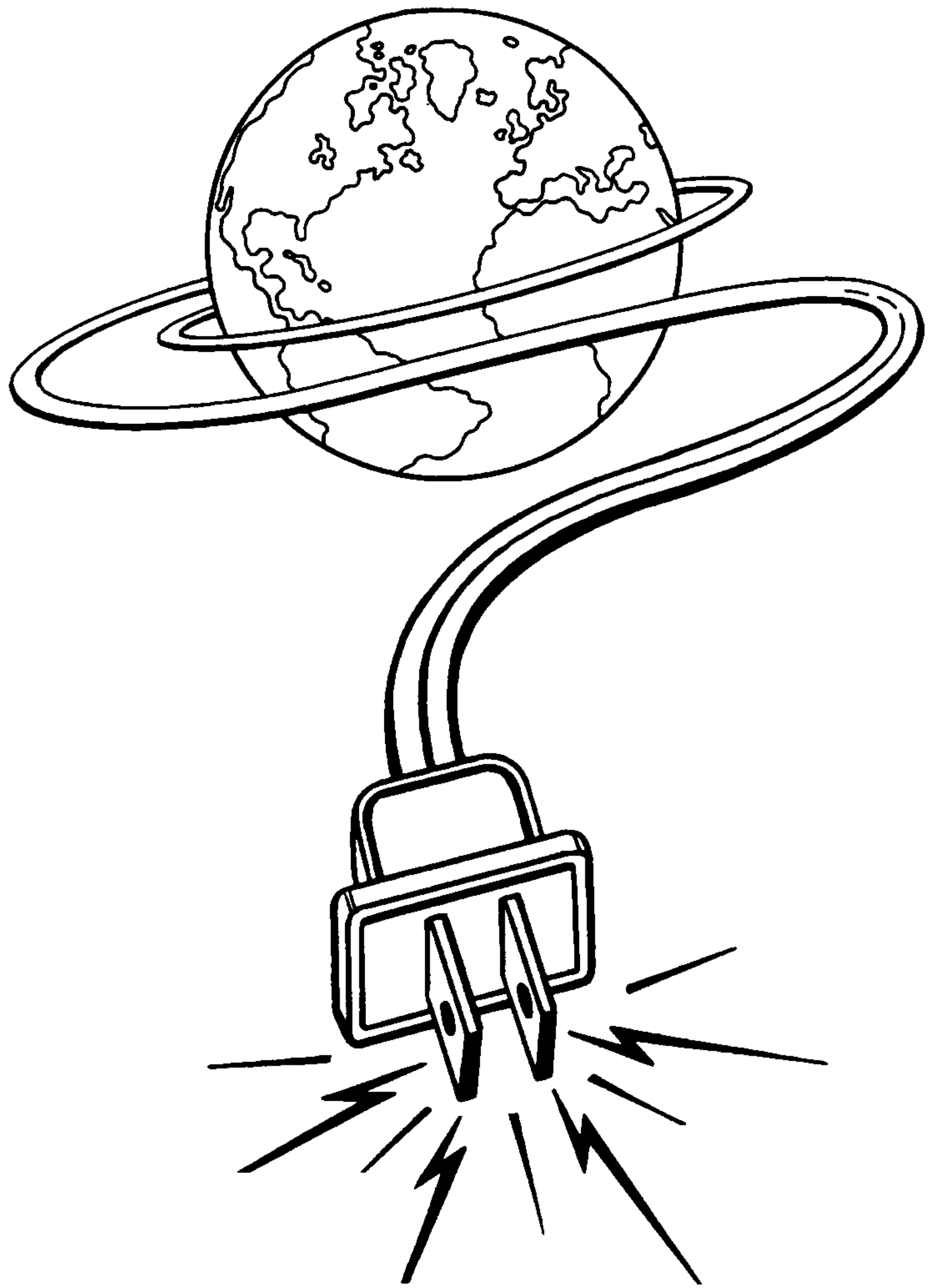
GENERATING ELECTRICITY: USING HIGH TEMPERATURE GEOTHERMAL AND OTHER RESOURCES

SECTION IV



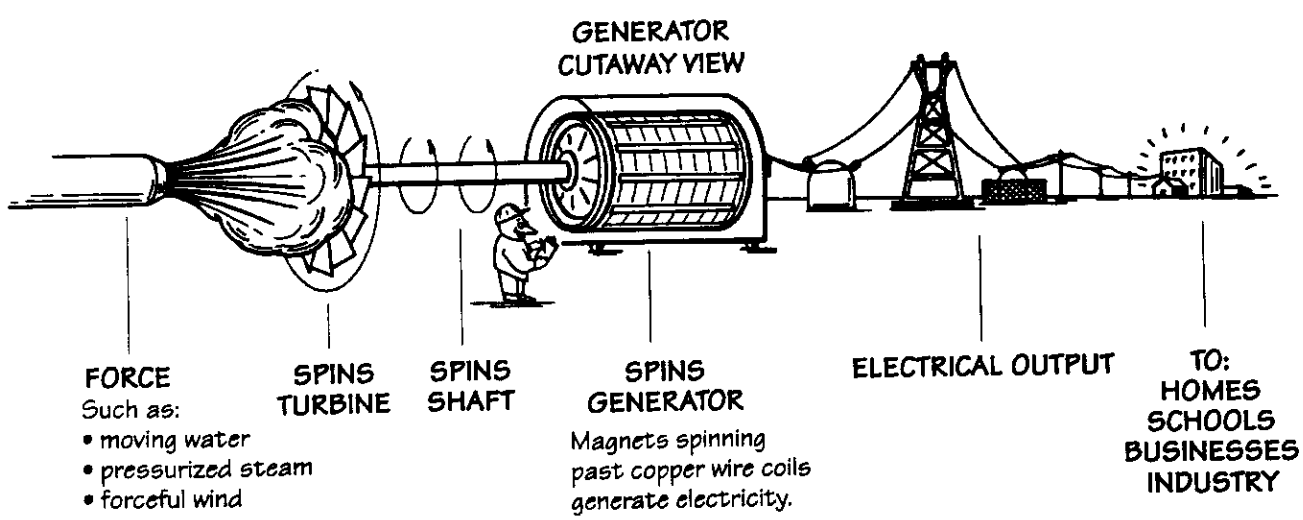
PRODUCING ELECTRICITY WITH A TURBINE GENERATOR

All of the electricity we use comes from energy resources, both renewable and non-renewable. These resources include water and steam, the wind, fossil fuels, the sun, uranium and other elements from the earth, and wood and other substances produced by living things (called biomass). Renewable and nonrenewable energy resources generate electricity in a variety of ways, frequently providing the force needed to turn turbines which run electricity generators.

Turbines were first used to produce electric current in the 1880's. There are many turbine designs, but they all operate on the same principle: a force - such as moving water, pressurized steam or steady wind - hits blades attached in a circle around a central shaft or long rod. The force causes the blades to move, which makes a shaft spin.

This turbine shaft is attached to huge magnets that spin between coils of copper wire. Magnets are surrounded by a *magnetic field.* As the magnets move past the wire coils, an *electric current* is generated: the attraction of the magnetic field makes tiny particles called *electrons* move. Electrons are so tiny that they cannot be seen except with special instruments, but when they move it creates electricity.

Altogether, the magnets, wires, and rod make up a device called a generator. A generator, turbine, and source of power is a power plant, no matter how large or small. Even a single windmill can be thought of as a power plant. But usually when we think about the generation of electricity we picture a huge power plant, filled with enormous turbine generators, humming with force and energy.



WHAT HAPPENS INSIDE A GENERATOR:
Producing Electricity Using a Magnet

Turbine electricity generators use powerful magnets and huge wire coils to produce electricity. The electricity is generated by either the rapid spinning of the magnets inside coiled wires or the spinning of coiled wires inside of enormous magnets. The process works either way. Turbines, turned by a force such as steam, provide the spinning power.

Magnets are surrounded by a magnetic field that is very "attractive." When a strong magnet (such as a bar magnet with "north" and "south" poles) moves, it's magnetic field changes. When wires are connected to make a complete pathway (a "circuit"), a changing magnetic field will produce an electric current in these wires if the magnet gets close enough. Wrapping the wires into coils will increase the amount of electric current. Moving the coils instead of the magnet also works.

You can test the idea that magnets can produce an electric current by doing the following demonstration.

Materials:
Per student group

- enough insulated copper bell wire to make a fifty-loop coil larger than the magnet
- a strong bar magnet with "poles"
- a current detector (galvanometer)

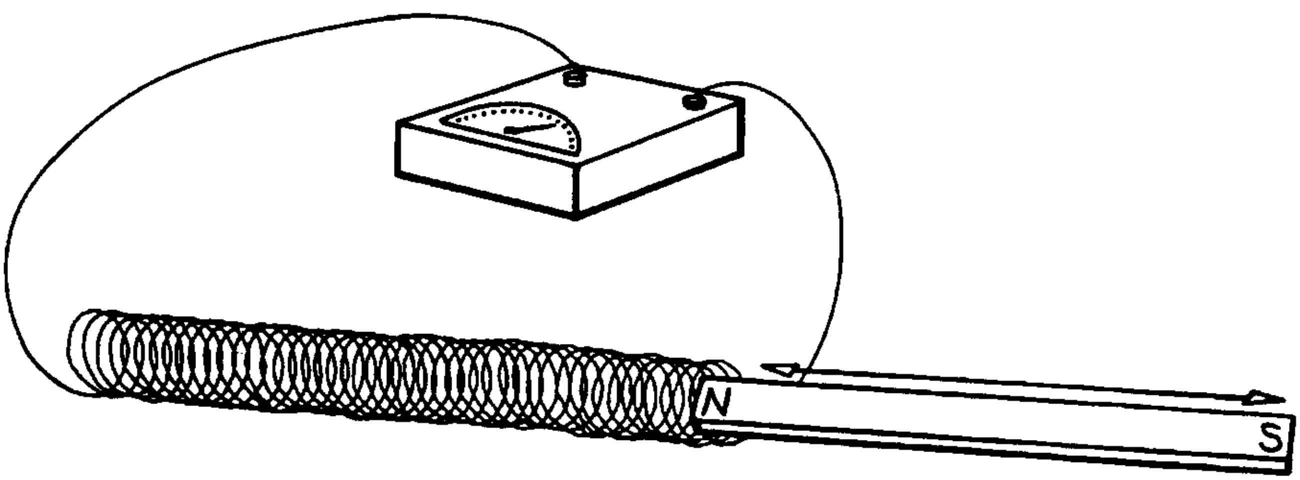
Directions:

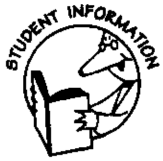
1.) Make a fifty-loop coil of the insulated copper wire through which you can slip the magnet.

