countries depend heavily on wood for cooking. This dependence is creating a serious deforestation problem. In some areas, women and children must spend several hours each day searching for fuelwood. Solar cookers could help improve these people's lives and reduce the rate of deforestation.

This activity is designed to:

- increase student understanding of the principles of solar heating
- increase student awareness of how energy is used in developing nations

You may want to use this activity as part of a global awareness or United Nations day in your class or school.

GRADES: 6–8

SUBJECTS: science, social studies, home economics

TIME: one class period for construction; one to eight hours cooking time
You may want to schedule a special "solar lunch" after the cooker is built. Food can be put in the cooker one to eight hours before the lunch.

MATERIALS: Since each solar cooker requires a lot of materials, you may want your class to build only one or two. A solar cooker requires:

- two large corrugated cardboard boxes with flaps—one fitting inside the other with about 5 cm between them on all sides and bottom (inner box should be at least 46 x 56 cm)
- a flat piece of cardboard about 20 cm longer and wider than the larger box
- a light piece of glass or Plexiglas about 50 x 60 cm
- a thin metal tray, painted black, about 42 x 52 cm
- dark cooking pots
- aluminum foil
- water-based glue
- lots of newspaper for insulation
- string (one foot long)
- a stick (approximately one foot long)

PROCEDURE:

1. Identify particular developing countries on a map and discuss what people in those countries use for energy.

2. Discuss firewood depletion in developing countries. Explain how solar cookers can help solve this problem. Describe some solar box cooker designs.

3. Ask students how energy gets from the sun to Earth. Ask about the difference between light and heat. Review the basics of solar energy collection, such as the storage, reflection, insulation, and heat absorption of materials with different colors and densities. You may want to have students experiment with different insulation materials and investigate the absorptive capacities of different colors before you build your cooker.

Note: Do not use Styrofoam for insulation. The heat could cause it to melt and emit toxic fumes.

4. Build the solar box cooker, using the directions on the student handout (pg. 23).

FOLLOW-UP:

1. Ask students the following questions:

    a. How does the solar box cooker work?
    b. In what parts of the world would solar cookers work the best? the worst?
    c. Are solar cookers difficult or expensive to make? Are there disadvantages to solar cookers? How do these disadvantages compare with the advantages of solar cookers, especially in less developed countries?
    d. How would your life be different if your family relied on a solar box cooker to cook your food?

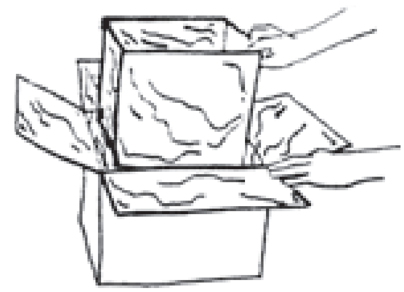
2. Have students research and build other designs for solar cookers.

3. Try using the cooker at different times during the school year. When does it take the longest time for food to cook? The shortest time? Why?

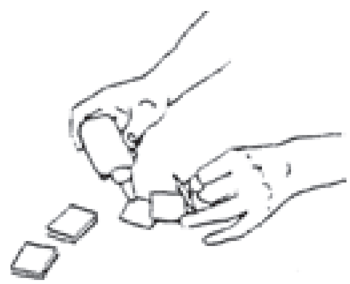
For plans and more information, contact Solar Cookers International, 1919 21st Street, Suite 101, Sacramento, CA 95814; (916) 455-4499; *solarcooking.org/sci.htm.*

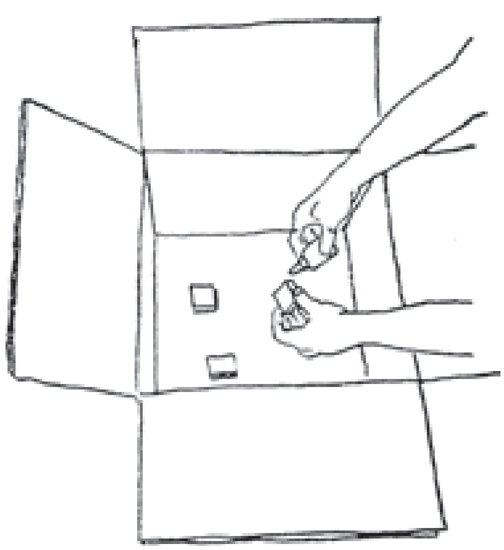
How to Build a Solar Box Cooker

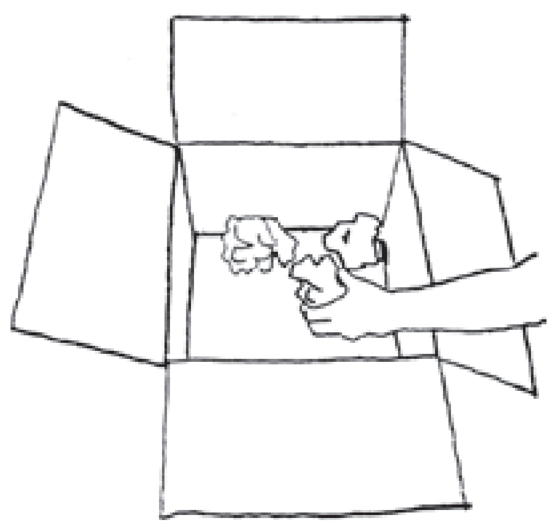
1. **Glue foil on the cardboard.** Dilute the water-based glue in a bowl, so that it will last a long time and you can brush-apply it. Glue foil completely over: (a) the inside *and* outside of the smaller box (cut off the flaps), (b) the inside of the larger box, (c) the inside *and* outside of the larger box's flaps, and (d) one side of the flat cardboard piece.



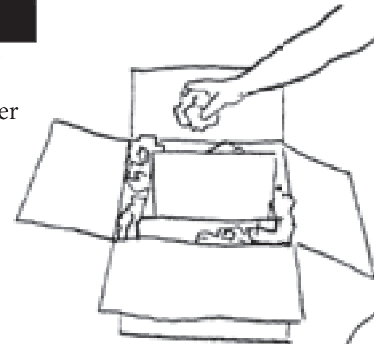
2. **Add bottom supports and insulation.** Cut out 4 cm squares from the discarded smaller box flaps. Glue them on top of each other to form eight pillars 2–3 cm high. Glue these pillars inside the bottom of the bigger box to support the inner box. Tear up newspaper sheets in fourths and crumple each piece into a lemon-sized ball. Cover the bottom of the bigger box with these balls.



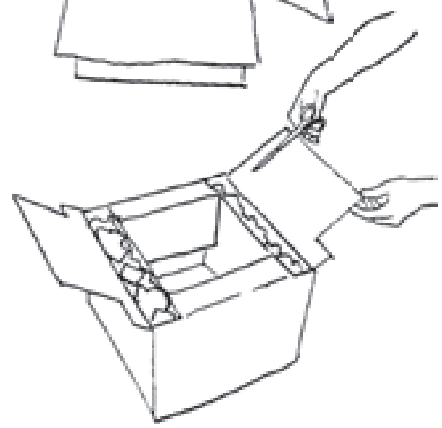




How to Build a Solar Box Cooker

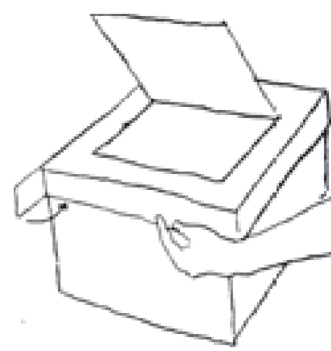


3. **Add inner box and side insulation.** Place smaller box inside the larger box. Stuff more newspaper balls between sides of boxes.

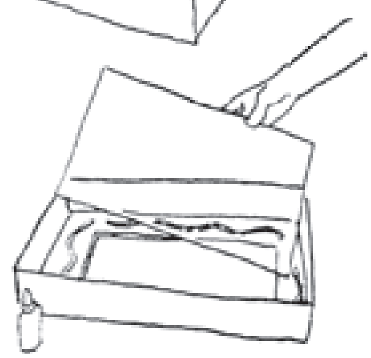


4. **Cut the flaps of the outer box so that they fit in the inner box.** Cut them so that they can be folded over, covering the top space between the boxes as well as the inner wall of the inner box (see diagram). Fold the flaps over and glue them.

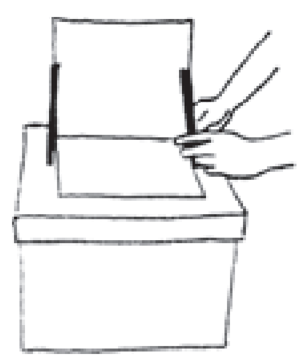
5. **Put the black tray in the box.** Paint it black if it isn't already. Use nontoxic paint.



6. **Make the lid.** Take the flat cardboard piece and center it, foil facing down, on top of the box. Fold down what sticks over the edges of the large box. You need to make four cuts in the cardboard to do this. Then, glue the folded edges of the lid together (not to the box). Make sure the lid fits snugly on the box.



7. **Glue the glass to the lid.** Cut 3 sides of a rectangle in the lid. This rectangle should be slightly smaller than the glass. Turn the lid over and glue the glass, around its edges, to the inside of the lid. Press it flat until the glue dries. If you use plastic wrap, stretch it out around the rectangular opening and tape in around the sides.



8. **Make a prop.** Bend up the cut-out rectangle in the lid so that it can reflect sunlight into the cooker. Attach a stick with string to the corner of the reflector and the side of the lid. If it is windy, you may want a prop on both sides.

You are now finished with your solar box cooker and are ready to cook!

Solar Box Cooker: Guidelines for Cooking Food

1. Put your food in covered black pots in the solar box cooker with the lid on.

2. Aim the box so the shiny side of the lid reflector faces where the sun will be in late morning (lunch) or early afternoon (supper). Tie the prop to hold the lid reflector where it shines the most sunlight into the box.

   Warning: Temperatures inside the cooker can reach 275 degrees Fahrenheit. Do not leave cooker unattended in a place where it could be disturbed by other students.

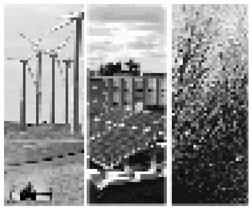
3. Food cooks better:

   - on a warm, sunny day in late spring, summer, or early fall
   - if you put it toward the back of the box
   - if you adjust the cooker often so that its shadow lies directly behind it
   - if you divide the food up into small pots

4. You need not stir the food while it is cooking. If you open the box during cooking, be careful of the high temperatures inside.

5. Most importantly, put the food in early, and don't worry about overcooking—solar cookers seldom overcook. Cooking times for recommended foods are:

   - one to two hours for rice, fruit, above-ground vegetables, pretzels
   - three to four hours for potatoes, root vegetables, some beans (including lentils), most bread
   - five to eight hours for most dried beans



Solar Houses

Solar houses are one of the simplest and oldest uses of solar energy. A solar house is designed to capture solar heat in cold months and remain cool during hot months, thus offsetting use of oil, natural gas, and electricity for heating and cooling.

Passive solar features—parts of a house that do not use mechanical devices for solar heating or cooling—can include south-facing windows, high-density building materials that absorb heat, and overhangs for shading. Active solar features can include pumps and fans that channel warm or cool air into storage spaces where it can be released at night.

This activity introduces students to basic principles of solar heating. Students construct their own model solar houses and then see which attain the highest or lowest indoor heat.

GRADES: 8–12

SUBJECTS: science, industrial arts

TIME: at least one class period to teach basics of solar heating and cooling; one class period to test temperatures of student model solar homes. Solar house construction should be homework, although you may want to have an in-class help session while students are working on their models.

MATERIALS: various materials supplied by the student, possibly including cardboard, plastic wrap, stones, or Plexiglas. Price of materials should not exceed five dollars; encourage students to recycle discarded materials.

PROCEDURE:

1. Ask students if they can name some ways in which the sun's heat is captured or lost by the earth (i.e., reflection, absorption, and radiation). Ask how they think a substance's color, density, and design affect how it absorbs or loses the sun's heat. Describe the basics of solar heating/cooling.

2. Ask students what they think a house that uses solar heating and cooling might look like. How is cool or warm air retained by such a house?

3. Distribute the handout "Solar House Assignment" (page 28). Give students a due date for the project.

4. Since the houses will be tested outside, you may want to make this a solar heating or cooling experiment, depending on the season. If it is fall, winter, or early spring, solar heating is appropriate. Alternatively, you may want to test the same houses both for solar heating in winter and solar cooling in summer. Students might receive extra

credit if they design a solar heated house that remains cool in summer.

5. Test the houses on the first sunny day after they are completed. See handout for specifics about house building and testing.

Note: *As the teacher, you may want to build your own model solar house to show the students after they build their own.*

This activity was contributed by Tom Wellnitz, science teacher at Shore Country Day School in Beverly, Massachusetts.

Solar House Assignment

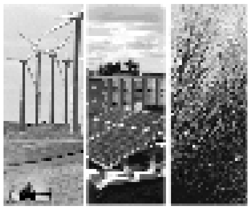
STUDENT HANDOUT

Your task in this assignment is to build a "house" that will be heated by the sun. Of course, you will not be building a real house, but you will be using many of the same ideas as a solar-heated house. Your house will be the size of a shoebox.

