Energy for Keeps:
Electricity from Renewable Energy

An illustrated guide for everyone who uses electricity

by Educators for the Environment

Teacher Edition
Grades 6 -12

A comprehensive inquiry-based unit
correlated to all applicable content standards
for California public schools, grades 6-8,
and to the National Science Standards

Earth Science ▪ Environmental Science ▪ Physical Science ▪ Social Studies ▪ Language Arts

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- Pre- and post-assessments
- More student activities
- Full standards correlations for grades 6-12

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Again, we are proud to offer this First Edition of *Energy for Keeps: Electricity from Renewable Energy.* It is our hope that all of our readers — teachers, students and everyone else — will enjoy it and learn from it.

Marilyn Nemzer
Editor
Executive Director, Educators for the Environment
October 2003

ABOUT THIS PUBLICATION

We consider this publication to be a work in progress. Please send comments and suggestions for future editions to Educators for the Environment, 664 Hilary Drive, Tiburon, California 94920 or to energyforkeeps@aol.com.

Energy for Keeps: Electricity from Renewable Energy was developed in response to repeated teacher requests for a comprehensive and even-handed study of renewable energy sources. It will be in public libraries and in classrooms in middle and high schools throughout California thanks to funding from the California Energy Commission. We hope that other government agencies and utilities will choose to distribute this guide (or an edited version) to additional schools and libraries throughout the United States. It is through education that we can help others understand how the energy choices we make affect our lives, our environment, and future generations.

ABOUT EDUCATORS FOR THE ENVIRONMENT

Educators for the Environment is a division of the California Study, Inc., a domestic nonprofit 501(c)(3) educational organization. Our mission is stated in our name. Our expertise is in energy and environmental education, with a focus on developing and disseminating credible, up-to-date, objective educational materials for youth and for the general public.

Our organization is committed to increasing public awareness about things people can do to help solve today's (and tomorrow's) environmental problems. More specifically, we address environmental issues from the standpoint of educators, seeking to engage the public in resolving those issues.

TO THE TEACHER

Educators for the Environment developed this guide to introduce your middle and high school students to the history, availability, technologies, and management of the energy resources we use to generate electricity. The emphasis in this unit is on renewable energy resources. To be thorough, we also include information on nonrenewable energy resources. Our goal is to encourage young people to be more aware of the impacts of their energy-related decisions.

The Discussion pages provide the background material for each chapter. Teachers of various disciplines will find tie-ins to their own coursework, including History, Civics, Geography, Language Arts, Math, Physics, and Earth and Environmental Sciences. We hope you will use this background information for study, for discussion and debate, and as touch-off points for further research. In most cases, this material forms the basis of understanding needed by students for participation in the activities found at the end of each chapter.

The Teacher pages provide directions for guiding students through each activity. You will also find supplementary information, activity extensions, adaptations, and suggestions for integrating the use of computer technology. Most of the activities suggest the use of working in cooperative groups; many are interdisciplinary and promote investigative learning, including use of the scientific method. We recognize that many of you have time constraints and hope you will freely adapt these activities to meet your specific classroom needs.

Most of the Student pages contain student directions for the activities. Some Student pages include additional information relevant to a particular activity.

Appendix. In the Appendix you will find a number of useful tools, including a Scientific Method Form for student use with some of the activities, an extensive Energy Timeline (especially useful with the first activity, “The Energy Times”), a glossary, a suggested list of additional information resources, and overviews of correlations to National Science Standards and to all applicable California Standards for grades 6-8.

Website: www.energyforkeeps.org. The entire file for this publication is available as a free download from our website. Additions and adaptations to this guide, along with other supplementary information, will be posted from time to time on this website.

Pre- and Post-assessments. These learning tools will be appearing on our website and in future editions of this unit. The Pre-assessment will give teachers a format for determining the concepts and general knowledge that students hold regarding energy use prior to working with this unit. The Post-assessment will deliver a forum in which students can reassess and reframe their understandings once the unit is completed.

Content Standards Correlations. Correlation overviews for grades 6-8 are in the Appendix of this unit See www.energyforkeeps.org for full correlations for grades 6-12.

Bookmarks. You can order a class set of Energy for Keeps bookmarks. Order from our website, send an e-mail to energyforkeeps@aol.com, fax a request to 415.435.7737, or write us at Educators for the Environment, 664 Hilary Drive, Tiburon, CA 94920. Bookmarks are free until the first printing runs out and are available as a free download from www.energyforkeeps.org.

Questions or Comments. We welcome your questions, comments, and suggestions for future editions of this guide or of our website. We invite you to call (415.435.1527), write, fax, or e-mail us.

Chapter 5 Survey Results. If you are willing, please send us your class results of the survey, "Renewable Resources for Electricity in Our Region," from the Chapter 5 activity. We want to keep an ongoing tally representing all participants.

Safety. Some of the activities suggested in this guide require the use of heat. Please stress upon your students the importance of the safety precautions discussed in "To the Student" on the following pages.

TO THE STUDENT

BENJAMIN FRANKLIN IS THE MASCOT for this unit on energy. We chose him not just for his famous experiments with electricity, but also because he always sought — through hard work and ingenuity — to understand the world around him and to make a positive impact on it.