2.) Attach the end wires of the coil to the galvanometer.

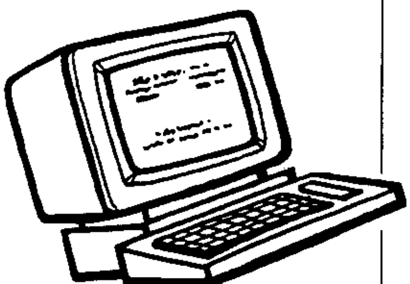
3.) Move one pole of the magnet in and out of the coil. There should be movement in the galvanometer.

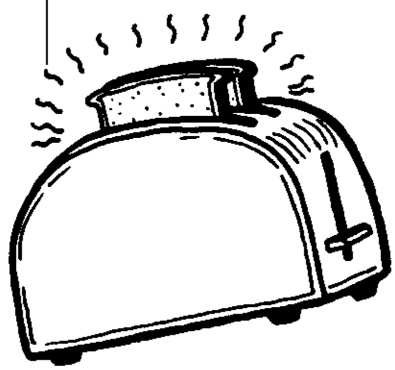
4.) Then try holding the magnet stationary and moving the coil over one of the magnet poles.



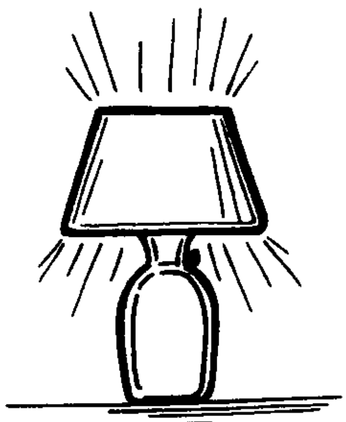


Understanding Electrical Terms

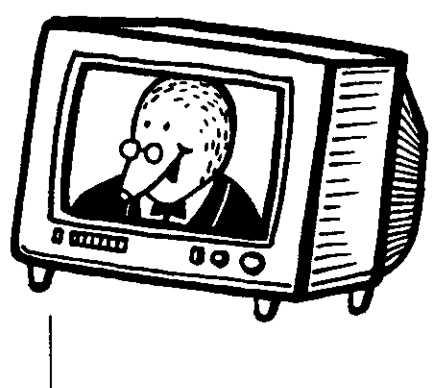


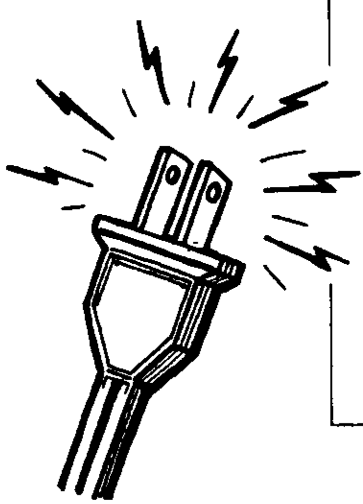


Electrons traveling through a wire can be compared to water molecules flowing through a pipe. *Voltage* (expressed in volts, named after the scientist Allessandro Volta) is what pushes the electrons, like pressure pushes the water. Current is the flow of electric charge. It is the amount of electrons flowing past a certain point per unit of time. The amount of current flowing in a wire in a given amount of time is expressed as *amperes* (or "amps"), named after Andre Marie Ampere). It is a rate of current flow similar to describing water flow in gallons per minute or liters per second. A *watt* is a unit of power and is the rate energy is used in electrical devices. One watt is the rate of current flow when one ampere is "pushed" by one volt. One watt is needed by a typical string of Christmas lights. A *megawatt* (one thousand kilowatts) is equal to one million watts, the amount needed to provide power (in the United States) to the homes of 1,300 people.



Electricity to Your Home





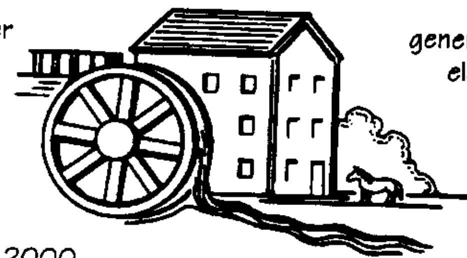
Electricity is sent from power plants to surrounding communities through power lines like the ones you see every day. If the electricity is traveling far, then high voltage is maintained. *Voltage* is the force with which a source of electric current moves electrons (remember, moving electrons are responsible for electric current). For safety, these high voltage power lines are installed on very high towers. Then, when the electricity arrives close to its destination, it goes through a *transformer* which "steps down" the voltage for use in homes and other buildings (in the U.S., this is usually 110 volts.) The high-voltage electricity may also be allowed to flow directly into certain machines and electric streetcars or monorails which can handle it directly, without a "stepdown."

PRODUCING ELECTRICITY WITHOUT STEAM

STUDENT INFORMATION

Many power plants use the force of steam to generate electricity, but as you will see steam isn't the only resource that can be used. There are a number of ways to generate electricity without using steam.

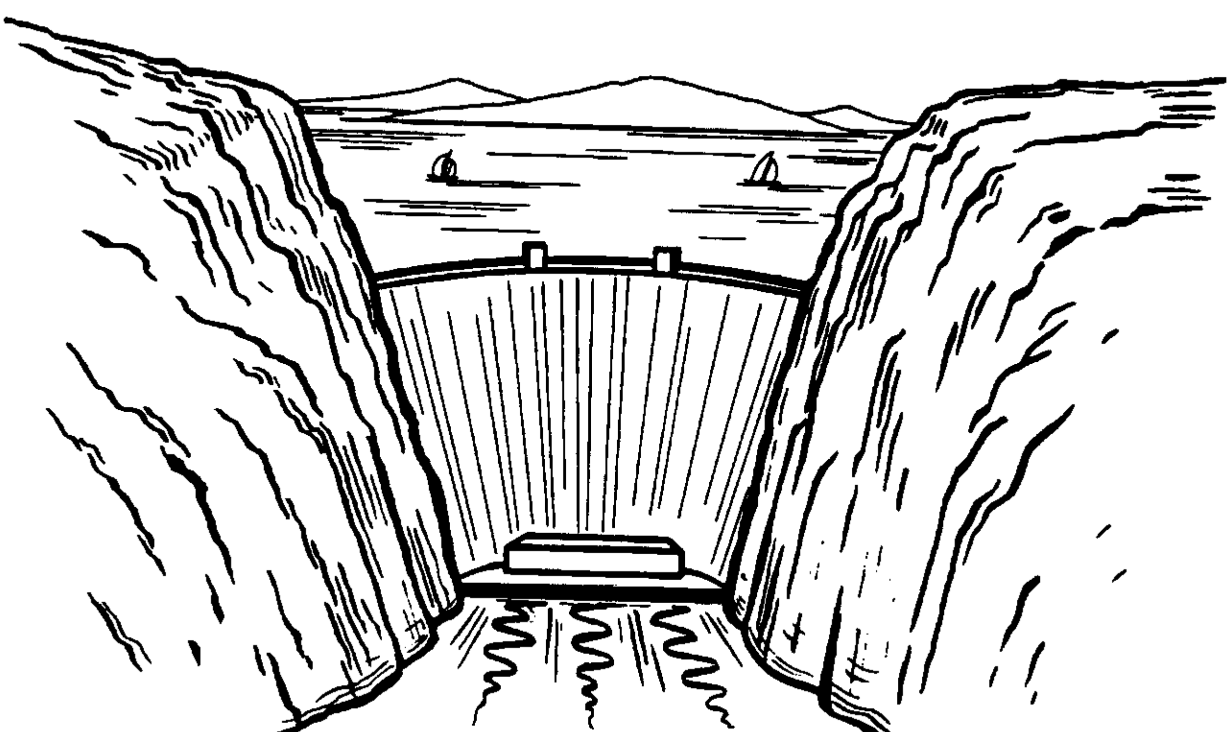
TURBINES AND WATER POWER



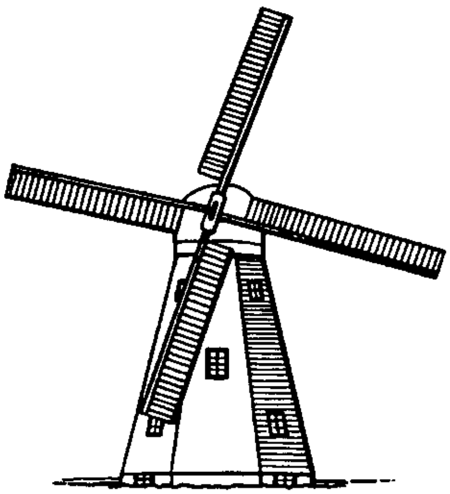
Machines that rely on the power of moving water have been in use since the times of the great *Library of Alexandria* (a center for study and experimentation, located in the capital of Egypt during the rules of the Persians, Greeks and Romans). There, over 2000 years ago, scientists worked with inventions such as the water clock. Since early 100 A.D., many types of water wheels have been invented, using buckets or paddles which catch the moving force of water, making the wheels turn. In the early 1800's water wheels were modified into turbines with curved, slanting blades like those of a propeller.