1. The winning house will be the one that, when placed outside on a sunny day between 11:00 AM and 12:30 PM, achieves the highest interior temperature.
2. Each house must be at least 10 cm x 25 cm x 10 cm (exterior dimension).
3. Houses must be attached to a piece of cardboard or wood (50 cm x 50 cm) to prevent being blown away by the wind. You may want to bring the house and base separately to school for ease of transportation.
4. On the base you should draw an arrow. Your house will be placed outside with the arrow pointed toward magnetic north, as determined by a compass.
5. Each house must have at least one window covered with at least 250 sq. cm of glazing material. "Glazing material" is any material that allows light, but not air, to pass through. It might be glass, Plexiglas, plastic wrap, etc.
6. Any materials may be used as long as they do not create a safety hazard. Try to use materials that have been thrown away. Total cost for materials should not exceed five dollars. Present a statement from your "funding agents" (parents) verifying this.
7. Due date: ___________________. Testing date will be the first school day after this date with acceptable weather.
8. Temperature recording: Temperatures will be recorded by placing a standard laboratory thermometer into the house from the side at a height of 8 cm.

QUESTIONS TO CONSIDER:

1. Which direction should the window(s) face?
2. How can you keep heat in the house?
3. Does the color of the interior make a difference?
4. Does the angle of the window make a difference?
5. What allows heat to get in during the winter but not during the summer?
6. In a real solar house, the temperature must be regulated to prevent overheating, even in winter. How is this done?



Photovoltaics

Photovoltaics is a technology for converting light directly into electricity. Most photovoltaic cells have two layers of “semiconductor” material—the same material used in computer chips. When light hits the photovoltaic cell, electrons travel from one layer to the other, creating a voltage (or charge) that can power an electrical device.

Photovoltaic cells (also called PV or solar cells) were first developed to power space satellites. Technical advances have steadily increased PV cell efficiencies, and their cost has dropped significantly. Solar cells are widely used in calculators and for remote power applications not connected to an electricity grid (such as rural villages, communications relays, and emergency lights, signs, and telephones). They are not yet economically competitive for large-scale electricity generation.

This experiment introduces students to photovoltaic cells and demonstrates their efficiencies under varying conditions.

GRADES: 7–12

SUBJECTS: science

TIME: two 45-minute class periods for all the experiments below; less time if you do fewer

MATERIALS: Divide students into groups of two to four. Each group needs:

- small solar PV cell with at least a 0.4 V output (these can be obtained from most scientific supply companies and electronics stores)
- 30 cm of wire (approximately 22 gauge)
- DC ammeter with a range of approximately 0–10 amps
- DC voltmeter with a low rating (1 or 5 VDC minimum rating is fine)

Depending on which experiments you do, you may also need:

- a strongly directional light source, such as a shaded desk lamp or flashlight
- magnifying glass
- cardboard
- aluminum foil
- glue
- small motor (approximately 1.5 VDC) or flashlight bulb

PREPARATION:

1. If you have not studied electricity in your class, you may want to discuss the basic concepts of electricity before proceeding.

2. Unless your school already owns some, you need to order PV cells in advance. Buy as many cells as you can afford; you can divide the class equally according to how many PV cells you have. Since each PV cell will be attached to an ammeter and voltmeter, the number of ammeters and voltmeters your school owns may be a limiting factor.

3. You should attach 15 cm of wire to each node of the PV cell, to connect it to the ammeter, voltmeter, bulb, or motor. Some cells come with clips or hooks around which you can manually twist wire; some do not. If yours does not, you may need to solder the wire ends to the cell before class. If yours does have a clip, you can have the students attach the wire themselves.

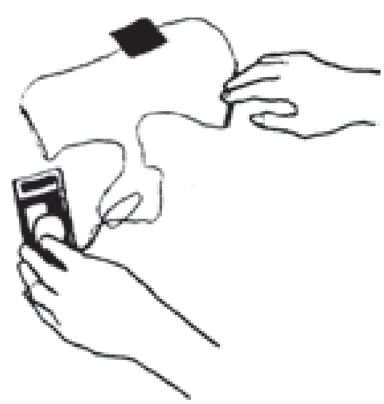
4. You will need a sunny day to do most of these experiments. Alternatively, you could do Experiments 1, 2, and 3 in the classroom, using fluorescent lights, but you will need an ammeter that will measure accurately between 0 and 1 amp to do this.

PROCEDURE:

1. Discuss with students the technology of photovoltaics and describe how a PV cell works. Distribute the handout "Photovoltaic Cells" (pg. 33). You might have students read about photovoltaics before the class period.

2. Distribute the solar cells. Tell students to be careful; PV cells are fragile. You may want to attach the cells to a stiff backing before class.

3. First, show students that PV cells can generate electricity. Ask each group to attach the two wires to the end of a flashlight bulb or a small DC motor. Put the cells under an intense lamp or in sunlight.



4. Have students attach their PV cell to an ammeter. Make sure the positive and negative ends of the PV cell wires match up with the ammeter. Assign one student in each group to measure and record current for the experiments below.

5. Run one or more of the experiments. Write on the board the scientific question for each experiment.

You might want to write the results (in amps) of each group's findings on the board. These can be averaged, and the class can draw conclusions from the data.

EXPERIMENT 1: How does light intensity affect how much electricity a solar cell can produce?

Procedure: Have students place the PV cell at distances of 4 cm, 12 cm, and 25 cm from a strongly directional light source other than the sun (a shaded desk lamp is good). The solar cell should be held facing directly at the light source. Ask students to measure the current of the cell at 4 cm, 12 cm, and 25 cm from the light source. Have students graph the results.

Follow-up: Have students draw conclusions from their measurements. Ask them if their graphs represent a linear or exponential function. Point out to students that what is being tested is the effect of *intensity* of light on PV cells.

Point out that light is more intense on a sunny day than on a cloudy day. What does this say about the best conditions for using PV cells? What time of day do they work best?

EXPERIMENT 2: How does the angle to the light source affect how much electricity a solar cell can produce?

Procedure: Have students place their PV cells on a horizontal surface in direct sunlight (either outside or on a sunny window sill). Measure the current. Then, have them point the PV cell directly at the sun: slant it so that its shadow is directly behind it, with the cell's face perpendicular to the sun's rays (one way to discover the sun's direction is to insert a stick in the ground and tilt it until it has no shadow). Measure the current. Students might also measure the PV cell's current at decreasing 15° intervals from the perpendicular (90°, 75°, 60°, 45°, 30°, and 15°), then graph the measurement. The result should be a sinusoidal curve.

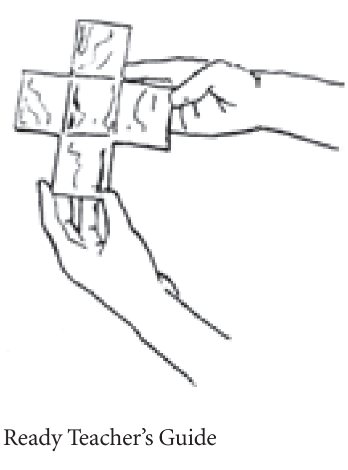
Follow-up: Have students draw conclusions from their measurements. Ask them: How could you increase the output of a PV cell during the day, when the angle of the sun's rays is constantly changing?

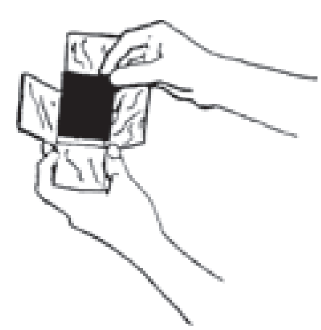
EXPERIMENT 3: How does concentrating the light affect how much electricity a solar cell can produce?

Procedure: Have students measure the current of a PV cell under a light source (a lamp or the sun). Then, have them concentrate the light source on the cell with a magnifying glass (move the magnifying glass around until a bright area appears on the cell). Measure the new current.

Alternatively, students can make a cardboard reflector. Cut out a cardboard shape and glue aluminum foil on the four flaps. Place the solar cell in the base and fold up the four side flaps to reflect light on the cell. Measure the new current.

Follow-up: Have students draw conclusions from their measurements. Ask: Does it make sense to concentrate sunlight on a PV cell? Point out that many PV cells today have concentrators on them.

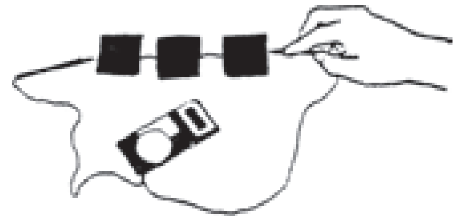




EXPERIMENT 4: How does putting several PV cells in a series affect how much electricity they can produce?

Procedure: Measure the voltage of a PV cell under a light source. Then connect several PV cells in series and measure the voltage produced under the same light source.

Now repeat the measurement by connecting several cells in parallel, and measure the *current* produced under the same light source.



Follow-up: Have students draw conclusions from their measurements. Ask: How much more voltage was produced, in comparison to the voltages produced by individual cells? How much more current was produced with the cells connecting in parallel, in comparison to the current produced by individual cells? You can point out that most modern PV systems have cells connected in series strings to raise the voltage to a useful level, and grouped in parallel to provide the desired power (current).

FOLLOW-UP:

To conclude the activity, you may want to do one of the following:

1. Summarize your findings by averaging together the measurements of all the groups.

2. Review the technology of photovoltaics, adding in information gained through the experiments.

3. Describe recent improvements and discoveries in photovoltaic technology (such as thin film or amorphous silicon cells).

4. Assign individual or group research projects in the following areas:

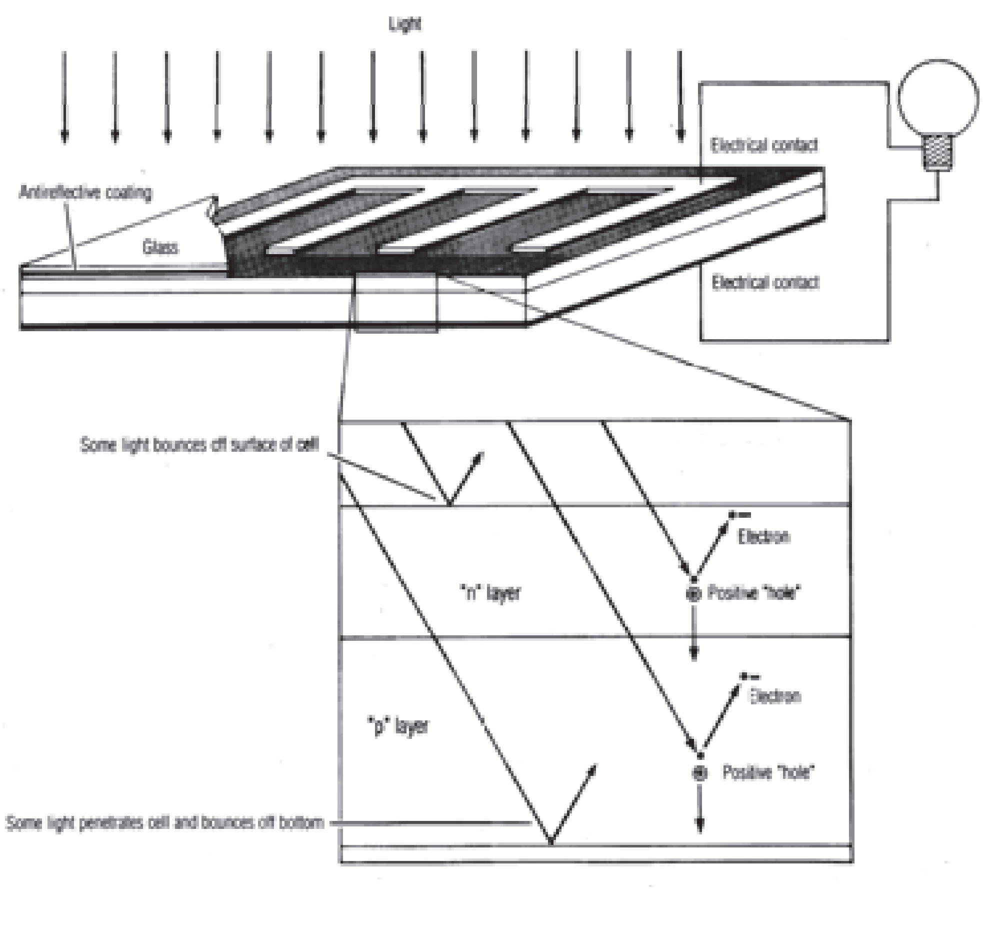
   a. photovoltaic efficiency
   b. kinds of PV cells, such as thin film or amorphous silicon
   c. technology of manufacturing PV cells
   d. costs of manufacturing PV cells
   e. new developments in PV technology
   f. current uses of PV cells

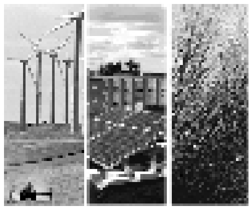
PHOTOVOLTAIC CELLS

A photovoltaic cell turns light directly into electricity.

Photovoltaic cells (also called PV or solar cells) are made of two ultrathin layers of silicon that are contaminated (or "doped") by two different substances. One layer is called the "n" layer and the other is called the "p" layer. There is a slight electrical difference across the two layers—that is, one layer is more positively charged, the other more negatively charged.

When light hits the cell, it knocks electrons off atoms in both layers. Since there is a difference in charge between the layers, electrons flow from one layer to the other. When an electrical device is attached to the cell, creating a circuit, these electrons flow through the circuit, creating electricity.





Wind Energy

This experiment shows students how wind energy can generate electricity. Specifically, it shows how wind propeller design affects the efficiency of wind machines.

GRADES: 7–12

SUBJECT: science

TIME: one class period (45 minutes) for building wind machines; one to two class periods for experiments and discussion.

MATERIALS: Divide students into groups of two or three. Each group needs the following materials to build one generator and three wind propellers:

- small electric fan or hair dryer (you will need a two-speed fan for Experiment 4)
- DC motor (1.5 V or larger)
- three corks of the same size (at least 2 cm in diameter)
- DC voltmeter with a low rating (1 or 5 VDC minimum rating is fine)
- a stiff ruler or piece of wood
- 60 cm of connecting wire (about 22 gauge)
- large rubber band
- fast-drying glue
- 18 paper clips
- pliers or wire cutters
- a pair of scissors
- thin cardboard (less than 2 mm thick, paper pad backing works well)

PREPARATION:

1. If you have not studied electricity in your class, you may want to review basic concepts of electricity before this activity. You may also want to distribute the Beaufort Wind Scale handout (pg. 39) a week before this activity.