Falling water has a great deal of force which can be used to turn turbines. When rivers are dammed and used to run huge turbines and generators, then we have a hydroelectric power plant (remember, hydro = water). The "fuel" in these plants is the force of the water; no fuel is burned. Water is also considered a renewable resource. Hydroelectric power plants presently produce more electricity than any other renewable resource. In the Pacific Northwest, for example, more than 50% of all electric energy is generated with hydropower.

Another, but limited, use of water power is a method that harnesses the energy of ocean tides, called tidal energy. Tidal energy uses the force of incoming and outgoing water (tides) to flow through turbines and generate electricity. It is being studied as a future energy source.

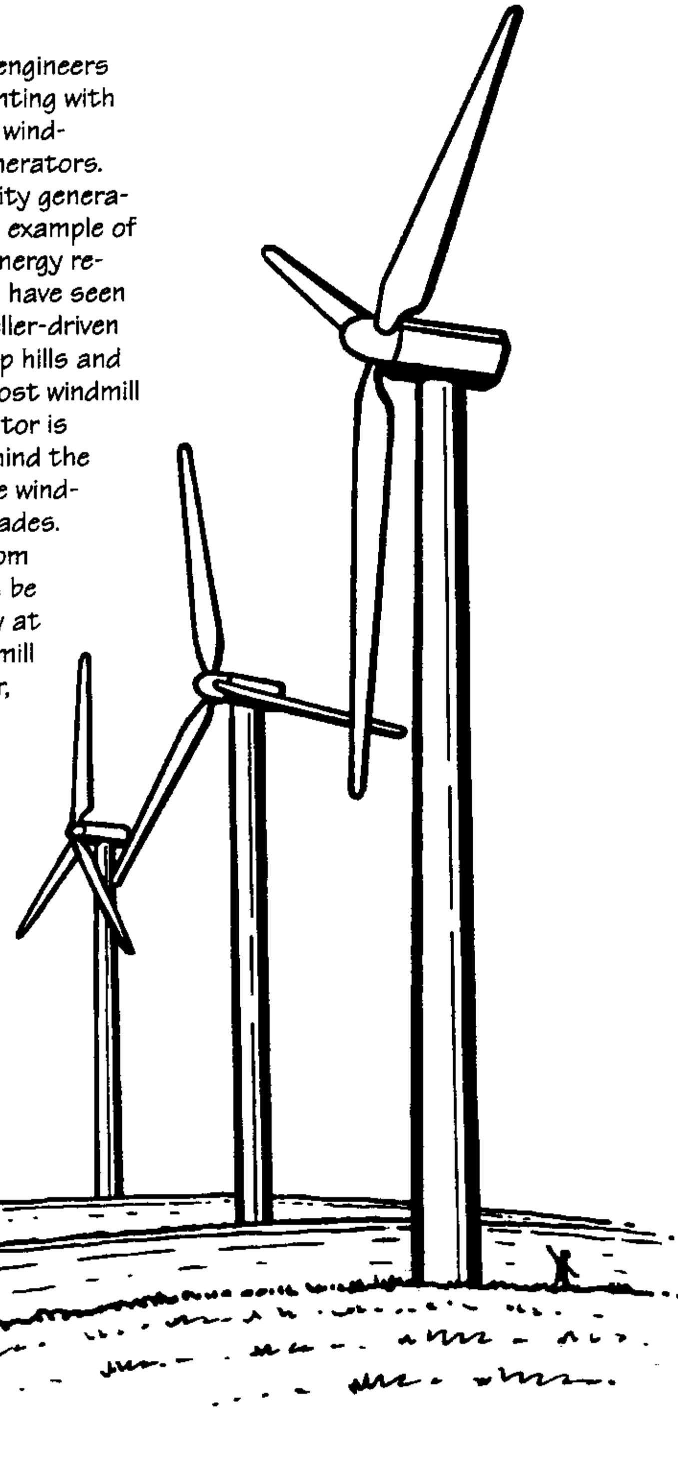


WINDMILLS AND WIND POWER

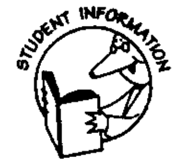


Windmills use the force of the wind the way turbines use the force of falling water. Windmills use sails or propeller-like devices to catch the power of the wind. The idea for doing this dates back to around the 10th century A.D. in Persia. There, whole fields of windmills, which were used to lift water for irrigation, were located in vast plains where powerful winds blew for months at a time. These windmills always faced the same direction. Then, around the 12th century A.D., Europeans invented windmills which could face into whichever direction the wind was blowing. This made them far more useful and versatile. All over the world, from Holland to Greece to the United States, windmills have been grinding grain, pumping water, charging batteries, and doing other useful work for centuries.

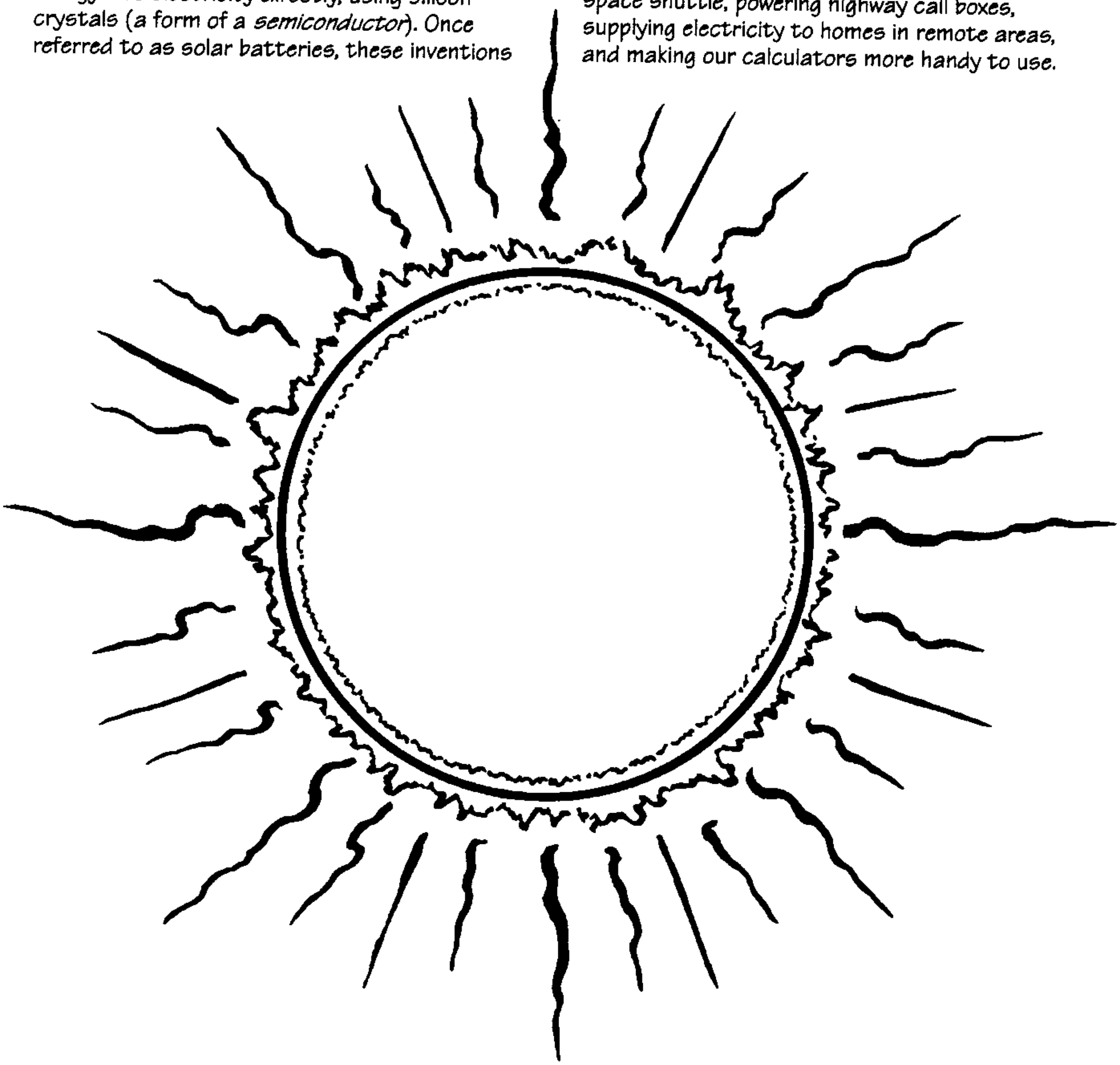
Since about 1940, engineers have been experimenting with the development of wind-powered turbine generators. Today, wind electricity generation is a very visible example of using a renewable energy resource. Many of us have seen fields of huge propeller-driven windmills found atop hills and windy passes. In most windmill designs, the generator is located directly behind the turbine, which is the wind-driven "propeller" blades. Some electricity from these windmills can be put to work directly at the site where the mill is located. However, most large "wind farms" sell their electricity to the local power company for use all over its service area.