2. You may want students to glue the wind propellers (see the handout on pg. 38) during an earlier class, depending on how fast your glue dries (Elmers glue takes 20–30 minutes to dry).

3. Cut the connecting wire into 30 cm pieces before class.

PROCEDURE:

1. Ask students if they know what "wind energy" is and how it is harnessed. Ask them to name some uses of wind energy and/or ask them to sketch wind machines. Describe modern wind technology.

2. Review the basics of electricity and electricity generation. Explain to them how a magnetic coil motor works. Show them a small, disassembled motor. Explain that you can make a simple electric generator from a small motor.

3. Distribute instructions. They tell students how to build a generator and three wind-propeller models to power it. Review these instructions if necessary.

4. Supervise construction, helping if problems arise.

5. When students finish, ask them to do Experiments 1, 2, 3, and 4 below. Begin each experiment by writing the experimental question on the board. Describe each experiment to them.

Note: *You might also begin by simply showing, with your own model wind machine, that wind energy can produce a current. Alternatively, you could show that rotating a motor shaft produces a current, by pulling a rip cord around the motor shaft.*

EXPERIMENT 1: How does the blade angle on a wind propeller affect how much electricity it produces?

Procedure: Attach Model 1 wind propeller to the motor shaft. Tilt the blades so that they are perpendicular to the end of the cork (Figure A). Place the wind machine in front of a working fan or hair dryer. Does the propeller spin? If not, slightly rotate the blades so that they are at a small slant (Figure B). Place the propeller in front of the fan or hair dryer. Keep tilting the blades in small increments until the propeller starts spinning. When this happens, measure the voltage produced. Keep tilting the blades of the propeller to see which angle produces the greatest voltage.

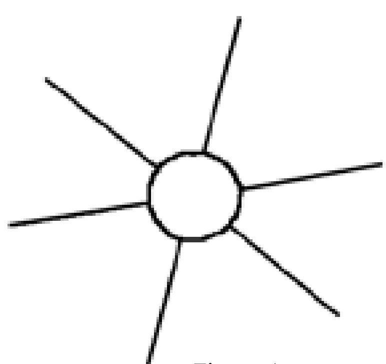


Figure A

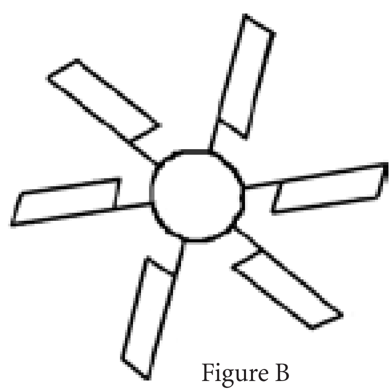


Figure B

Ask students to draw conclusions about how blade angle affects how fast a propeller can spin, and why.

EXPERIMENT 2: How does the size of the blades on a wind propeller affect how much electricity it can generate?

Procedure: Keep the wind blades on Model 1 at the angle at which they produced the greatest voltage. Measure the voltage again. Then, attach the Model 2 wind propeller to the motor shaft, with the blades at the same angle. Put it in front of the fan or hair dryer at the same distance as you did with the first propeller. Measure the voltage produced by this wind turbine.

Ask students to draw conclusions about how the size of wind blades affects how fast a propeller can turn, and why.

EXPERIMENT 3: How does the shape of the blades on a wind propeller affect how much electricity it can generate?

Procedure: Keep the wind blades on Model 2 at the same angle as in Experiment 2. Measure the voltage again. Then, attach the Model 3 wind propeller to the motor shaft, with the blades at the same angle as the Model 2 wind propeller. Measure the voltage.

Ask students to draw conclusions about how the shape of propeller blades affects how fast they can spin, and why.

EXPERIMENT 4: How does wind velocity affect the amount of electricity a wind machine can produce?

Procedure: Using any of the propellers created in previous experiments, place the wind machine in front of a two-speed fan. Turn the fan on low speed and measure the voltage. Then turn the fan on high speed and repeat the measurement.

Ask students to hypothesize about how wind speed affects the electricity output of wind machines. What conditions would probably be necessary for a good site for commercial wind energy generation?

You might end the activity by holding a contest to see who can produce the most efficient wind turbine. Give them identical corks and a total surface area that all their propeller blades must add up to, independent of their shape (6 sq. cm, for instance). Given this constant area, see which students can design the most efficient turbine.

FOLLOW-UP:

1. Ask students if they think they could build a wind turbine strong enough to power a flashlight bulb (average voltage: 2.5 V). How would they alter the turbine design to do this?

2. Ask students to picture what the ideal, most efficient wind turbine would look like, considering what they have learned in the experiments. Discuss the models they suggest. Show pictures of actual modern wind turbines.

3. Assign independent research projects on wind energy. Possible topics are:

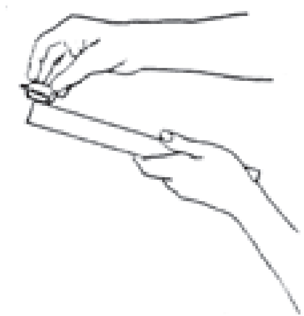
- different kinds of wind turbines
- recent advances in wind turbine design
- wind energy potential in the United States
- problems with wind turbines
- uses for wind machines other than electricity generation
- wind energy storage
- historical uses of wind power
- current uses of wind power around the world

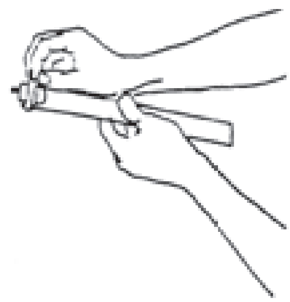
Wind Machine Instructions

STUDENT HANDOUT

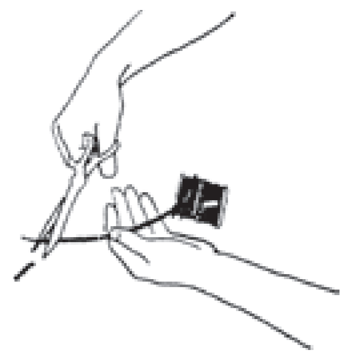
This sheet tells you how to build your own wind machine for generating electricity.

First, get a small motor and a ruler or piece of wood from your teacher. Attach the motor to the end of the ruler by wrapping it with a rubber band.

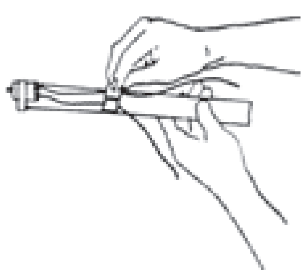


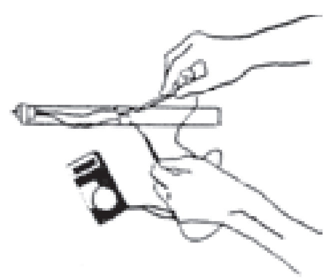


Second, cut two 30 cm pieces of electrical connecting wire. With a pair of scissors, take off 2 cm of rubber insulation from both ends of the two wires. Do this by pinching softly with the scissors on the rubber casing, cutting it slightly, then pulling the scissors toward the wire's end, removing the casing.



Next, attach one end of each wire to one of the motor's outlets. Tape the wires to the molding (at the end without the motor). Attach the other two ends of the wire to a voltmeter.





Now you're ready to build the actual wind propellers. There are three models you'll need to build.

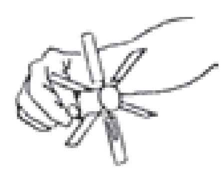
Wind Machine Instructions

STUDENT HANDOUT

MODEL 1: Take six paper clips. Snip off part of each clip with pliers or wire cutters. Straighten out the bottom part of each clip.

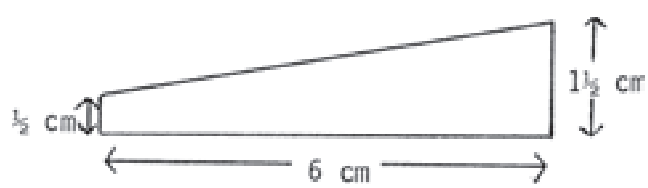
Then cut out six pieces of cardboard 1 cm x 3 cm. Glue or tape the central part of each paper clip to the bottom of a cardboard piece. Leave time for glue to dry (20 minutes).

Take a cork and poke the six wind blades into it. Insert the blades about 5 mm from the end, spaced equally around the circumference of the cork. To loosen up a hole, you may want to stick a pin in beforehand.



MODEL 2: Follow the same directions as Model 1, but this time cut cardboard rectangles that are 1-1/2 cm x 4 cm.

MODEL 3: Follow the same directions as Model 1, but this time cut the cardboard in the following shape:



Note: This shape has the same surface area as Model 2.

To use a wind propeller, place the cork end furthest away from the wind blades on the motor's shaft. Make sure the shaft goes in the exact center of the cork and do not wiggle it (which will loosen its hold on the motor).

Wind Machine Instructions

This is the Beaufort Wind Scale. It is used to measure wind speeds. It relies on human observations, not mechanical devices, to calculate the speed of the wind.

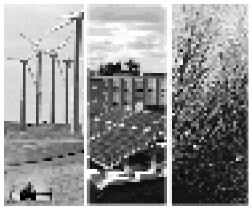
BEAUFORT NUMBER	DESCRIPTION	OBSERVATION
0	calm (0–1 mph)	smoke rises vertically
1	light air (2–3 mph)	smoke drifts slowly
2	slight breeze (4–7 mph)	leaves rustle; windvane moves
3	gentle breeze (8–12 mph)	twigs move; flags extended
4	moderate breeze (13–18 mph)	branches move; dust and paper rise
5	fresh breeze (19–24 mph)	small trees sway
6	strong breeze (25–31 mph)	large branches sway; wires whistle
7	moderate gale (32–38 mph)	trees in motion; walking difficult
8	fresh gale (39–46 mph)	twigs break off trees
9	strong gale (47–54 mph)	branches break; roofs damaged
10	whole gale (55–63 mph)	trees snap; damage evident
11	storm (64–72 mph)	widespread damage
12	hurricane (73–82 mph)	extreme damage

EXERCISES:

1. Measure the wind using the above scale. Measure it on three different days at three different times during the day, preferably in the morning, midday, and afternoon or evening. Record your observations.

2. At what time of day do the fastest winds usually occur? the slowest winds?

3. Any wind over 8 mph can be used to generate electricity. Currently, though, it only makes economic sense to build wind turbines in areas where the wind exceeds 15 mph most of the time. Could you generate electricity in your area?



Biomass

Biomass is organic material (material from plants or animals) that can be burned to produce heat or can be converted into liquid or gaseous fuels. This experiment shows students how to produce a combustible gas by destructive distillation, or pyrolysis, of biomass.

Biomass combustion does produce carbon dioxide, a heat-trapping gas. However, if all land used to grow biomass is replanted, there is no net addition of carbon dioxide to the atmosphere.

Before 1900, biomass—in the form of wood—was the United States' main energy source, but today it provides only four to five percent of the nation's primary energy needs. It could supply more. Using waste for biomass is especially promising. Crop and animal wastes or organic municipal wastes can be burned or converted into fuels instead of being dumped in landfills. Methane is collected from some landfills and burned for energy, and ethanol from grain surpluses is converted into a gasoline additive in some parts of the country. There is also considerable potential for growing biomass energy crops for thermal energy or fuel.

Converting biomass to liquid or gaseous "biofuels" is convenient for fueling vehicles. Gasification, pyrolysis, and fermentation are some of the processes that can turn biomass into fuels such as syngas, methanol, or ethanol.

GRADES: 10–12

SUBJECT: science (chemistry)

TIME: one class period (45 minutes)

MATERIALS: Divide the class into groups of two to four. Each group needs the following:

- biomass source—small wood chips are suggested (you could use cut-up splints)
- large test tube and test tube holder
- Bunsen burner
- rubber stopper with one hole
- glass tubing that fits snugly in stopper hole
- wood splint
- mass balance
- safety glasses

CAUTIONARY NOTE: *The gas produced in this experiment can be explosive under pressure. Close supervision is recommended. Students should wear safety glasses. Be careful that students are not burned by the burner or splint flame. Provide adequate ventilation; make sure the test tubes are vented as illustrated in the diagram.*

PROCEDURE:

1. Ask students if they know what biomass is. See if they can name some kinds of biomass. Ask them to think of ways biomass can supply human energy needs.

2. Describe different kinds of biomass to them. Show how they are used as energy sources in the world today. Describe what biofuels are and how they are created and used.

3. Perform the experiment. Explain the directions carefully beforehand; distribute the directions as a handout (pg. 42). Supervise the students closely; for safety reasons, you may want to divide the class into groups of a size that is most easily managed.

FOLLOW-UP:

1. Ask students to draw conclusions from their measurements. How much mass was lost from the wood in the test tube? Where did this extra mass go? What was the mass of the gas?

   Note: The lost mass will not tell you precisely how much gas was produced, because not all gases will burn.

2. Would this be an efficient way of producing biofuels? Discuss why or why not. You may want to discuss the advantages and disadvantages of using energy to convert biomass to biofuels.

3. Assign independent research projects on biomass. Possible topics are:

   - biomass from crop and animal waste or from human trash
   - different kinds of biomass and how they are used as energy sources
   - biofuels that are used today, such as ethanol, methanol, or syngas
   - techniques of biofuel conversion
   - potential future biofuels or sources of biomass
   - advantages and disadvantages of biomass use
   - biomass and land use issues

This activity was adapted from *Science Projects in Renewable Energy and Energy Efficiency*, compiled by the National Renewable Energy Laboratory, Boulder, Colorado, 1991.