SOLAR CELLS AND SUN POWER

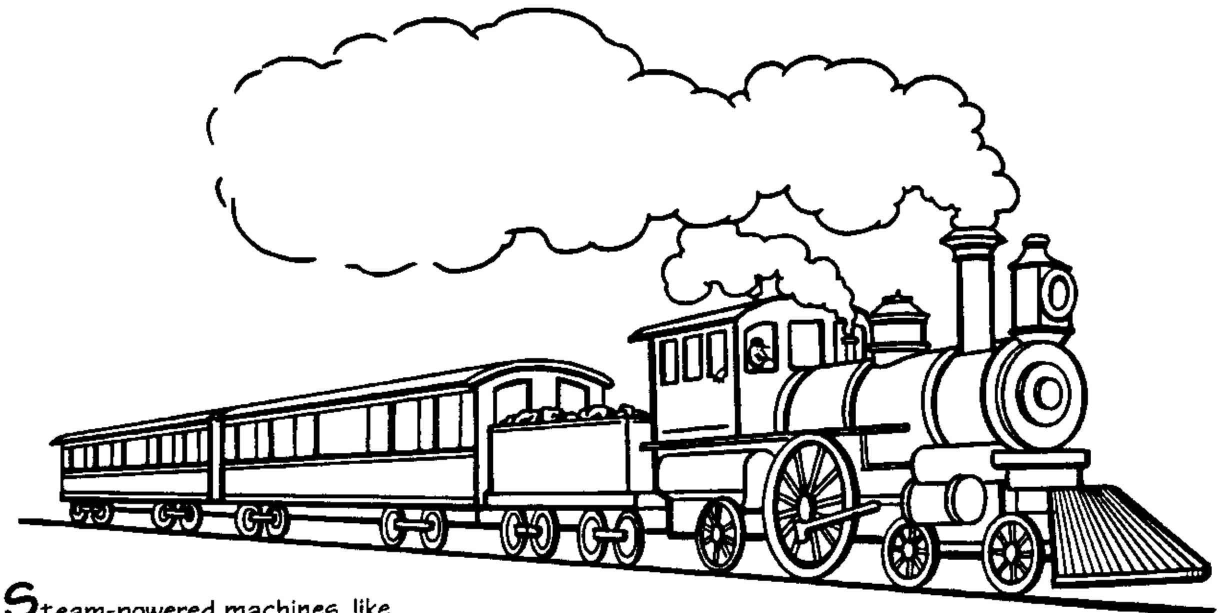


Since the dawn of time, energy radiating from the sun has been making life easier for humans: growing plants, warming the earth, heating the air and water ... the list goes on and on. In the 1950's engineers invented a way to convert *solar* energy into electricity directly, using silicon crystals (a form of a *semiconductor*). Once referred to as solar batteries, these inventions grabbed the light of the sun to power the electronic equipment of the first satellites. Now referred to as solar cells, or *photovoltaic cells*, these amazing devices are put to work in a variety ways including running part of the space shuttle, powering highway call boxes, supplying electricity to homes in remote areas, and making our calculators more handy to use.



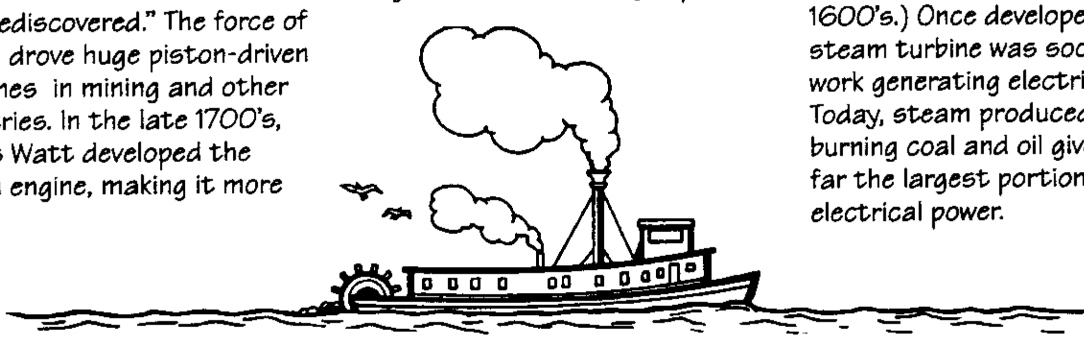
Electricity can also be generated using the sun's energy by heating water to produce steam at a solar thermal power plant (See p. 55).

PRODUCING ELECTRICITY *WITH* STEAM



Steam-powered machines, like water-driven machines, also date back to the days of the Alexandria Library, although the power of steam didn't actually enjoy widespread use until 1700. Then steam's force was "rediscovered." The force of steam drove huge piston-driven machines in mining and other industries. In the late 1700's, James Watt developed the steam engine, making it more efficient. Steam-driven trains, paddle wheel boats, ocean liners, and passenger carriages soon followed. Up to this point, steam was not used to generate electricity, but it was certainly kept busy!

The first modern steam-driven turbine was invented by a Swedish dairy operator in 1882. (The idea was suggested by an Italian engineer in the late 1600's.) Once developed, the steam turbine was soon put to work generating electricity. Today, steam produced by burning coal and oil gives us by far the largest portion of our electrical power.



WHAT IS STEAM?

Steam is the vapor form of water and develops when water boils. It is made of very tiny heated water particles called *molecules* which are bouncing around and bumping into each other at very high speeds. These heated water molecules are also spreading out and expanding in every direction they can. If we confine or trap water in a container, with a pipe as an opening, and heat the water to steam, it will create great pressure in the container and will rush out the pipe with a great deal of force. This force (the "power" of steam) can be put to work turning a turbine connected to an electricity generator (see p.48).

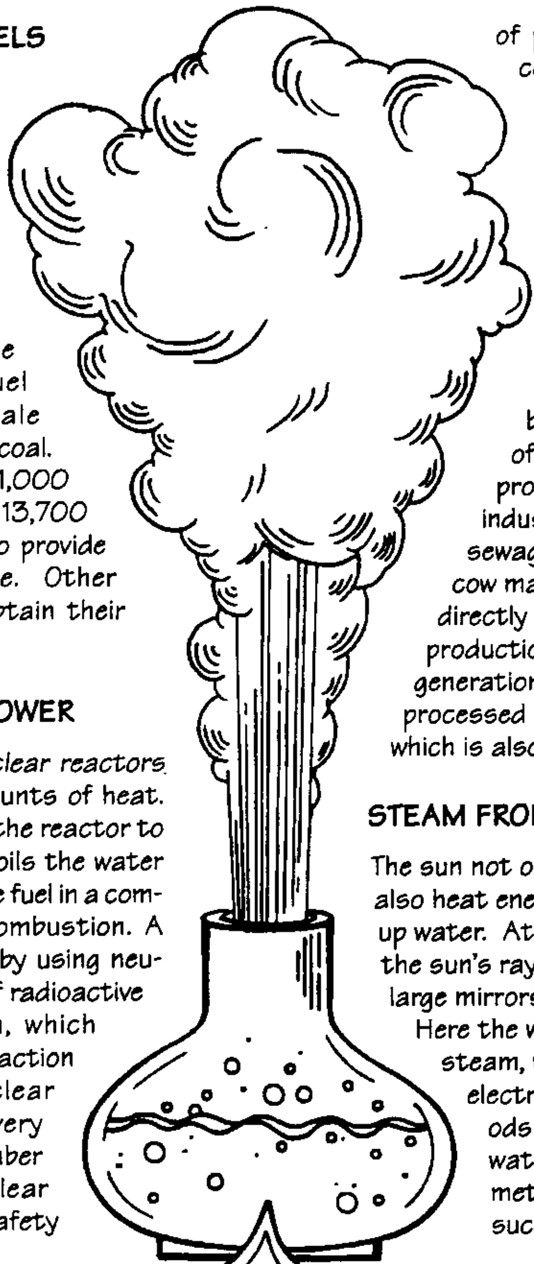
Steam can be either manufactured or natural :

"Manufactured" means we make it. To make steam we need to boil water, and this means we need a heat source.

Natural steam is the kind that comes from geothermal resources.

GENERATING ELECTRICITY FROM *MANUFACTURED* STEAM

In order to manufacture steam we need fuels to heat up the water. These fuels include some renewables and some nonrenewables: fossil fuels, nuclear fuel, biomass (biofuels) and, again, our friend the sun.



STEAM FROM FOSSIL FUELS

Fossil fuel power plants burn fuels such as coal, oil, and *natural methane gas.* Fossil fuels must be burned (combusted) in order to release their energy, mostly in the form of heat. This heat is then used to boil water, making steam that spins turbine generators. Most fossil fuel power plants are large-scale operations. Many of them use coal. A typical power plant (about 1,000 megawatts) might burn up to 13,700 tons of coal a day in order to provide the needs of a million people. Other types of fossil fuel plants obtain their heat from oil or natural gas.

STEAM FROM NUCLEAR POWER

Nuclear power plants use *nuclear reactors* which produce enormous amounts of heat. This heat is transferred from the reactor to a steam generator where it boils the water to steam. Nuclear reactors use fuel in a completely different way from combustion. A nuclear reaction is produced by using neutrons to "split" the nucleus of radioactive materials such as uranium, which results in a controlled chain reaction that releases energy. Nuclear power plant technology is very complicated; it includes a number of ways to control the nuclear reaction and provide for the safety of plant workers and neighboring communities.

STEAM FROM BIOMASS (BIOFUELS)

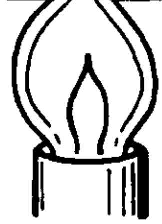
Steam for electricity can also be produced by using substances that come from living things, called biomass (or biofuels). The oldest and most common form of biomass is wood. Other forms of biomass include other forest products, crops, agricultural and industrial wastes, algae, and sewage and solid wastes (including cow manure!). Biofuels can be burned directly to provide heat for steam production that is used in electricity generation. Some biofuels can also be processed into ethanol and methanol which is also burned as a fuel.

STEAM FROM THE SUN

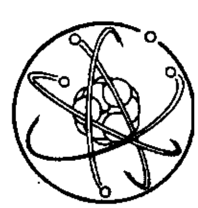
The sun not only produces light energy, but also heat energy which can be used to warm up water. At a solar thermal power plant the sun's rays can be focused by rows of large mirrors directly on a large water tank. Here the water gets hot enough to make steam, which can then run the turbine electricity generators. Other methods of using the sun's heat to boil water also exist, but this direct method seems to be the most successful so far.

COAL

OIL



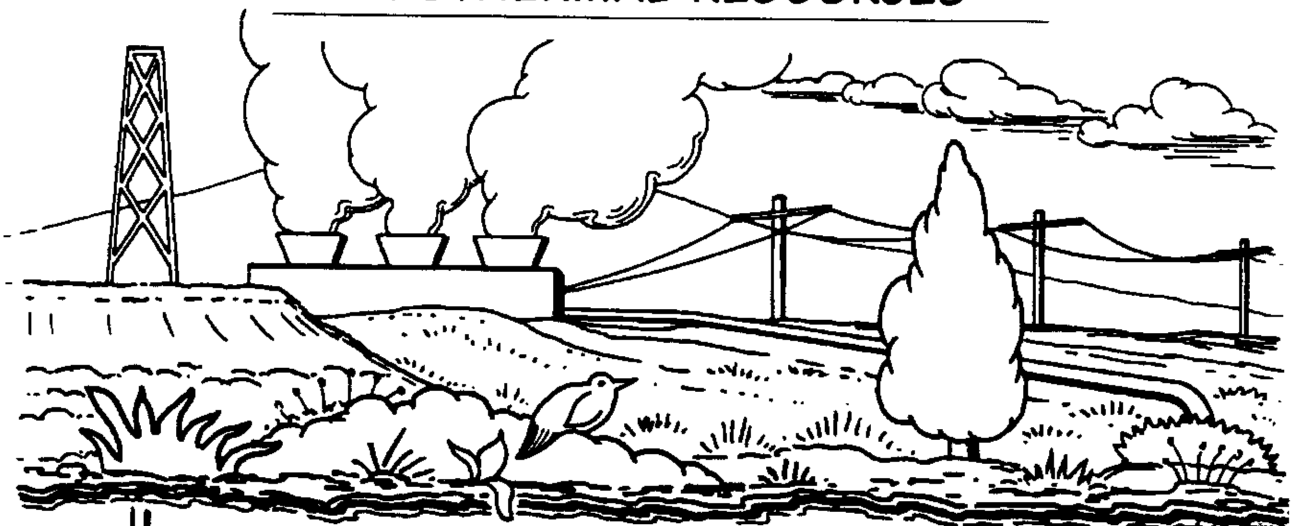
NATURAL GAS



NUCLEAR

BIOMASS

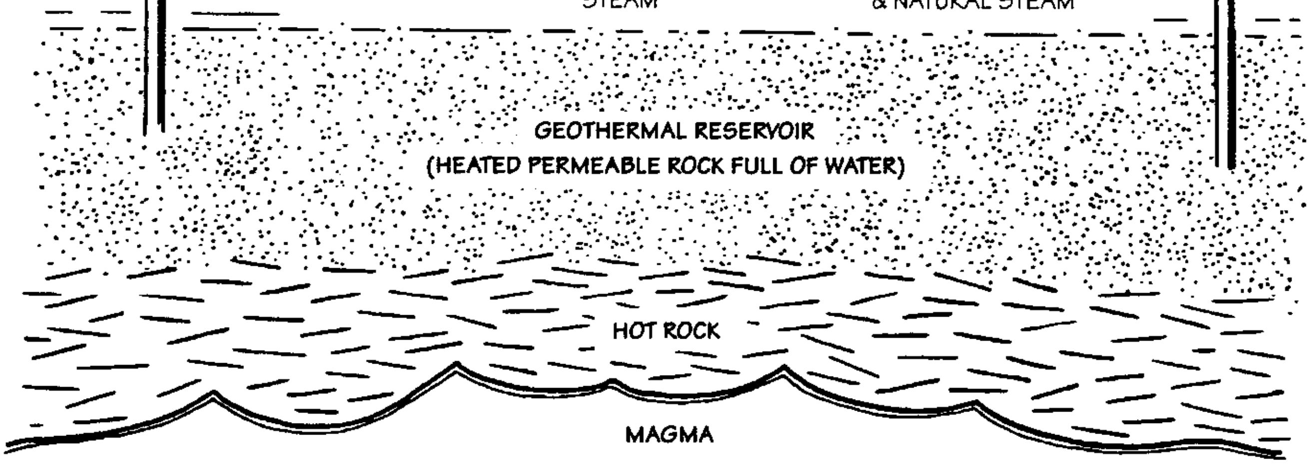
GENERATING ELECTRICITY WITH *NATURAL* STEAM AND HEAT FROM GEOTHERMAL RESOURCES



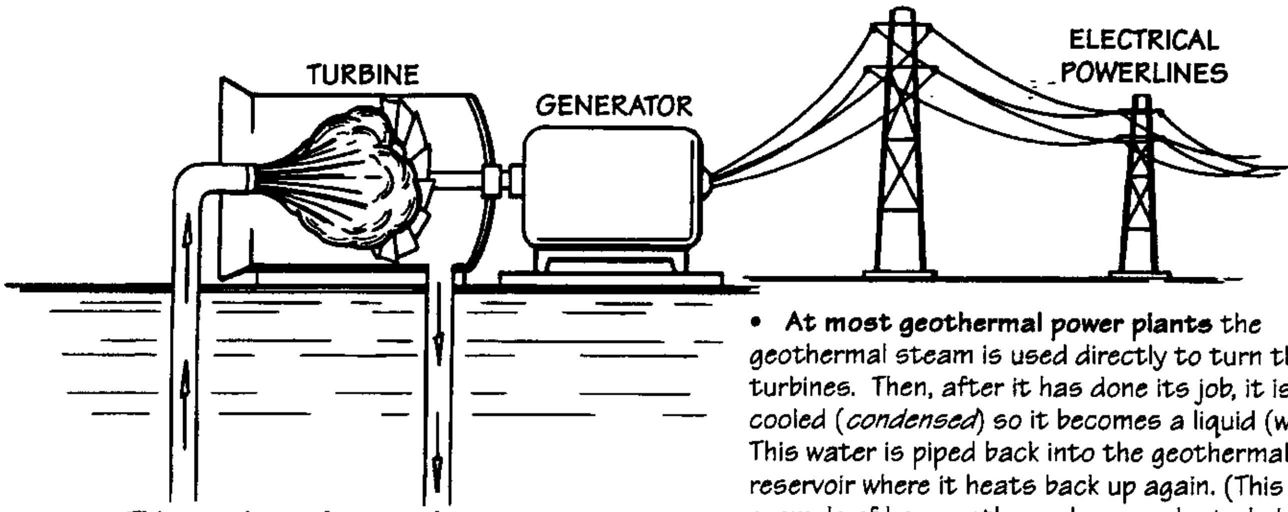
As you know, in many places around the "Ring of Fire," where magma comes very close to the earth's surface, there are sometimes geothermal reservoirs — areas underground where the hot rocks contain heated groundwater. The temperature of the water and steam in these reservoirs can reach 700° F (371° C) — more than three times that of boiling water !

To get to the hot water and steam underground, geothermal engineers drill wells (just as wells are drilled to bring up water or oil). The boiling hot, steamy water comes up the well and the steam is directed through pipes right into the power plant, where it provides the force that spins the turbine electricity generators.

HEAT :	HEAT FROM BURNING FUEL	HEAT FROM HOT ROCKS AND MAGMA
+	+	+
WATER =	WATER =	UNDERGROUND RESERVOIR =
STEAM	MANUFACTURED STEAM	GEOTHERMAL HOT WATER & NATURAL STEAM