Instructions for Creating Fuel from Biomass

In this experiment you will create a gas that is a combustible fuel. This gas is produced by pyrolysis, or the heating of biomass in the absence of oxygen.

1. Determine the mass of your test tube (including stopper and glass tubing) using a balance. Stuff the test tube full of wood chips or whichever biomass source you are using. Leave just enough space at the top so that (a) you can put the rubber stopper on and (b) you can insert the glass tubing so that its end doesn't touch the biomass.

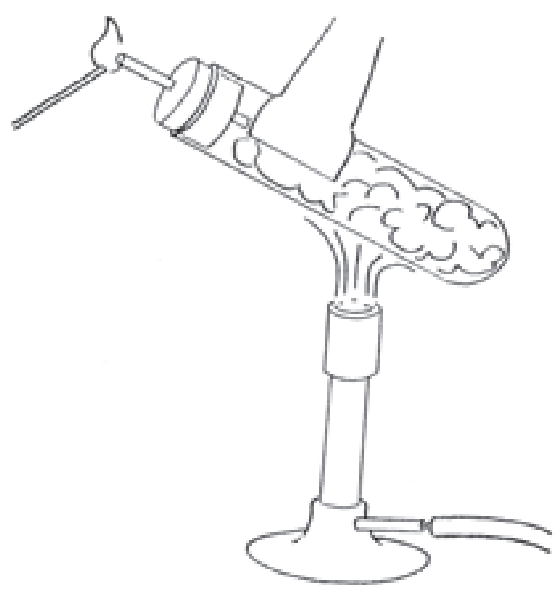
   Determine the mass of the filled tube using a balance. The mass of the wood will equal this number minus the mass of the test tube (with stopper and tubing). Write this number down.

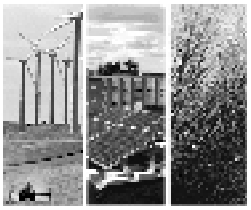
2. Ask your teacher to check your setup so far. Then the teacher will show you how to light the Bunsen burner. Put on your safety glasses. Once the burner is lighted, clamp the tube with the test tube holder and put it over the flame (picture below). Be careful not to burn yourself.

3. After a while, invisible gas will be released from the end of the glass tubing. Light a splint and hold it about 2 cm away from the glass tubing end. Record how long this gas is released, as well as how long it burns (it may be difficult to keep the flame lit).

4. After no more gas is produced, turn off the burner and let the wood and tubing cool down. Then determine the mass of the remaining material in the test tube.

   mass of remaining wood = mass of partially filled test tube – mass of empty test tube





Playing It Cool: A Renewable Energy Economics Game

This game simulates some of the economic changes necessary to make renewables succeed as large-scale electricity sources. Students buy and sell electricity from various sources—coal, oil, natural gas, nuclear, and renewables—under a variety of economic conditions. By seeing prices rise and fall, students learn about economic barriers and opportunities for renewables.

In the United States today, some renewable sources can generate electricity at a price competitive with fossil fuels, but most utilities do not opt for renewables. Why is this? For the following reasons:

- Oil, coal, and natural gas are cheap and easily accessible (as of 2001).
- Many utilities are unfamiliar with renewable energy technologies, which are generally very different from conventional fossil fuel technologies.
- At the present time, renewables are not appropriate in all areas.
- Environmental costs are not reflected in the economic costs of fossil fuels and nuclear power.
- The fossil fuel and nuclear industries are well established, whereas the renewable industries are still small in comparison. This makes energy from renewables harder to get and, in some cases, more expensive.

Through the game, students should:

1. Observe that the relative price of renewables changes according to environmental regulations, renewables' availability, economic infrastructure, and the prices of fossil fuel and nuclear power.

2. Be able to explain how these economic conditions affect the price of renewables.

3. Understand the concept of a "level playing field." A level playing field is a state of open economic competition where energy sources are subsidized equally and where an energy source's environmental cost is reflected in its price.

GRADES: 8–12

SUBJECTS: social studies, economics, math

TIME: three to five 45-minute class periods

MATERIALS:
- 20 or fewer copies of the game instructions (student handout, pg. 47)
- 10 energy source description cards (pg. 48)
- 10 technology and supply advance cards (pg. 49)
- 5 News Flash pages (pg. 50; you may want to make these into transparencies)
- 10 or fewer copies of utility buyer cards (pg. 53)

- 10 copies of energy source selling cards (pg. 54)
- index cards
- tape
- $350 worth of play money for each utility, in $1, $5, $10, $20, and $50 denominations
- $500 extra play money, in small denominations, for teacher

PLAYERS NEEDED: at least 15 students

PREPARATION:

1. Photocopy game instructions, energy source description cards, utility buyer cards, and energy source selling cards.

2. Prepare transparencies of News Flash pages.

3. Prepare approximately $4,000 worth of play money.

Note: *This is a rewarding but complex game, which will work best when students have some knowledge of renewable energy and/or economics, and when there is plenty of time for play and discussion. During the rounds, the "energy marketplace" will be somewhat chaotic.*

PROCEDURE:

1. Tell students they'll be participating in a game about renewable energy called "Playing It Cool."

   a. Clear the center of the room to form a marketplace.
   b. Pick 10 students to be power plants representing different energy sources. Give each a different energy source description card (coal, oil, nuclear, natural gas, solar thermal, photovoltaics, wind, hydropower, biomass, and geothermal), an energy source selling card, and an index card. These students should write the name of their energy source on the index card and tape it to the front of their shirts. This will allow the utilities to identify the energy sources quickly during the game.
   c. Assign the rest of the students to be utilities. If more than 10 students are left, ask some students to team up as one utility. Give each a utility buyer card and $350.
   d. Tell students that you will be the banker for the game.
   e. Distribute copies of the instructions (student handout) to all students.

2. Read the following out loud to the class (or improvise your own material):

   "The year is [current year], the place, the United States. The American economy is sputtering along, using more and more electricity each year.

   [Pointing to students with utility cards] "You people are the utilities, and you provide electricity to American industry and the public. As utilities, you must provide electricity every hour, every day—at the cheapest price you can get it.

   "You can choose to purchase electricity from a variety of energy sources. These people here represent power plants generating electricity using various energy sources [ask them to raise their hands as you read their names]: coal, oil, natural gas, nuclear, solar thermal, photovoltaics, wind, hydropower, biomass, and geothermal. [Ask each energy source to read his or her description card out loud.]

"Your goal—as either a utility or energy source—is to make as much money as you can. As utilities, you buy from the energy sources offering the lowest prices. As energy sources, you offer energy at prices that are high enough for you to make money and low enough that utilities will want to buy energy from you."

3. Go through the specific instructions (student handout) with the students. You may want to read the instructions out loud to the class. You should stress the following points:

   - The goal of the game is to make money.
   - Utilities *must* buy five energy units per round, or be fined. Energy sources do not, however, need to sell all of their units in any given round.
   - Students must keep records of their purchases and sales.

4. Begin the game. Tell students that each round will last five minutes.

   Run through Round 1 as a sample round. Begin by reading News Flash 1, and then read the production costs to the energy sources (or project them on a transparency). Next, pick one technology and supply advance card randomly and read it out loud. Each technology or supply advance changes prices for the duration of the game. Make sure the energy sources write the numbers down. Give the energy sources time to ask each other what prices they plan to set during the round. This will give them a preliminary sense of what price to offer, although they can change it during the round.

   Announce that the marketplace is open. Energy sources may write their selling prices on a piece of paper to hold up for utility buyers.

   When an energy source has sold all of his or her units, he or she should sit down. Similarly, utilities that have purchased their five units of energy for the round should sit down. Announce to the class when one minute is left in the round. Remind utilities that they will be forced to pay a fine if they do not purchase five units of energy.

   When five minutes are up, announce that the energy marketplace is closed. Give students a few minutes to record their sales, purchases, and profits. Collect production costs from the energy sources.

   After the round, review the directions if problems arose. You may want to run this round again, now that students know what to expect.

5. Run Rounds 2, 3, 4, 5, and 6 like Round 1.

   It is possible that some energy sources or utilities may go bankrupt. You may allow them to solicit each other for loans, or simply sit out for the rest of the game.

6. After the final round, discuss the game with the class. Draw a version of the Class Data Sheet (pg. 55) on the blackboard, and get students to fill in the data themselves. After this is done, you may ask students any or all of the following questions:

   General questions:

   a. What did you like or dislike about this game? Was it "fair"?

   b. How do changes in energy prices affect the average American consumer? Ask students to imagine how they would be affected by price changes.

Questions for utilities:

a. From which energy source(s) did you buy the most units throughout the game? What influenced your decision to buy units from these sources?

b. Do you think that cost should be the only factor in determining where utilities buy their electricity?

c. List three or four factors that seemed to influence the price of energy. Did these factors cause the prices to increase or decrease?

d. Were any sources of energy consistently expensive or consistently cheap? Why do you think the game was set up that way?

e. Are environmental costs figured into the cost of energy in this game? Which energy sources would have the highest environmental costs?

f. Do you think that energy prices in the United States are determined by a free, open, competitive market? In your opinion, should the government encourage renewable energy use through subsidies?

Questions for energy sources:

a. Were you able to sell all of your units of energy each round?

b. What change(s) gave you more units to sell (greater availability)?

c. What factor(s) seemed to influence the utilities to buy from you? How did you try to encourage them to do so?

d. Why did you have to pay a production cost at the end of each round? What does this cost represent? Be as specific as possible. (Answers could include cost of machinery, land, labor, etc.)

e. What factors influenced your production costs?

f. Environmentally speaking, how "clean" was your energy? Were the environmental effects of producing electricity from your energy source included in its cost?

g. Do you think that energy prices in the United States are determined by a free, open, competitive market? In your opinion, should the government encourage renewable energy use through subsidies?

7. You may want to end by reviewing some of the material covered.

One way to wrap up is to have students discuss how this game differs from real life. The following are some of the important points to stress:

a. Energy conservation is not an option in this game. In general, it is cheaper to use energy more efficiently than it is to purchase or produce additional energy.

b. Economic change usually occurs slowly. Change does not always happen with sudden "news flashes." Energy source availability, for instance, usually changes gradually, but unexpected international events or environmental disasters can lead to sudden changes.

Playing It Cool: Student Instructions

UTILITIES:

You will start the game with $350.

You must buy five units of energy each round. If the round ends before you have bought your units, you will have to pay the bank a fine equal to the highest price offered for a unit of energy during the round times the number of units you need.

When each round begins, find out what prices different energy sources are offering. Then buy from as many sources as you wish, but *keep the amount you spend as low as you can.*

Write down on your buyer's card which kinds of energy you bought and how much each cost. At the end of each round, write down how much money you spent.

ENERGY SOURCES:

Make as much money as you can each round, by selling energy units to utilities.

At the beginning of each round, you will be given a production cost. This is how much it costs you to produce one unit of electricity from your source. A technology and supply advance card drawn at the beginning of each round could reduce this cost and increase the available amount of your energy source. Make sure that you write down any changes in cost caused by a technology or supply advance for your energy source.

Since your goal is to make as much money as possible, charge utilities the highest price you can for one unit of energy. But remember, you're competing with other energy sources, so if you charge too much, utilities will buy from other sources.

Before or during each round, you can ask other energy sources how much they plan to charge per energy unit. This will give you a sense of how much you should charge. If you need to, change the price you offer during the round to remain competitive.

Keep track of the number of energy units you sold during a round, and the price you charged for each unit. Write this information down on your energy source selling card at the end of the round. Since some energy resources are limited, *you cannot sell more energy then you have available for each round.* Any unsold units remaining at the end of the round are forfeited.

At the end of each round, you must pay the banker your total production cost. This amount is the production cost per energy unit multiplied by the number of units you sold.

Mark down how much money you have left after you pay the banker.

ENERGY SOURCE DESCRIPTION CARDS

Wind

When wind blows on a wind turbine, its blades turn, powering an electricity generator. Electricity from wind is cheap, and it produces no pollutants. Wind turbine "farms" require large amounts of land, though, and only windy areas can generate electricity economically. Currently, wind generates electricity in large-scale wind-farms as well as in small backyard operations.

Geothermal

Geothermal energy is heat energy stored underground in Earth's crust, in water, rock, or magma. Geothermal energy from water reservoirs is cheap, although there are limited areas where it can be tapped. Other types of geothermal energy are under development.

Solar Thermal

In a solar thermal system, mirrors concentrate sunlight on a liquid, heating it into steam. This steam then turns a generator. Solar thermal energy is not yet widespread, and will probably be practical only in sunny regions.

Hydropower

Hydropower is energy from moving water. In a hydroelectric dam, falling water turns a turbine, creating electricity. Hydropower generates about seven percent of U.S. electricity. Most feasible hydropower sites have already been developed, however. Building large new dams floods extensive areas, causing social and environmental disruption.

Nuclear Fission

When unstable, or radioactive, atoms split, they produce large amounts of heat. Nuclear reactors use this heat to create steam, which then powers electricity generators. Nuclear energy is expensive, though, and can be dangerous. Radioactive leaks can pose problems to public health and safety, and the United States currently has no adequate method of disposing of radioactive waste.

Coal

Burning coal produces heat, which can then boil water and drive a steam turbine. Coal is a nonrenewable resource, but the United States has large reserves of it. Although it is one of the cheapest ways of generating electricity, burning coal produces more air pollution than other energy sources and contributes to global warming.

Photovoltaics

A photovoltaic, or solar, cell converts sunlight directly into electricity, without any polluting by-products. Solar cells are practical for applications that are isolated from major power lines, but they are still expensive for utility-scale use. Technical advances and mass production will help bring their price down in the next decade.

Oil

Burning oil is used to drive a combustion turbine, an engine similar to those used in jet planes. Oil is a nonrenewable resource and is relatively cheap at present. Much of our oil is imported from the Middle East, however, so our supply is vulnerable to conflicts in that region. Burning oil produces carbon dioxide, a heat-trapping gas, and other air pollutants.

Natural Gas

Burning natural gas is used to power a combustion turbine, similar to those used in jet planes. Domestic natural gas supplies are more limited than coal, making them vulnerable to sudden price increases as demand rises. Natural gas produces the least carbon dioxide and other air pollutants of any fossil fuel when it is burned.

Biomass

Biomass is plant matter that can be burned to produce heat and electricity or converted to liquid and gaseous fuels. Biomass can be organic material from trash and other wastes, or it can be grown specially for energy use. The price of biomass varies widely depending on its nature. Burning biomass produces carbon dioxide, a heat-trapping gas, but if the land used to grow biomass is replanted, the new plants remove equal amounts of carbon dioxide from the atmosphere, resulting in no net contribution to global warming.

TECHNOLOGY AND SUPPLY ADVANCE CARDS

(Cut these out, mix them up, and pick one at the beginning of each round)

TECHNOLOGY ADVANCE!

Scientists develop new techniques for producing photovoltaic cells, doubling their efficiency and slashing their production cost in half.

- Photovoltaic production costs are $5 less, and 4 additional units are available.

TECHNOLOGY ADVANCE!

Energy engineers perfect the parabolic trough system, a method of solar thermal electricity generation. Now it can produce electricity at lower cost and with increased efficiency.

- Solar thermal production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

Energy engineers develop new techniques for burning coal. Coal-fired power plants will now burn coal more efficiently and produce fewer pollutants. As a result, electricity generation from coal will cost less.

- Coal production costs are $1 less.

SUPPLY ADVANCE!

Extensive new reserves of natural gas have been discovered in the United States.

- Natural gas production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

A new gas-cooled nuclear reactor is developed. This reactor, when standardized and developed across the country, will provide electricity more cheaply and safely than before.

- Nuclear production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

Geological engineers discover how to harness hot dry rock, a form of geothermal energy.

- 10 more units of geothermal energy are available.

TECHNOLOGY ADVANCE!

The ZP5552 model wind turbine, called “the biggest breakthrough in wind technology since the sailboat,” has hit the markets. This ultra-efficient, low-cost wind turbine will slash wind-generation prices.

- Wind production costs are $3 less, and 10 more units are available.

SUPPLY ADVANCE!

Opening the Alaska National Wildlife Refuge to oil drilling increases U.S. reserves of oil.

- 1 more unit of oil is available.

TECHNOLOGY ADVANCE!

An efficient technology for converting wood to a combustible gas has been developed. This technology should reduce the cost and increase the availability of biomass energy.

- Biomass production costs are $1 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

New, small-scale hydro technologies are developed, resulting in a decrease in cost and increase in availability.

- Hydropower production costs are $1 less, and 2 more units are available.

ROUND 1

BUSINESS AS USUAL .... Business is proceeding as usual in the U.S. energy industry.

The United States uses fossil fuels such as coal, natural gas, and oil for most of its electricity. Nuclear power provides 21 percent of U.S. electricity. Renewable energy provides only 10 percent, mostly from hydropower.

The U.S. government subsidizes the fossil fuel and nuclear power industries. Neither the utilities nor these industries have to pay fully for environmental problems caused by these energy sources.

By contrast, the renewable energy industry is poorly funded by the government. Renewable energy sources are not as well developed as they could be. However, some renewable sources, though not widely used, are already economically competitive with other sources for generating electricity.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	6	50
Oil	8	10
Natural Gas	6	25
Nuclear	10	25

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	9	1
Photovoltaics	25	1
Wind	8	1
Hydropower	6	6
Biomass	5	2
Geothermal	5	2

ROUND 2

NEWS FLASH!!! .... AP – Growing concern over global warming has caused Congress to approve a "carbon tax" that will affect all utilities that burn fossil fuels.

When implemented, this tax will require utilities that burn coal, oil, and natural gas to pay a fee for each ton of carbon dioxide they produce.

This tax will make energy from fossil fuels more expensive and will encourage the development of renewable energy technologies.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	10	10
Natural Gas	7	25
Nuclear	10	25

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	9	2
Photovoltaics	25	2
Wind	8	2
Hydropower	6	7
Biomass	5	3
Geothermal	5	3

ROUND 3

NEWS FLASH!!! .... AP – In an unexpected move, Congress removed research and development (R&D) subsidies for the nuclear power industry.

Over the last few decades, the Department of Energy spent a large portion of its R&D budget on nuclear energy. Over the next decade, the nuclear power R&D budget will be reduced by five percent per year, bringing nuclear research in line with research on renewable energy by 2010.

"We felt that federal funding for nuclear power was excessive in light of the nuclear industry's performance over the past 30 years," said Senate leader Neil O'Tip.

Congress also repealed the Price-Anderson Act, which limits a nuclear plant's liability in case of a nuclear accident. Nuclear plant insurance rates will now skyrocket.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	10	10
Natural Gas	7	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	9	3
Photovoltaics	25	3
Wind	8	3
Hydropower	6	7
Biomass	5	4
Geothermal	5	4

ROUND 4

NEWS FLASH!!! .... AP – In what is perceived as a victory for the renewable energy industry, Congress today passed big new tax credits for renewable energy development.

Power producers that build new renewable energy plants instead of fossil fuel or nuclear plants will receive a large tax break. Congress enacted the tax credits to spur the development of clean, sustainable, renewable energy.

As a result of the tax credits, electricity from renewable sources is expected to become much more available. It should also be less expensive.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	10	10
Natural Gas	7	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	15
Photovoltaics	15	10
Wind	5	15
Hydropower	6	8
Biomass	5	10
Geothermal	5	6

ROUND 5

NEWS FLASH!!! .... AP – Cloudy spell in California enters sixth week; confidence in solar energy plummets.

Thirty-six days of clouds, rain, and fog in most of California have caused utilities in that state to reconsider their heavy investments in solar energy. The freak weather has made electricity from California's solar thermal and photovoltaic power plants virtually unavailable, while increasing the demand for electricity as people spend more time indoors.

California utilities took advantage of renewable energy mix credits passed by Congress several years ago and have been buying solar thermal and photovoltaic units as fast as suppliers could provide them. Approximately 10 percent of California's energy is now provided by solar. Unfortunately, this electricity is available only when the sun is shining, as adequate methods of storage have not yet been perfected.

Concern over the reliability of solar energy has caused utilities to cancel orders for new solar thermal and photovoltaic plants. These cancellations are expected to cause bankruptcies and business failures in the relatively young solar industries.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	15	5
Natural Gas	13	25
Nuclear	20	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	7
Photovoltaics	11	5
Wind	5	15
Hydropower	6	9
Biomass	5	10
Geothermal	5	6

ROUND 6

NEWS FLASH!!! .... AP – Iraq invades Kuwait; oil prices soar.

In a sneak attack, Iraqi troops pushed over the border into Kuwait late last night. Tensions between the two countries over oil-production quotas, which led to a similar conflict in 1991, had been mounting over the past year.

Hostilities between the two countries, which could be lengthy, are expected to impede the flow of oil from the Middle East to the United States. In early trading on international markets today, the price of oil was up $10/barrel.

Skyrocketing oil prices are almost certain to mean an increase in the cost of electricity. Although only three percent of the nation's electricity is generated from oil, a rise in oil prices has historically produced a parallel rise in the price of natural gas. Oil and gas together account for 19 percent of the nation's electricity production.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	15	5
Natural Gas	13	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	15
Photovoltaics	11	10
Wind	5	15
Hydropower	6	9
Biomass	5	10
Geothermal	5	6

UTILITY BUYER'S CARD
(Buy 5 units of energy each round)

		KIND OF ENERGY BOUGHT	COST
ROUND 1	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 2	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 3	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 4	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 5	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 6	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	

ENERGY SOURCE SELLING CARD

____
(name of your energy source here)

	PRODUCTION COST	AMOUNT AVAILABLE TO SELL	AMOUNT SOLD	AMOUNT TO PAY BANKER (production cost x amount sold)	PROFIT (money left)
ROUND 1					
ROUND 2					
ROUND 3					
ROUND 4					
ROUND 5					
ROUND 6					

CLASS DATA SHEET

ENERGY UNITS PURCHASED

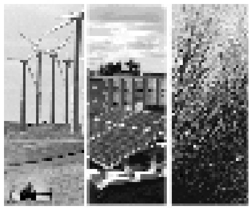
(to be filled in by utilities)

	COAL	OIL	NATURAL GAS	NUCLEAR	SOLAR THERMAL	PHOTOVOLTAICS	WIND	HYDROPOWER	BIOMASS	GEOTHERMAL
ROUND 1										
ROUND 2										
ROUND 3										
ROUND 4										
ROUND 5										
ROUND 6										

ENERGY SOURCE PROFITS

(to be filled in by energy sources)

	COAL	OIL	NATURAL GAS	NUCLEAR	SOLAR THERMAL	PHOTOVOLTAICS	WIND	HYDROPOWER	BIOMASS	GEOTHERMAL
ROUND 1										
ROUND 2										
ROUND 3										
ROUND 4										
ROUND 5										
ROUND 6										



The Government Energy Budget: A Simulation

This simulation encourages students to weigh the relative merits of various energy sources and envision the future of energy use in the United States.

Each year, the Department of Energy (DOE) spends about $4 billion on research and development of future energy supplies. In this simulation, students will decide how this money should be spent. Through this activity, students will:

- understand that no single energy source can supply all of the nation's energy; a variety need government support
- be able to identify some of the advantages and disadvantages of different energy sources
- practice decision-making skills and prepare oral presentations aimed at persuasion
- experience the difficulty of developing fair energy policies that satisfy everyone

GRADES: 9–12

SUBJECTS: social studies, economics, science

TIME: two to three 45-minute class periods

NUMBER OF STUDENTS: 12 or more

PROCEDURE:

A. Setup: one half-period
   1. At least one week before you plan to conduct the simulation, tell the class that they will be participating in a simulation on the future of America's energy policy.

   2. Appoint at least three students to represent the Department of Energy. Tell them that they will determine future government spending on energy. Their decisions will help determine which energy sources will prosper and expand in coming decades.

   3. Appoint one or two students to be advocates for each of the following energy sources. (If you would like the students to work together in larger teams, you can use just a portion of this list.)

      - biomass
      - coal
      - energy conservation and efficiency improvements
      - geothermal

- hydrogen
- hydropower
- natural gas
- nuclear fission
- nuclear fusion
- oil
- solar
- wind

Tell these students that their job is to get the Department of Energy to give as much money as possible to their particular energy source.

4. Explain that the Department of Energy provides money for the research and development of various energy sources. The agency submits a budget to Congress that sets out which energy sources need research money the most and which are most crucial to the nation's future.

   In the past, most of the money has gone for research on nuclear fission, nuclear fusion, and fossil fuels. In the late 1970s and again recently, energy conservation and, to a lesser degree, renewable energy have also received significant amounts, although these sources still receive only a small fraction of the total budget.

   In part to satisfy the various politically powerful energy industries, the DOE budget has been split among a wide range of energy sources. But even if politics were not a factor, this strategy would still make sense, since the United States will need a variety of sources in the future.

   For the purposes of this simulation, the Department of Energy will have 100 energy dollars to split among the various energy sources.

5. Give the students who will be the advocates for the various energy sources a homework assignment. They will have to prepare a three- to five-minute presentation asking the Department of Energy for money. In order to make their presentation, they need to find out as much as they can about their energy source. In particular, they should find out the following:

   - what its advantages are (possibilities include current low cost, potential future low cost, safety, low environmental impact, plentiful supply, availability within the United States, flexibility in terms of where and how it can be used)
   - what its disadvantages are (possibilities include high cost, safety concerns, environmental problems, limited supply, reliance on foreign suppliers, only works in certain places or for limited uses)
   - what its current state is (how widely it is used, what it is used for)
   - why it needs government research and development money (to develop cheaper or more efficient technologies for using it, to find new uses for it, to find ways to reduce its environmental impact)

   With this information in mind, the students should prepare a presentation that will persuade the Department of Energy to give them a large share of the department's $100. Their presentation should include:

   - why their energy source needs government support
   - why their energy source is important to America's future
   - why the use of their energy source should be expanded

B. The simulation: one to two periods (depends on how many of the 12 energy sources are used)

1. Have the students who represent the Department of Energy sit in the front of the class.

2. Explain that each of the energy advocates (or teams of energy advocates) will have an opportunity to present the case for their energy source.

3. Have each energy advocate or team make a three- to five-minute oral presentation to try to persuade the Department of Energy representatives to support their energy source.

4. After each presentation, the DOE representatives should be allowed to question the energy advocates. The DOE representatives should especially try to find out each energy source's disadvantages. The energy advocates should respond to all questions truthfully, but should nevertheless try to place their energy source in the best possible light. They should not volunteer negative information about their energy source.

5. After all the energy advocates have made their presentations, give the DOE representatives an assignment (either for homework or class time). Tell them they have to prepare a $100 budget. They can divide this money any way they choose among as many energy sources as they would like to fund. They should meet as a group to make their decisions. Tell them that they will have to justify their decisions and explain them to the class.

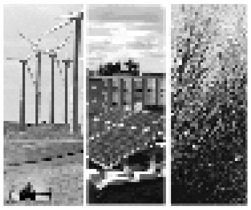
C. The Department of Energy's decisions: one half-period

1. In another class period, after the DOE representatives have had a chance to meet and prepare their presentation, ask them to present their budget to the class. Remind them that they need to explain why they decided to give different energy sources their recommended amounts of money.