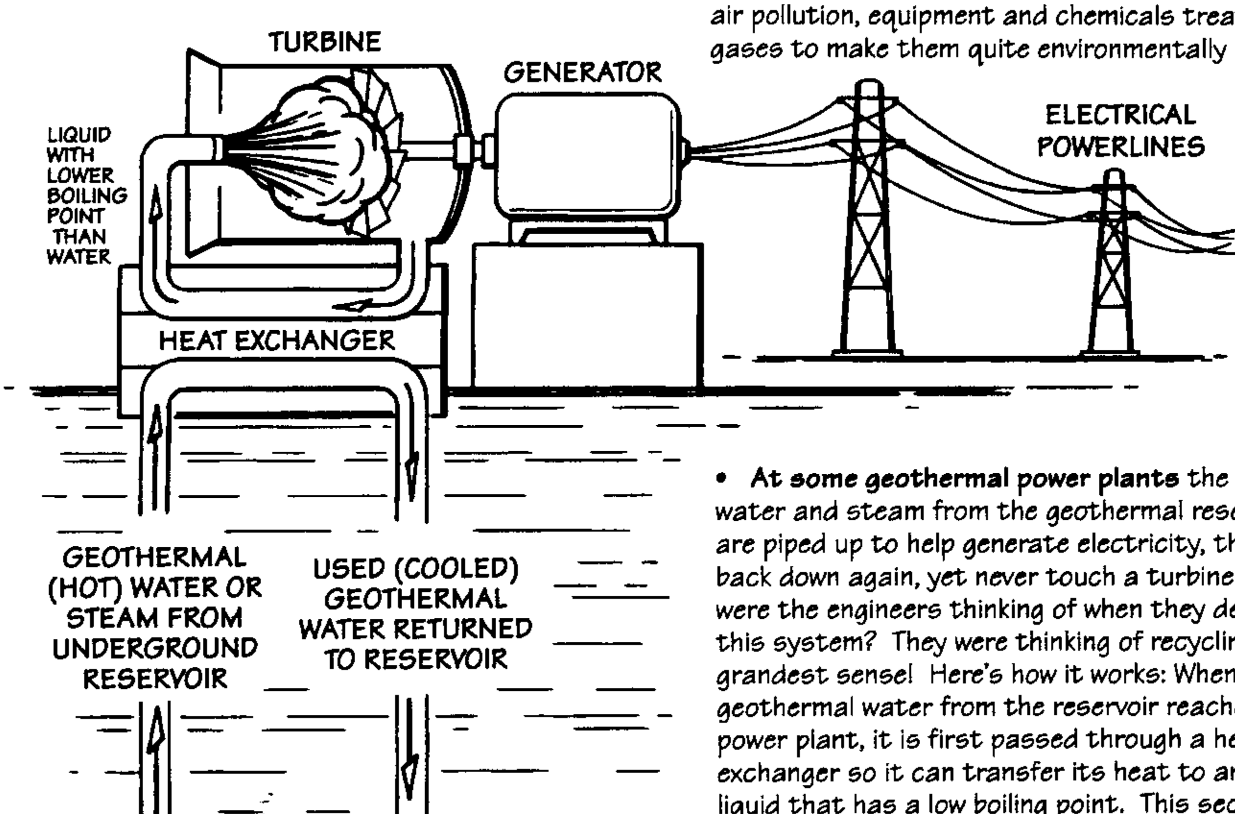


GEOTHERMAL POWER PLANTS



This geothermal power plant uses geothermal steam to turn a turbine.

• **At most geothermal power plants** the geothermal steam is used directly to turn the turbines. Then, after it has done its job, it is cooled (*condensed*) so it becomes a liquid (water). This water is piped back into the geothermal reservoir where it heats back up again. (This is an example of how geothermal power plants help "recycle" and renew the geothermal resource.) Some gases (mostly carbon dioxide) are contained in geothermal steam. Because of concerns about air pollution, equipment and chemicals treat these gases to make them quite environmentally safe.



This geothermal power plant uses geothermal water with a heat exchanger system to turn a turbine.

• **At some geothermal power plants** the hot water and steam from the geothermal reservoirs are piped up to help generate electricity, then piped back down again, yet never touch a turbine! What were the engineers thinking of when they designed this system? They were thinking of recycling in its grandest sense! Here's how it works: When the hot geothermal water from the reservoir reaches the power plant, it is first passed through a heat exchanger so it can transfer its heat to another liquid that has a low boiling point. This second liquid "boils," it begins to *vaporize* — just as water vaporizes (becomes steam). This new vapor is then used to turn the turbines. The beauty of this system — called binary (bi = 2) because it uses two liquids — is that both the geothermal water and the other liquid recirculate continuously in their separate pipes, so that both are used over and over again and nothing is wasted. Nothing at all goes into the air. This is a 100% clean form of electrical power production.

ALL STEAMED UP: MAKING A MODEL GEOTHERMAL STEAM ENGINE

In this activity, you will be exploring several ideas.

First, you will be demonstrating how steam is used to turn a turbine engine. In order for steam to hit the turbine with enough force to make it move, it must be rushing from its source at high pressure. In this demonstration, you'll notice that the steam is coming through a small hole, which forces the steam to come out with the greater force needed to move the turbine blades.

Second, you will be creating a visual demonstration of energy conversion. Remember that energy comes in different forms and can be converted (changed) from one form to another.

Simply speaking, in this activity heat energy is converted into mechanical energy. The same is true in a geothermal power plant.

The next step at the geothermal plant would be to convert the mechanical energy of the moving turbine into electrical energy using the generator.

The Geothermal Education Office acknowledges this contribution of the National Energy Foundation.

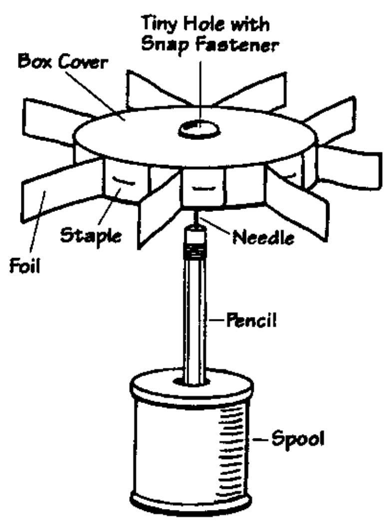
Materials:

Per student group:

- cover of a round box such as a small cardboard ice cream container
- heavy duty aluminum foil
- a snap fastener (the kind without a hole in the middle)
- a needle
- a pencil with eraser
- an empty thread spool

For all groups:

- a stapler
- a tea kettle or pot with lid
- a stove or burner
- an oven mitt
- kitchen or barbeque tongs
- cellophane tape
- water
- ruler
- scissors



Directions:

1.) Cut the foil into eight pieces each 7.5 cm long and 5 cm wide. Fold each piece in half.

2.) Staple and/or tape each piece to the box cover.

3.) Push the end of the needle (the "eye" end) into the eraser of the pencil. Be careful of the pointed end sticking up.

4.) Put the box cover on the point of the needle. Work with this until the box cover hangs straight and even. Make a tiny hole at this balance point.

5.) Push the bottom half of the snap fastener into this hole.

6.) Put the point of the pencil into the hole in the spool.

7.) Rest the box cover with snap fastener on the point of the needle.

8.) Boil water in the kettle or pot with lid (place the lid slightly off center so that the steam will push out strongly from one side).

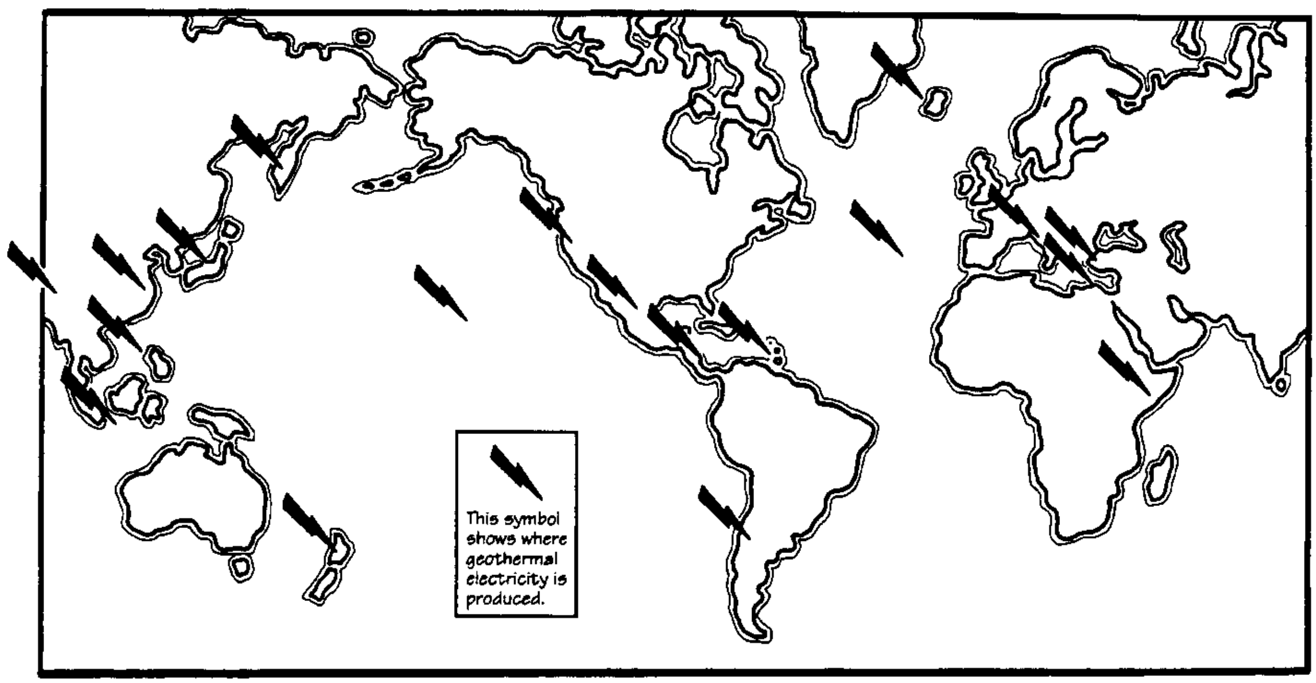
9.) Wearing the oven mitt, hold the device with the tongs near the steam coming out from the kettle (or gap in pot + lid). Observe what happens.

10.) Be ready to discuss where the wheel gets its power to turn and how this relates to geothermal power plants.

GEOTHERMAL ELECTRICITY TODAY

The geothermal energy industry is a growing electricity producer. 5,700 megawatts of "geothermal electricity" (the equivalent of over a hundred million barrels of oil per year) are "current"ly being produced in many countries around the world — mostly in Italy, New Zealand, the Philippines, Japan, Indonesia, Central America, Mexico, and the western United States. And geologists are doing lots of exciting exploration in many other promising locations so that the geothermal megawatt numbers will soon be on the rise.

In the United States geothermal power plants have the ability to produce over 2,500 megawatts of electricity – enough to meet the electrical needs of more than 3 million households. Using this much geothermal energy saves the equivalent of about 50 million barrels of oil each year.



DID YOU KNOW ?

Geothermal and the Environment

☞ The geothermal water that is used in power plants is always sent back into the geothermal reservoir so that surface water and fresh ground water stay clean and safe to use.

☞ In the U.S. more electricity is produced from geothermal resources than from wind and solar combined.