2. In follow-up discussions, other students can comment on whether they agree with the DOE's budget recommendations.

D. Optional follow-up activities

- As a class, students can develop a list of the advantages and disadvantages of all the energy sources.
- Write letters to your congressional representatives and to the Department of Energy explaining the class's budget recommendations. Ask for their reactions.



Coal Comes to Anytown: A Public Meeting

In this activity, students will participate in a mock public meeting to determine a site for a new energy facility in their community. The occasion for the meeting is public concern over a power company's proposal to build a coal-fired generating plant near your town.

This activity will help students:

- understand that all electricity-generating facilities have both positive and negative impacts on the communities in which they are located
- experience the difficulty of finding an energy source that meets the needs and demands of different interests in a community
- gain an appreciation of the importance of citizen participation in energy decision making
- practice decision-making skills and prepare oral presentations aimed at persuasion

The announcement of a location for a new energy facility often creates a public uproar in the community where the facility is to be built. Citizens who may have been previously uninterested in energy issues or the environment suddenly become concerned with air pollution, visual pollution, noise, land use, the health and safety risks of the proposed energy source, carbon dioxide emissions, and global warming.

Often, citizens form committees to stop proposed energy facilities from being built. Some community members may express a not-in-my-backyard, or "NIMBY," attitude. They do not care what energy source is used, as long as it is built somewhere else, far away from their own neighborhood. Public opposition is most common with large fossil fuel and nuclear generating plants, but it is important to remember that there are also site-related issues associated with hydro, solar, wind, geothermal, and biomass power sources. Citizen groups working to stop these renewable energy facilities may become increasingly common as these sources of energy are developed.

It is important that citizens who are concerned about the environment realize that it is unrealistic to demand an impact-free power source. Unless people are willing to stop using electric power entirely, communities must be willing to accept electricity-generating plants in their area. At the same time, politicians and energy regulators must take responsibility for choosing the best technology or site for a new power plant, instead of assuming any will do. They must also consider seriously the possibility of conserving energy as an alternative to new energy supplies, as energy efficiency measures may make construction of a new plant unnecessary.

GRADES: 9–12

SUBJECTS: social studies, environmental studies, geography, science

TIME: three to four 45-minute class periods (one for the introduction and two to three for the hearing, plus one to two weeks for independent research)

STUDENTS NEEDED: 15 or more

MATERIALS:
- large map of your county
- one role card for each student—you can write these on index cards
- Renewables for the Nation handout for each student (pg. 64)
- Energy Source Information handout for each student (pg. 65)

PREPARATION:

1. Prepare one role card for each student (see the teacher information sheet on pg. 63).
2. Photocopy Renewables for the Nation and Energy Source Information handouts.
3. Using the map, site a new coal plant in your county. It should be located as close as possible to your town, keeping in mind that it must be next to a source of water for cooling and near a port or rail line to receive the coal.

PROBLEM STATEMENT:

The president of the United States has announced a new energy independence program. Her/his goal is to have each county in the nation produce 20 percent of the electric power it uses within its own borders. In order to meet this goal, a power company is proposing to build a new 100-megawatt coal-fired power plant in your county.

This plan has evoked strong feelings in the county. Citizens have quickly taken sides on the issue. In order to make a decision that best reflects the interests of the community, county officials have scheduled a public meeting on the plan. They have invited representatives of different energy sources, including coal, to testify before the county council.

The county council has three options: it can recommend that the power company's plan be approved; it can propose a different site for the coal plant; or it can suggest sites for alternative sources of energy. After hearing testimony from a variety of energy advocates, the council will discuss and deliberate the merits of each energy proposal and attempt to come to a consensus.

Note: If you are located in a densely populated urban area, it might be impossible to site a power facility in your county. In this event, you can expand the area to a 50-mile radius, keeping in mind that the objective of the activity is for students to come to terms with the environmental impact of a project in their area. Conversely, if your county is very large, you may want to limit the area to your town, so that students will not be tempted to site energy facilities at a great distance from where they live.

PROCEDURE:

1. Read or distribute the problem statement to the students. Show them where the power company plans to site the coal plant on the county map.

2. Explain to students that they will be role-playing members of the county council or energy advocates in a mock public meeting. Distribute one role card and the student handouts to each student.

3. Explain to students that energy advocates are responsible for promoting their source of energy. Possible advantages of their energy source for the county can include low environmental impact, low immediate cost to consumers, low long-term cost to the public, and jobs created in construction, operation, and maintenance of the energy facility.

County council representatives are responsible for representing their constituencies. They should consider the advantages of each technology, as well as the possible negative impact of any proposed facility on the people they represent, including loss of land, pollution of air and water, possible health risks, and a possible rise in electric rates.

4. Let students who are advocating the same sources of energy or representing the same interests meet to come up with a research plan.

5. Schedule a date for the county hearing. Give students at least a week to prepare. Students who are representing the same energy source or constituency should work together.

   Energy advocates should research their sources of energy and come up with a specific plan for an electricity-generating facility. Each advocate or team of advocates should prepare a five-minute presentation for the council.

   County council members should research the attitudes of their constituencies. One way to do this is to have them actually speak to a sample of people in the community about their attitudes toward different energy sources. They should also draw up a list of questions to ask the energy advocates.

6. On the day before the hearing, distribute a schedule. Each advocate or team will be allowed five minutes to make a presentation. After each presentation, there will be a five-minute question period for committee members.

7. Hold hearings. This may take two to three class periods, depending on the size of your class.

   You, the teacher, will preside over the hearings as county energy commissioner. At the end of the presentations, the committee will retire for one class period to discuss the options. Energy advocates can use this time to prepare a written siting proposal.

8. Have the committee choose a spokesperson to announce its decision. Each member can explain his or her reasons for coming to this conclusion. Discuss the implications of the committee's recommendation for the county. Which groups are likely to support the plan? Which might oppose it?

9. It is possible that the committee will be unable to reach a consensus. In this case, discuss what might happen then in a real community. Possible outcomes could include:

   - The project is delayed, leading to increased cost and possible power shortages.
   - The power company's plan is adopted by default.
   - One faction in the council mobilizes a powerful constituency and lobbies higher authorities to accept its plan.
   - The county energy commissioner overrides the committee's authority.
   - State authorities intervene to speed up the process.
   - The federal government sues the state or county for failing to comply with the law.
   - The issue is placed on the ballot.

   Discuss how each interest group and the community at large might be affected by these outcomes.

VARIATIONS:

1. Let energy advocates lobby committee members in advance of the hearing. They could also post advertisements for their energy sources in the classroom.

2. Invite other classes or parents to attend the hearing. These outsiders would represent the general public in the county. Assign two students to be reporters for a local newspaper. Have the reporters interview energy advocates and committee members and write a series of articles on the power company's plan and some alternatives. Distribute these articles to other classes or parents in advance of the hearing to give them some background. At the end of the hearing, ask the audience to vote on the plan and alternatives. The committee can then use the results of the vote in making their decision.

EXTENSIONS:

1. Discuss how energy decisions are made in your area. Are there any avenues for citizen participation? Your state public utility commission or department of energy should have such information.

2. Find out how your local electric utility plans to meet demand over the next 25 years. Do they expect to purchase electricity from new generating facilities? Have students write to members of the utility's board of directors with their recommendations for the future.

Note: *Maps depicting state renewable energy potential are periodically updated. To obtain up-to-date maps, please visit the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy at www.eere.energy.gov.*

Coal Comes to Anytown: Preparing Roles for the Public Meeting

The following are possible student roles for the public meeting:

County council members

- Two businesspeople: factory owner, computer distributor, department store manager, etc.
- Two environmentalists: environmental club member, park ranger, etc.
- Two consumer group members
- Two labor people: construction worker, coal miner, technician, farmer, etc.
- One tourism person: hotel manager, restaurant owner, etc.
- One health person: doctor, nurse, health insurance agent, etc.

Energy advocates

- Two coal
- Two nuclear
- Two oil
- Two natural gas
- Two waste-to-energy
- Two biomass
- Two wind
- Two solar thermal
- Two solar electric
- Two geothermal (if applicable in your area)
- Two hydro (if applicable in your area)

For variation #2:

- Two reporters

You should make council member roles as specific to your community as possible. For instance, if you live in an area with large coal deposits or timber resources, you may want one of the students representing labor interests to be a coal miner or logger. If you live in a community with a national or state park, one of your environmentalists could be a park ranger.

To prepare the energy advocate cards, refer to the Renewables for the Nation and Energy Source Information handouts to determine which energy sources would be feasible in your region. If hydro, solar, geothermal, or wind resources are not present in your area, do not use these cards.

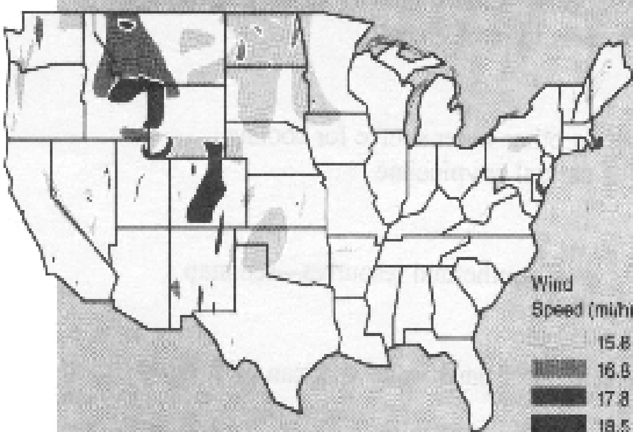
Prepare as many role cards as there are students.

Renewables for the Nation

The potential of renewable energy has often been seen as tightly restricted to the few sites that offer the very best resources. Today individual renewable options still tend to be regionally defined, but technology advances will expand practical applications into medium-grade resource areas—and to far more of the country than was thought possible a decade ago.

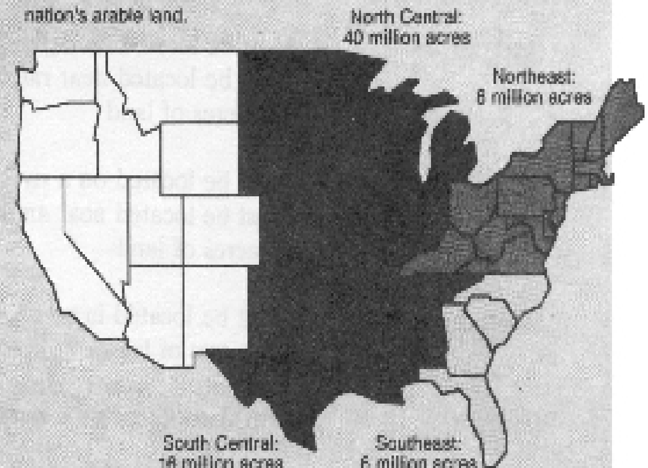
Wind

The midwestern states extending from North Dakota and Montana down to New Mexico have much greater wind generation potential than the few California sites developed to date. The ability to back up a good intermittent wind resource with plentiful hydro makes the Northwest look promising as well.



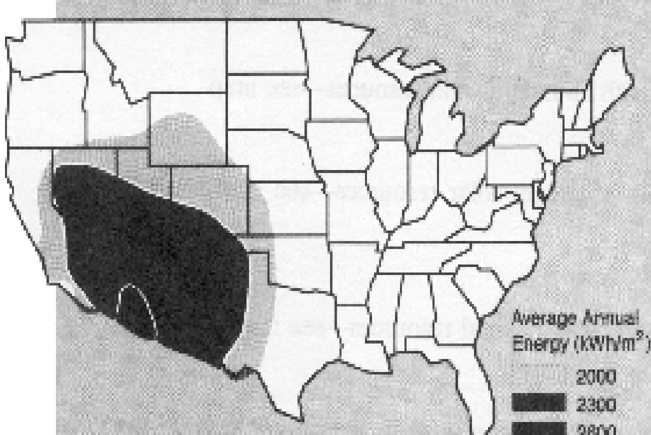
Biomass

The Midwest is ideal for growing short-rotation woody crops and other combustible vegetation, which could be planted on land that is idle or has only marginal value for growing food. The total U.S. energy crop potential is some 70 million acres—almost 18% of the nation's arable land.



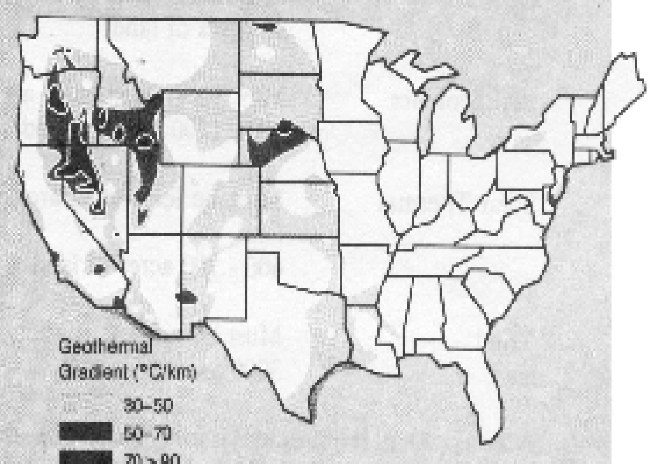
Solar

The desert regions of the United States hold the obvious first opportunities for significant penetration of solar technologies, although photovoltaics can be economic for remote low-power applications in virtually all parts of the country.



Geothermal

While most of the land west of the Missouri River is underlain by hydrothermal or hot dry rock resources, geothermal development for the foreseeable future will concentrate on pockets with thermal gradients of at least 70°C/km.



Credit: Electric Power Research Institute

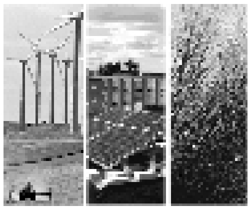
Energy Source Information Sheet

STUDENT HANDOUT

Energy Source	**Site Requirements**
Biomass	Must be located on a river, lake, or other water source for cooling Must be located near a source of biomass (plants, trees, organic municipal waste)—see map 100–200 acres of land (although the amount of land needed to supply fuel for the plant would be much greater)
Coal	Must be located on a river, lake, or other water source for steam and cooling Must be located near rail line or port to receive coal 300 acres of land (although the amount of land required to extract, process, and deliver the fuel would be much greater)
Natural Gas	Must be located on a river, lake, or other water source for cooling Must be located near an existing natural gas pipeline 30 acres of land (although the amount of land required to extract, process, and deliver the fuel would be much greater)
Geothermal	Must be located in an area with good geothermal resources—see map 50–300 acres of land
Hydro	Must be located on a river, downstream from a valley that can be flooded
Nuclear	Must be located on a river, lake, or other water source for steam and cooling Must be located on a site where there is little danger of earthquakes Must be located in an area that would be possible to evacuate 1,000 acres of land (This is for a 1,000-megawatt plant. Small nuclear power plants are not generally available.)
Oil	Must be located on a river, lake, or other water source for cooling 30 acres of land (although the amount of land required to extract, process, and deliver the fuel would be much greater)
Photovoltaics	Must be located in an area with abundant solar resources—see map 900–1,200 acres of land (although PV arrays could be placed on the rooftops of existing structures)
Solar Thermal	Must be located in area with abundant solar resources—see map 300–500 acres of land
Wind	Must be located in area with abundant wind resources—see map 1,100–4,000 acres of land depending on the size of the turbines (The actual footprint of the turbines and access roads is much smaller, allowing for farming, grazing, or other land uses in the remaining area.)

Note: Land requirements are for a 100-megawatt plant and are extrapolations from 1997 data from the Electric Power Research Institute, the Department of Energy (DOE, 1983), and the American Wind Energy Association (2002), which referred to many generating facilities of different sizes. Therefore, the numbers listed on this sheet may not be accurate.

Suggested Additional Activities and Lessons



Suggested Additional Activities and Lessons

SCIENCE AND TECHNOLOGY

Have your class investigate renewable technologies. Divide the class into groups and have each group read about and explain to the class the scientific principles and technology underlying the following renewables:

- solar thermal energy for heating homes and water, daylighting for buildings
- solar thermal electricity generation
- photovoltaic cells
- wind energy
- biomass for electricity generation, heat, and transportation fuels
- hydropower
- geothermal energy

Organize a science fair based on renewables. Have students create science projects demonstrating the technology of renewables.

The sun is the origin of most of the energy on Earth. Trace renewable energy sources back to their solar origins.

Build a model solar car, or build several and hold a race.

Build passive solar devices such as a model solar greenhouse or solar food dryer. Where are these devices in use today?

Build a model parabolic dish collector. Describe its operation and show where these technologies are currently in use.

Research photovoltaic efficiency. Find out what current PV research is being done and how it is improving PV efficiency.

Bring in a PV cell and measure how much energy it produces with a voltmeter. Have students calculate on a worksheet how much area would have to be covered with such cells to produce 25 kWh/day (the average power use of a home). Speculate how increased efficiency might increase that output.

Discuss the pros and cons of large-scale biomass production. Ask different students to research one advantage or disadvantage of biofuel production. Have a debate as to whether a large portion of U.S. land should be turned over to biofuel production.

Research hydropower technology. What are the differences between large-scale and small-scale hydropower? Find out where the largest dams and hydroelectric developments in the United States are. What are the social and environmental disadvantages of hydropower? How do these weigh against the advantages?

Have students design, build, and test a model waterwheel.

Research which biofuels can be used for transportation. Where are they in use today? What has their success been?

Discuss how geothermal energy can be extracted and put to use. Show on a map the places where geothermal energy is currently used. Have students build a cutaway model of Earth, showing how geothermal energy is extracted.

Study how power can be harnessed through the sea:

- Research, discuss, or develop a model of an OTEC (ocean thermal energy conversion) floating power plant.
- Research, discuss, or develop a model of a tidal power plant.
- Research what is being done in wave-to-energy generation.

Discuss energy storage. Investigate methods of storing solar and wind energy. Build a model battery.

SOCIAL STUDIES, ECONOMICS, HISTORY, GEOGRAPHY

Discuss the possible socioeconomic effects of a large-scale transition to renewables. Devise a simulation in which different students represent different members of the community: fossil-fuel power plant worker, a townsperson, a utility company, etc. Have each student imagine what a transition to renewables would be like from his or her perspective. Debate whether a renewable energy generating plant should be built in your hometown.

Have students research how much renewable energy would have to be developed to meet half of our energy needs by the year 2030, without great increases in energy efficiency. Then have students research how much renewable energy would have to be developed if energy efficiency kept energy consumption constant. Compare the two results and discuss the need to couple conservation measures with renewable energy technology.

Research the cost of electricity generation from renewables and nuclear power. Compare the two. Compare the advantages and disadvantages of renewable energy versus nuclear power. Have students debate the merits of renewable energy versus nuclear power.

Have students research energy use in different countries around the world. Which countries use the most renewable energy? Which use the most in proportion to their total energy use? What types of renewable energy are most widely used? How does the type of energy used in a country affect people's lifestyles?

Study energy use at 50-year intervals in U.S. history, beginning with the colonial period. What kinds of energy were used during each period? What caused changes in the types of energy being used? How did changes in the types of energy used change the economy and society of the United States? Have students write a story about what their life might have been like during each of these periods, incorporating the types of energy they would have used to cook food, get to school, do chores, entertain themselves, etc.

Research historical uses of wind, solar, and water power. Collect historical photos and create a display on the history of these technologies.

Study the availability of different types of renewable resources—solar, wind, hydropower, geothermal, and biomass—in different regions of the United States. You can use the maps provided in the "Coal Comes to Anytown" activity (pg. 64) as a resource. Have students determine which type(s) of renewable energy might be most feasible in each region of the country. Find out which regions or states currently use the most renewable energy and which use the least.

Have students draw a "futures wheel" for a transition to specific renewable energy sources in the United States. A futures wheel is a teaching tool designed to help students sort out what might happen if a particular event were to occur. To prepare the wheel, a single topic or event is placed at the center. Off this "hub," students place events or actions that might result from this central idea. These secondary actions in turn trigger tertiary actions and the wheel keeps expanding. For example, a shift to greater use of biomass for auto fuels could produce the following effects (draw your own diagram):

- more land for energy crops—more money and jobs for farmers and workers in farm-related industries—less unemployment—less migration from Farm Belt states
- less land for food crops—less food to export—more world hunger
- increased use of fertilizers and pesticides on land—water contamination and erosion increase
- less demand for gasoline—lower gas prices
- more factories for fuel production—more jobs—less unemployment
- auto fuels pollute less —less money spent on pollution abatement—less air pollution—health improves—less money spent on health care

Discuss how likely or unlikely these scenarios are.

LOCAL PROJECTS

Organize a class visit to a local renewable energy site, such as a hydropower plant, a wind turbine, or a solar-powered house.

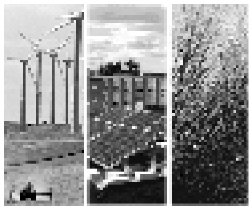
Call up your local utility and see if any of the electricity they purchase is generated by renewable sources. If so, which sources, and what percentage of their total electricity is generated by renewables? If not, what factors led to their decision not to use renewables? Discuss the economics and practicalities involved in a transition to renewable energy sources.

Discuss which renewable sources could be harnessed in your area. Have students look at maps of your area; let them suggest where renewable energy sources might be best sited.

ENGLISH

Have students read and report on science fiction stories that describe new or future energy sources. Alternatively, have students write their own stories that envision a sustainable energy future.

Action Projects



Action Projects

Why action?

Many students are no longer content with simply learning about environmental problems and proposed solutions in their classes. They want to know what they can do to make a difference.

As a supplement to your unit on renewable energy, you may want to provide your students with ideas for actions they can take to accelerate the development of renewable energy in your state and in the nation as a whole. These actions could be primarily educational, such as setting up a display on renewable energy in the school library, or they could include a political component such as sponsoring a letter-writing campaign to the governor, state legislators, or members of Congress. You may find that working on an action project to "save the earth" motivates your students to learn more about renewable energy than working on a research paper for a grade.

What kind of action?

The activities we recommend are generally aimed at increasing awareness and use of large-scale applications of renewable energy. While small-scale projects such as building a solar greenhouse or buying a small windmill are good for demonstrating the principles behind renewable energy, these projects are unlikely to persuade the general public or energy decision makers that renewables are ready to provide a significant portion of our nation's energy. Because large projects take time, you will need to remind your students that their work is important, even if they do not see results right away.

How should you start?

If you or your students are interested in developing an action program on renewables, it is important to choose and carry out activities appropriate to the current state of renewable energy in your community. Have your students ask the state energy office about state and local energy regulations. The students can contact local electric utilities to inquire about present and planned use of renewables in the area. Your state department of transportation should know about any plans for using alternative fuels. This information will give you and your students a sense of what action needs to be taken to make renewables a reality in your community.

Suggested actions

A list of possible projects for your students follows. You can help them review the list and decide what activities interest them.

Educational Action Projects

Public opinion is an important force shaping energy policy in the United States. If public expectations of renewable energy technologies are raised, improved policies will follow.

Educational Displays

- Organize a renewable energy fair at your school. Invite manufacturers and retailers of renewable products and utilities to present displays. Advertise the fair in your local newspaper and invite reporters to come.
- Sponsor a public tour of a local solar-powered building or other renewable energy facility.
- Ask your school librarian to set up a display of books on renewable energy.

Written and Spoken Word

- Have students write a series of articles on renewables for your school paper.
- Have students communicate with other students and organizations around the country through electronic computer networks.
- Set up an informational table on renewables in your school cafeteria or at a local mall on a weekend.
- Conduct a poll of student and community attitudes toward renewable energy. Have a local paper publish the results.
- Hold a student debate on renewable versus nonrenewable energy futures.
- Invite a speaker to address the school or a parents' group.
- Have your students teach a lesson on renewables to an elementary school class.

Contests

- Organize a renewable energy science fair.
- Sponsor a design contest for posters or t-shirts. Display the entries in the library.
- Hold a contest to design and build a model solar car.

Miscellaneous

- Organize a fundraising event, such as a solar cookout, raffle of a photovoltaic panel, renewable energy film screening, or theme dance or concert. Use the money you raise to buy books on renewables or a photovoltaic panel for the school. Alternatively, you could raise money to purchase a solar panel or solar cookers to send to a developing country. Students could then correspond with teenagers in the village where their panel or cookers were sent. Solar Cookers International (see pg. 88) can provide information on this type of project.

Sample Action Programs

Here are two sample action programs on renewables. You should choose projects from the list above that most interest your students when designing your own action program.

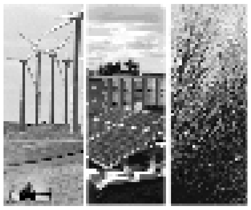
School Program

Event	Audience
1. poster exhibit display in library	whole school
2. table in cafeteria with information	whole school
3. renewable energy science contest	science classes
4. poster/t-shirt design contest	whole school
5. article in school newspaper	whole school
6. debate on renewables	social studies classes

School/Community Program

Event	Audience
1. poster exhibit display at town library, opening with speaker	general public
2. community poll on renewables	general public
3. renewable energy fair at school with fundraiser	students, parents, businesses, general public
4. information table at local mall	general public

Glossary



Glossary

Active solar system. A system that collects solar energy through mechanical means, usually including collectors, pumps, and fans. An example is a solar hot water heater, where water is pumped to a rooftop solar collector for heating. See also *passive solar system.*

Baseload power. Electricity supplied on a continuous, 24-hour basis. See also *peaking power.*

Battery. A device for storing electrical energy as chemical energy. When an electrical load is attached to a battery, the chemicals inside the battery react, creating an electrical current.

Biofuels. Fuels created by the chemical, biological, or thermal treatment of biomass.

Biomass. Organic material from plants. Biomass can be burned to produce heat energy or can be converted into liquid and gaseous biofuels.

Efficiency. The fraction of energy consumed by a device that goes to produce useful heat and work. Efficiency is expressed as a percentage: a car engine is 12 percent efficient if 12 percent of the chemical energy in its gasoline is converted into the mechanical energy of its wheels.

Electricity. The flow of electrons through a conducting material, such as metal wire. An electron is one of the particles that make up an atom.

Energy. The capacity to do work. Energy can come in many forms. Kinetic energy is the energy of a moving object. Chemical energy is the energy stored in fuels.

Ethanol. A fuel produced by fermenting grains such as corn or wheat. Recently developed biochemical processes can also produce ethanol from wood and other plants.

Fossil fuels. Fuels, such as coal, oil, and natural gas, that are derived from accumulations of plant and animal life over the ages. Fossil fuels are a depletable, or nonrenewable, resource.

Fuel. Any liquid, gas, or solid that can be burned to produce heat or electricity.

Fuel cell. A device that turns the chemical energy of hydrogen-rich fuels directly into electricity—without combustion—in a manner reminiscent of batteries.

Generating capacity. The maximum rate at which a power plant can generate electricity, expressed in kilowatts or megawatts.

Geothermal energy. Heat stored in Earth's crust. Geothermal energy is not strictly "renewable," since heat reservoirs accessible from Earth's surface can be depleted. However, the resource is extremely large. Different kinds of geothermal energy that can be tapped are:

> *Geopressured resources.* Pockets of water and methane under extremely high pressure, usually located in conjunction with oil and gas.
>
> *Hot dry rock.* Heat stored by rocks deep in Earth's crust.
>
> *Hydrothermal energy.* Hot water or steam trapped in reservoirs relatively close to the surface.