☞ Geothermal power plants give off very few pollutants when compared to power plants that use fossil fuels. In fact, binary power plants give off no carbon dioxide, sulfur oxides, or nitrous oxides – the main "bad guys" in the showdown between clean air and pollution.

☞ The world's largest geothermal electric power plant development is found in Lake County, CA. In 1991, this county became the first and only county to meet all of California's really tough air quality regulations.

☞ It takes less land to produce electricity from geothermal resources than from almost all other energy resources.

GEOTHERMAL TOMORROW

Improvements in geothermal technology and engineering techniques will soon allow us to use geothermal energy even more in the future than it is today. Possibilities already being explored involve using the heat directly from hot "dry" rocks and magma — without the need for a natural geothermal reservoir. Both of these methods involve piping water down into these very hot underground areas so it can heat up. The result — even more geothermally heated hot water and steam will be available to turn turbines in power plants around the world.

IT'S "POWER"FUL

Long ago, in the first century AD, some inventive Greeks attached paddles to a long stick and placed it into a stream of running water. As the water hit the paddles, the center stick turned and thus one of the first waterwheels was invented. Since that time, waterwheels and their cousins, the turbines, have been put to work in many ways, eventually ending up in enormous turbine electricity generators that produce the electricity we so casually use everyday.

For centuries, human beings have been discovering ways to harness the forces of the natural world in order to improve or change their lives. From the discovery of the many uses of simple machines such as the lever and the knowledge of fire's potential to the era of the microchip, women and men have been discovering and rethinking new uses of power. With each discovery, or "reinvention," life changed somehow. People generally thought each change was for the better. Now, in retrospect, some changes may not be viewed to be as beneficial as people originally thought.

We may take for granted some of the discoveries that led us to where we are today. Some research into the history of power may allow us to recapture a sense of wonder about the natural world and and how we use its "power"ful forces.

Suggested Activities:

1.) Pick a topic and select a variety of resources for information.

<u>Suggested Topics</u>
(pick any others of your own):

- the use of fire
- inventions developed by ancient civilizations (such as Egyptian, Phoenician, Greek and Roman)
- the Industrial Revolution
- the use of water wheels during the California Gold Rush
- Thomas Edison
- James Watt
- Allesandro Volta
- Andre Marie Ampere
- uses of power sources in transportation
- the atomic age and nuclear reactors
- the mining industry around the world

2.) Find out all about your topic. Be sure to ask who, what, when, where, and how.

3.) If possible, make sketches (illustrations and/or diagrams) of the subject of your topic.

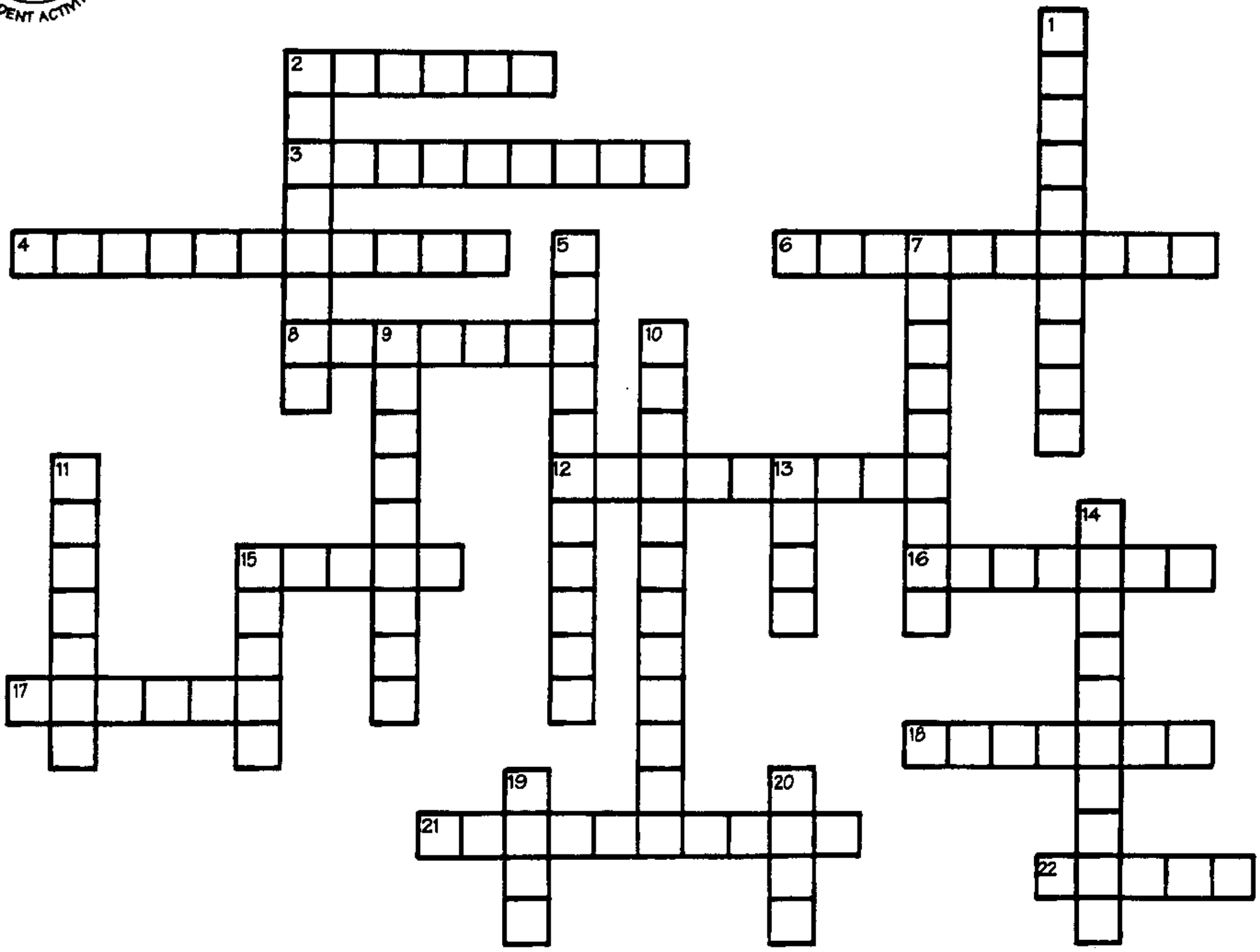
4.) What creative processes and/or series of events lead to the discovery, invention, or development of your topic?

5.) Discuss whether your topic was considered to improve life at the time it was developed.

6.) Discuss whether you considered the use of your topic to really be an improvement. Conversely, do you think we'd be better off without it? Be sure to give your reasons why.

7.) Besides improvement of life, what other motivation may have been involved in the development of your topic? (Consider: greed, power, desire to help others, "the need to know" and so forth).

POWER PUZZLE



ACROSS — ELECTRIFYING PUZZLE CLUES — **DOWN**

ACROSS

2 a material that "attracts" certain metals
3 uses magnets and coiled wires
4 water that has collected under the earth's surface
6 central station for electricity production
8 a machine with turning blades used in making electricity
12 an underground area of hot permeable rock full of water
15 coming from the sun
16 a form of power that comes from "splitting" atoms
17 country which began using windmills around the 10th century A.D.
18 a continuous flow of electrons
21 ancient capital, home to great library
22 "hydro" means ____________

DOWN

1 fuel from ancient living things, such as coal
2 one million watts
5 the energy of moving electrons
7 tiny particles; part of an atom
10 using resources wisely
11 fuel from living things
13 in electricity: measurement of the amount of "push" electrons are getting
14 heat from the earth
15 heated water vapor
19 a form of energy that can warm our homes
20 ________drives windmills to produce power

POWER PUZZLE WORD BANK							
Alexandria	current	fossil fuel	groundwater	megawatt	powerplant	solar	volt
biofuel	electricity	generator	heat	nuclear	renewable	steam	water
conservation	electrons	geothermal	magnet	Persia	reservoir	turbine	wind

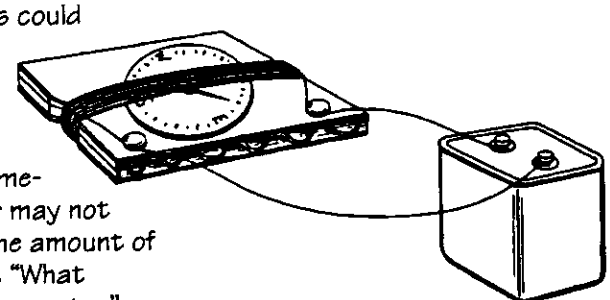
Science Activity: What Happens Inside a Generator
(student worksheet included)

Materials: Per student group
- strong bar magnet with "poles"
- enough insulated copper bell wire to make a fifty-loop coil larger than your magnet
- current detector (galvanometer)

Management suggestions:
The magnetic field of the magnet will cause movements of the electrons in the wire, generating electricity. Students should see that it doesn't matter whether the coil or the magnet is moving. If the galvanometer doesn't react, try making more wire coils, or try a stronger magnet. Also, some current detectors are better than others. You may want to check with your local electronics store if your detector doesn't work. You may also wish to try making your own galvanometer. A suggestion for making one follows.

Science Activity: Building a Galvanometer (Current Detector)
(no student worksheet)

You may wish to demonstrate to your students how a galvanometer works. This could coordinate with the previous student activity, "What Happens Inside a Generator." This homemade galvanometer may not be able to detect the amount of current produced in "What Happens Inside a Generator," but you might try it and see.