Hydrogen fuel. Hydrogen gas, which burns cleanly to produce water vapor. Hydrogen can be produced from coal, natural gas, and biomass, or by passing a strong electric current through water. It may be an ideal fuel for future vehicles.

Hydropower. Energy harnessed from flowing water. In some hydroelectric facilities, water is collected behind a dam and then used to turn a turbine, generating electricity.

Kilowatt (kW). A unit of power equal to 1,000 watts. One kilowatt would run 10 100-watt light bulbs.

Kilowatt-hour (kWh). The amount of energy expended by using one kilowatt for one hour. The United States consumed 3.4 trillion kilowatt-hours in 2001.

Least-cost planning. A principle increasingly being applied by electric utilities, in which investments in energy efficiency or energy supply are decided on the basis of the lowest costs that would have to be passed on to consumers. Least-cost planning is a key element in promoting greater efficiency of energy use.

Level playing field. A state of competition between energy sources in which all costs, including environmental and social costs, are considered equally. Also, on a level playing field, the government gives balanced support to all energy sources.

Megawatt (MW). A unit of power equal to 1,000 kilowatts. An average coal-fired power plant produces around 500 MW of electricity.

Methane. A gas produced from the decomposition of biomass. Methane can be burned to produce heat or electricity. It is also the main component of natural gas, a fossil fuel.

Methanol. An alcohol fuel created by thermochemical treatment of coal or biomass, or conversion of natural gas.

OTEC (Ocean thermal energy conversion). A method of electricity generation that uses the temperature difference between warmer, surface ocean waters and deeper, cooler waters to drive a turbine. OTEC is still in the early stages of development.

Passive solar system. A system of heating that captures solar energy without the use of collectors, pumps, and other devices. An example is a house that has large, south-facing windows. See also *active solar system.*

Peaking power. Electricity supplied during times of peak demand. Peaking power is more expensive than baseload power, since peaking plants do not run all the time and generally use more expensive fuels than baseload plants. See also *baseload power.*

Photovoltaic (PV). Ability to convert light energy directly into electricity. See also *solar cell.*

Power. The rate at which energy is consumed or generated.

Public utility commission or *public service commission.* A state agency that oversees utility rates and regulations.

Renewable energy. Energy that is constantly renewed by natural processes. Renewable energy sources such as solar, wind, and hydropower are inexhaustible.

Solar cell. A device for converting sunlight directly into electricity. When light strikes the two ultrathin layers of a solar cell, electrons migrate from one layer to the other, creating an electric current. Also called a photovoltaic cell.

Solar energy. Energy that comes from sunlight.

Solar panel or *module.* A large, flat panel covered with solar cells.

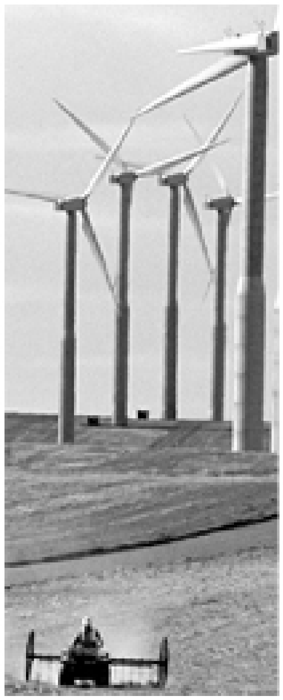
Solar thermal system. A device that collects solar energy in the form of heat and uses it for heating or generating electricity. In solar thermal electric plants, water is heated to the boiling point and then used to drive a turbine. Types of solar thermal collectors include:

> *Central receiver.* In a central receiver system, sunlight is reflected onto a tall tower by mirrors on the ground.
>
> *Parabolic dish.* A dish-like mirror concentrates sunlight into a point. Dishes achieve higher temperatures than troughs.
>
> *Parabolic trough.* A curved, trough-like mirror concentrates sunlight onto a long pipe filled with oil or water.

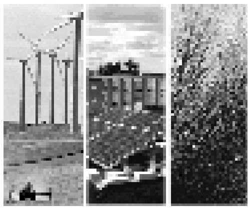
Turbine. A bladed machine that turns when air, water, or steam passes through it, generating electricity.

Utility. A company that supplies electricity to consumers. In some states, utilities operate as regulated monopolies. In this case, a utility can own its own power plants and/or buy electricity from other utilities or independent power producers. In states with deregulated electricity markets, utilities act only as electricity providers. They purchase electricity from power producers and supply it to their customers. Public utilities are owned by a public body, such as a municipality. Investor-owned utilities are owned by private investors.

Wind power. Energy harnessed from the wind.

Resources Guide



Resources Guide

CURRICULUM AND ACTIVITY RESOURCES

The following organizations offer print and audiovisual materials focusing on aspects of renewable energy or providing a rationale for expanding the use of renewables. The views expressed in these materials do not necessarily reflect the views of the Union of Concerned Scientists.

Bullfrog Films. P.O. Box 149, Olney, PA 19547; (800) 543-FROG; email: ***video@bullfrogfilms.com;*** **Web:** ***www.bullfrogfilms.com.*** Bullfrog Films is the oldest and largest producer of environmental films in the United States. There are many videos covering energy issues, including passive solar homes, the environmental impact of energy development, and energy conservation.

Geothermal Education Office. 664 Hilary Drive, Tiburon, CA 94920; (800) 866-4GEO; email: ***geo@marin.org;*** **Web:** ***geothermal.marin.org.*** The Geothermal Education Office (GEO) produces and distributes educational materials about geothermal energy to schools, energy/environmental educators, libraries, industry, and the public. GEO has geothermal energy videos as well as a curriculum guide and free printed materials for students and teachers.

National Energy Foundation. 3676 California Ave., Suite A117, Salt Lake City, UT 84104; (801) 908-5800; email: ***info@nef1.org;*** **Web:** ***www.nef1.org/educators.html.*** The National Energy Foundation (NEF) develops educational resources for education relating primarily to energy, water, natural resources, science and math, technology, conservation, and the environment. NEF offers a comprehensive "Energy, Technology, and Society" kit that encourages students to investigate energy concepts, technologies, and social issues through the focus of renewable energy. The curriculum is interdisciplinary and can be used in science, social studies, environmental studies, and industrial arts classes.

Pitsco, Inc. P.O. Box 1708, Pittsburgh, KS 66762; (800) 835-0686; email: ***orders@pitsco.com;*** **Web:** ***www.shop-pitsco.com.*** Pitsco provides teachers and schools with hands-on, technology-based materials related to alternative energy, including videos, teaching guides, and kits for students to build their own renewable energy generators.

University of California, Berkeley, Great Explorations in Math and Science (GEMS). Lawrence Hall of Science #5200, Berkeley, CA 94720; (510) 642-7771; email: ***gems@uclink.berkeley.edu;*** **Web:** ***www.lhsgems.org/gems.html.*** GEMS publishes teacher's guides and materials for inquiry-based science and mathematics education. Teacher guides are clearly organized and easy to use, and include an overview, materials list, and preparation requirements followed by clear, step-by-step directions.

The Video Project. P.O. Box 411376, San Francisco, CA 94141; (800) 4PLANET; email: ***video@videoproject.net;*** **Web:** ***www.videoproject.net.*** The Video Project creates award-winning educational videos on the environment, science, and social studies. Its collection of energy videos cover oil dependence, renewable energy technologies, and alternatives to fossil fuels.

ORGANIZATIONS

Private and Nonprofit Organizations

American Solar Energy Society (ASES). 2400 Central Avenue, Suite G-1, Boulder, CO 80301; (303) 443-3130; email: *ases@ases.org;* Web: *www.ases.org.* ASES is the national society for professionals and citizens involved with solar energy. It provides forums for the exchange of information on solar energy applications and research, publishes and disseminates the bimonthly magazine *Solar Today*, and promotes education in fields related to solar energy. It has regional chapters throughout the country. Publications list is available on the Web.

National Energy Education Development Project (NEED). 8408 Kao Circle, Manassas, VA 20110; (703) 257-1117; email: *info@need.org;* Web: *www.need.org.* NEED provides materials on all major energy sources to K–12 teachers, conducts an annual awards program to recognize achievements in energy education, and provides training for students and teachers. A magazine, *Energy Exchange*, is published three times a year and is free to schools. NEED is supported through state and federal grants, corporate contributions, and the sale of program materials.

Public Citizen. 1600 20th St. NW, Washington, DC 20009; (202) 588-1000; Web: *www.citizen.org.* Public Citizen is a nonprofit research and advocacy organization founded by Ralph Nader to address environmental and consumer issues. Its Critical Mass Energy Project has produced reports on renewable energy, energy efficiency, and nuclear power.

Solar Cookers International (SCI). 1919 21st St., Suite 101, Sacramento, CA 95814; (916) 455-4499; email: *info@solarcookers.org;* Web: *solarcooking.org/sci.htm.* SCI provides educational materials and training about solar box cookers and works with organizations around the world to promote their distribution.

Student Environmental Action Coalition (SEAC). P.O. Box 31909, Philadelphia, PA 19104-0609; (215) 222-4711; email: *seac@seac.org;* Web: *www.seac.org.* SEAC is a grassroots democratic network of high school and college students with hundreds of chapters in the United States and Canada. SEAC is an activist organization that works on environmental and social justice issues. SEAC has regional offices and chapters all over the country.

World Resources Institute (WRI). 10 G St. NE, Suite 800, Washington, DC 20002; (202) 729-7600; email: *front@wri.org*; Web: *www.wri.org.* WRI helps governments, environmental and development organizations, and the private sector address concerns about the relationships between natural resource destruction, poverty, and hunger in developing countries, and economic development in both developing and industrialized countries. WRI produces *World Resources: A Guide to the Global Environment*, an annual report on the state of the environment, and an accompanying teacher's guide.

Worldwatch Institute. 1776 Massachusetts Avenue NW, Washington, DC 20036; (202) 452-1999; email: *worldwatch@worldwatch.org;* Web: *www.worldwatch.org.* The Worldwatch Institute informs policy makers and the general public about the interdependence of world economics and environmental support systems. They produce publications about renewables, sustainable development, cropland scarcity, and population growth, as well as *State of the World*, a yearly overview of the global environmental situation.

Government Agencies

Department of Energy Efficiency and Renewable Energy (EERE). U.S. Department of Energy, Mail Stop EE-1, Washington, DC 20585; (202) 586-9220; email: *eeremailbox@ee.doe.gov*; Web: *www.eere.energy.gov.* EERE is a comprehensive resource for the U.S. Department of Energy's renewable energy and energy efficiency information. EERE provides educational materials and training for teachers who want to design science and energy curricula. The website contains a library of 80,000 documents and 600 energy-related links.

Energy Information Administration. EI 30, 1000 Independence Ave. SW, Washington, DC 20585; (202) 586-8800; email: *infoctr@eia.doe.gov;* Web: *www.eia.doe.gov.* The EIA is a statistical agency within the U.S. Department of Energy that seeks to provide energy data and analysis to better inform government, business, and the general public. Its *Annual Energy Outlook* is an excellent resource on the current U.S. energy situation and a forecast for the future. Information on specific geographic areas, fuel sources, and sectors is also available. The EIA's "Energy Education Resources: Kindergarten Through 12th Grade" provides a list of generally free or low-cost energy-related materials.

Environmental Protection Agency (EPA). Ariel Rios Building, 1200 Pennsylvania Ave. NW, Mail Code 3213A, Washington, DC 20460; (202) 260-2090; Web: *www.epa.gov.* The EPA seeks to provide leadership in the nation's environmental science, research, education, and assessment efforts. The EPA's Office of Environmental Education provides teachers with curriculum resources, community service project ideas, and informational materials for use in the classroom. There are also online resources for students, including science project ideas.

National Renewable Energy Laboratory (NREL). 1617 Cole Blvd., Golden, CO 80401-3393; (303) 275-3000; Web: *www.nrel.gov.* NREL is the U.S. Department of Energy's top laboratory for renewable energy and energy efficiency research and development. In addition to in-depth information on renewable energy technology, it provides teachers with direct access to current research. Energy curricula, activities, and projects are also available on the website.

Your state energy office and state capitol. All states have energy offices. Contact yours to find out what materials it can offer on renewable energy, and ask how it is involved with promoting renewable energy sources. The National Association of Energy Officials website *(www.naseo.org)* provides a directory.

Industry Trade Associations

These groups represent various renewable technologies. Their membership is composed of businesses, manufacturers, consultants, utilities, and consumers. They offer educational and promotional materials and often set industry technical standards.

American Bioenergy Association
209 Pennsylvania Ave. SE
Washington, DC 20003
biomass: (703) 516-4444
biofuels: (202) 467-6540
email: *info@biomass.org*
Web: *www.biomass.org*

American Wind Energy Association
122 C Street NW, Suite 380
Washington, DC 20001
(202) 383-2500
email: *windmail@awea.org*
Web: *www.awea.org*

Geothermal Energy Association
209 Pennsylvania Avenue SE
Washington, DC 20003
(202) 454-5265
email: *gea@geo-energy.org*
Web: *www.geo-energy.org*

National Hydropower Association
1 Massachusetts Ave. NW, Suite 850
Washington, DC 20001
(202) 682-1700
email: *help@hydro.org*
Web: *www.hydro.org*

Renewable Fuels Association
1 Massachusetts Ave. NW, Suite 820
Washington, DC 20001
(202) 289-3835
email: *info@ethanolrfa.org*
Web: *www.ethanolrfa.org*

Solar Energy Industries Association
1616 H St. NW, #800
Washington, DC 20006
(202) 628-7745
email: *info@seia.org*
Web: *www.seia.org*