Materials:
- small compass
- clear tape
- heavy cardboard
- fine, insulated, copper bell wire
- brass paper fasteners
- large lantern battery

Directions:
1.) Cut a small platform out of the cardboard and fasten the compass to it with tape (see picture). Cut two slots at the North and South markings on the compass.
2.) Wind about fifty turns of the wire through the slots and around the compass and cardboard (see picture). Leave about two feet (60 cm) of wire free at each end.
3.) Put two paper fasteners through the cardboard and twist the free ends of the wire around them once or twice. Scrape (or strip) away about an inch of insulation from each of the free ends.
4.) Have students watch as you attach the exposed ends to the terminals of the battery. The needle of the compass should move, indicating that electricity is flowing. Because electricity creates a magnetic field, the compass detects it. This instrument is a "galvanometer" and is used to detect current.
5.) Have students watch as you reverse the wires so they touch the opposite terminals. They will see that the needle moves in the other direction. This is called "reversing the polarity." Students will see that the electric current will flow in either direction.

Science Activity: All Steamed Up
(student worksheet included)

Materials: Per student Group:
- cover of a round box such as small cardboard ice cream container
- heavy duty aluminum foil
- a snap fastener (the kind without a hole in the middle)
- needle
- pencil with eraser
- an empty thread spool

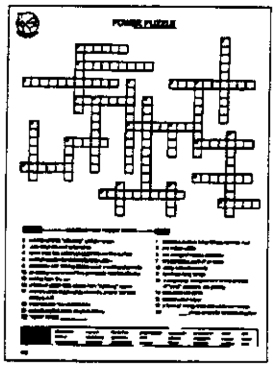
For All Groups:
- stapler, ruler, scissors
- tea kettle or pot with lid
- stove or burner
- an oven mitt
- kitchen or barbecue tongs
- cellophane tape
- water

Directions: Found on student worksheet.

Management suggestions:
Caution all students about the dangers of working around heat and steam. You may want to provide direct supervision with younger students while they work around the steam.

FOR THE TEACHER, cont.

Social Studies/Language Arts Activity: It's Powerful
No management suggestions.



Student Activity Page: Power Crossword Puzzle

ANSWERS

Across:
2. magnet **3.** generator
4. groundwater **6.** powerplant
8. turbine **12.** reservoir
15. solar **16.** nuclear
17. Persia **18.** current
21. Alexandria **22.** water

Down:
1. fossil fuel **2.** megawatt
5. electricity **7.** electrons
9. renewable **10.** conservation
11. biofuel **13.** volt
14. geothermal **15.** steam
19. heat **20.** wind

Math/ Social Studies Activity: "How Much Do You Use?
(no student worksheet)

Discuss how electric power companies know how much electricity is being used in a home by explaining the following: when your family pays for your electricity bills, you are paying for the quantity of energy delivered during a specific time period. This energy is sold in units called kilowatt-hours (a kilowatt-hour tells you how much electricity is being used). A device called a meter records the energy used by all the electric circuits in your home. You can read your own meter. Get someone to show you where the meter is outside your home. The meter has 4 or 5 dials – depending on how old it is. Newer meters have five dials.. The dials record kilowatt-hours in units of 100,000, 10,000, 1,000, 100 and 10. When the pointer is between two numbers , read the lower number. If it is between 0 and 9, read it as 9 because the zero is really a 10. If it is on 0 or between 0 and 1, read as 0 (the zero is really a 10, but is recorded as a zero).

Have your students do something like the following:
1. Locate your meter at home with the help of an adult. Read your meter and record the reading, the time and the date.
2. The following day, go out at the same time read and record your meter reading.
3. Subtract the previous day's reading from the next day's. The answer will be the amount of electrical energy you used.
4. Bring your data to school and combine it with the readings of the rest of your class. Using these figures, find the average electrical usage for your class.
5. Bonus: Call your energy company for information about how much energy various electrical appliances in your home use. Pick out the ones that use the most energy. Think about how you and your family could cut back on energy use. Talk this over at home.

Science Activities: If your students show interest in doing more activities with energy sources such as wind or solar power, you will find many references available that have excellent, fun activities. Some suggestions include:

a.) Construct or purchase a wind vane and anemometer (measures wind speed) and use them to see what the best site would be around your school to set up a wind-powered generator.
b.) Test various windmill propeller shapes and sizes to see which one works best.
c.) Use a solar cell, voltage meter, and mirrors to see which position and how many mirrors produce the greatest amount of electric current.
d.) Use various solar cells and model cars; test to see which combination goes the fastest.
e.) Burn nuts to measure the amount of biomass energy available in plant matter. Several resources have good experiments for this.

Values Clarification: Have student groups research various energy resources (include as many as possible). Then have a "town council" meeting where students act out the roles of various citizen groups who want "their" form of energy resource to be used for a proposed power plant in their community.

Environmental and Civic Concerns

If your class discusses energy resources and how their use affects the environment, you may want to include some of the common concerns regarding each one.

Biomass : The energy from biofuels is released by combustion and therefore they have to produce some pollutants. Most biofuels are less polluting than fossil fuels. For example, ethanol and methanol (chemically converted forms of biofuels) produce less carbon monoxide and other pollutants than fossil fuels. Wood typically has no sulfur emissions. Biofuels are renewable and can supplement or replace conventional fuels such as fossil fuels. They are also a way of recycling nature's wastes. However, they won't "catch on" as a replacement for conventional fuels unless it is cost-effective to use them. At present, wood wastes that can be converted into pulp and paper sell for much higher price than they would if used for energy. How cost-effective biomass energy is also depends on the promise of a long-term, nearby and steady source of biofuel material. For example, if a biofuel product has to be transported far or if it is expensive to process, then it won't seem attractive as an alternative to conventional fuel.

Fossil Fuels: The use of fossil fuels may result in harmful effects on the environment. These effects are: increased air pollution, *acid rain*, a chance of oil spills, *ground water pollution*, and possible *global warming*. Fossil fuel power plants are now under public and governmental pressure to control their emissions. As we learn to use more conservation and renewable energy sources, we need a "weaning" period away from fossil fuel use. At present the spotlight is on using more natural gas because, of all the fossil fuels, natural gas produces the fewest pollutants.

Another major concern is the tremendous rate at which we are using fossil fuels (a nonrenewable resource). Also, the United States imports a great deal of its oil not only because we consume more than we produce, but because we have depleted much of our original resources. Using renewable energy sources and conserving energy reduces the rate at which we are consuming fossil fuels and decreases our dependence on foreign oil.

Geothermal: Geothermal is a clean and reliable energy resource that isn't being used as widely as it could be. Some of the reasons for this are:
a) Geothermal resources often occur in forests or uninhabited areas. In these areas, some people object to the "industrial look" of power plants. **b)** Some geothermal resources are found in "protected" areas and cannot be developed. **c)** We can only use geothermal where we find it. Steam cannot be transported long distances, as can coal or oil. **d)** Because fossil fuels can be transported to a noncontroversial plant site, investors often find them more appealing.
e) As with fossil fuels, drilling for geothermal resources can be costly and time-consuming.
f) Some geothermal sites can produce polluting gases - though far fewer than those asociated with fossil fuels - about 1/1000 of the pollution produced by coal plants, for example. Geothermal power plants produce a fraction of the carbon dioxide and sulfur dioxide associated with fossil fuel power plants. In the past, geothermal power plants did produce some hydrogen sulfide, which is now almost completely removed with modern scrubber systems.

FOR THE TEACHER, cont.

Nuclear: Nuclear reactors don't cause the kind of air pollution that would come from a fossil fuel plant because nothing is burned. Nuclear fuel and nuclear reactions, however, emit harmful *radiation* that has to be carefully contained. Nuclear plants also have to ensure against an uncontrolled nuclear reaction which could cause great damage and release radiation. The biggest concern is the disposal of nuclear waste (left over after producing and using nuclear fuels). Nuclear waste gives off radiation for up to thousands of years before it is considered "safe." At present, there is a great deal of public concern regarding the safety of nuclear waste production and disposal.

Solar: Solar photovoltaic plants use rows and rows of huge solar cells which convert larger amounts of the sun's energy into electricity. At present, the wider-spread usage of these "sun farms" is affected by high cost, the need for direct and steady sunlight, and the amount of space required. Solar thermal plants also need a large supply of sunlight and quite a sizable amount of space. Also, as with wind farms, solar farms may not be considered an attractive addition to an otherwise beautiful landscape. Engineers are working on ways to reduce the cost and size of solar farms so that we can make greater use of the plentiful energy provided by the sun. Some individual homes far from power lines already get much of their energy from the sun.

Water: Hydropower is considered a relatively clean and economical energy source. However, hydroelectric power plants can cause great changes in the environment of the area in which they are located, because free-flowing rivers are dammed. This can affect the local plants, fish and other wildlife, recreation, and sometimes even other local industries. The use of hydroelectric power plants is not expected to increase much in the near future because there are very few possible sites left in the United States that can be developed. The Northwest has many hydroelectric plants with most of the sites already being used. For those remaining sites, the biggest concern is how development would affect endangered fish runs.

Tidal energy isn't very common because it is restricted by location, the harshness of tidal forces, and high costs. However, some energy experts see promise for the use of tidal power in the future.

Wind: Windpower is a clean, safe energy resource. Because the wind only blows at certain times, wind farms must be situated in locations which have frequent steady winds. For example, Oahu, Hawaii, with its steady trade winds, was home to wind farms which could have provided for 10 percent of Hawaii's energy needs. Even though wind energy is no longer being used to generate power in Hawaii, it is still considered an imporant part of Hawaii's energy plan. More than 16,000 wind turbines in California are generating 2.7 billion kilowatt hours of electricity every year. Researchers are trying to find ways to make wind electricity generators even more useful, such as improving methods to store energy for use when the wind doesn't blow.

Another issue is that some people see windfarms as artistic additions to the landscape, but others consider a large windfarm to be unsightly and, at times, noisy. This concern is addressed by locating windfarms far from residential and scenic areas. Finally, effects on bird populations are carefully monitored to make sure few accidents between birds and blades occur.