BENJAMIN FRANKLIN: 1706 - 1790

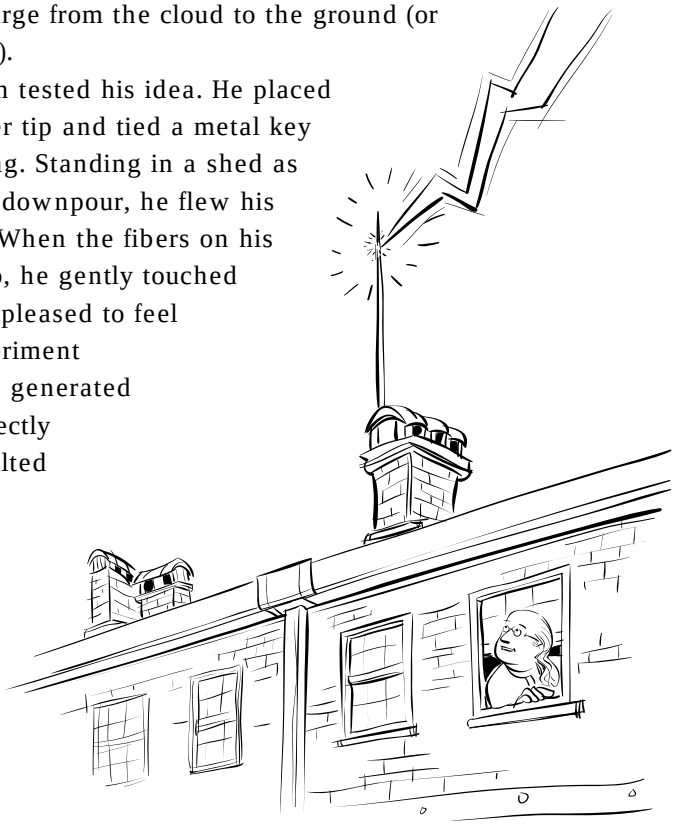
The best-known story about Ben Franklin is that he experimented with electricity by flying a kite in a raging lightning storm. In reality, he did not stand directly out in a storm, nor was he actually trying to have lightning strike his kite. One day in June of 1752, however, he did fly his kite while a storm was brewing, hoping to draw the "fire" (electrical charge) out of the clouds so that he could study it further.

By this time, Ben had already been studying electricity. He had correctly proposed that the sparks resulting from what we now call static electricity — an object of great fascination at that time — were due to excess electrical charges building up in an object and then leaping, or discharging, to an object of lesser charge. He speculated that thunderclouds also could build up excess electrical charges and that lightning was the discharge from the cloud to the ground (or other object, such as a house).

So on that stormy day Ben tested his idea. He placed a metal wire on a kite's upper tip and tied a metal key to the bottom of the kite string. Standing in a shed as protection from the potential downpour, he flew his kite up into the dark clouds. When the fibers on his kite string began standing up, he gently touched the key and must have been pleased to feel an electrical charge. His experiment confirmed that thunderclouds generated static electricity. He also correctly concluded that lightning resulted from the build-up and discharge of excess electrical charges.

NEVER A DULL MOMENT

Life with Ben must have been pretty interesting. Imagine living with him while he was testing his new invention, the lightning rod. A metal rod on the roof attracted lightning, which traveled safely to the ground through a wire, sparing the house from fire. In one experiment, he threaded the wire right through the inside of his own house along the staircase banister. One stormy night the family awoke to the sound of bells clanging wildly. It turned out that Ben had attached metal bells to the wire along the banister, so that he would be alerted when electricity passed through to the ground.



Ben was not just an avidly curious scientist, but also a writer, a publisher, an inventor, a civic leader, and a statesman. He had his own print shop where he wrote and produced a newspaper and an annual almanac, among other publications. His many inventions include the lightning rod, the first bifocal glasses, the Franklin stove (a freestanding fireplace), and the odometer (which measures mileage). He began the nation's first lending library and the first fire department. He was Postmaster General of the American colonies. He contributed significantly to the writing of the Declaration of Independence and worked for the abolition of slavery. To top it off, his close diplomatic and scientific ties with Europe influenced France to support the colonial Americans during the Revolutionary War.

As you can see, Ben Franklin was a man who made many valuable contributions to science and society, contributions that we can appreciate to this day.

SAFETY PRECAUTIONS

- Always review all directions before beginning any project or scientific experiment.
- Use caution and take your time when cutting and assembling any project.
- Always work with or near other people. Report accidents or hazards to your teacher (or other adult) at once.
- If working with heat or open flames, long hair should be tied back and long sleeves rolled up. Wear safety goggles, if available. Learn the location of safety equipment and supplies. If a fire starts, react quickly but do not run, and do not panic. Always get adult help. A small fire can often be extinguished with a fire extinguisher, baking soda, sand, or a fire blanket (or even a rug). If a piece of your clothing catches on fire, immediately drop and roll. If any fire cannot be extinguished immediately, the entire class should always exit the room.

CHAPTER 1

A BRIEF HISTORY OF ENERGY
How our use of energy has changed over time

VOCABULARY

A.D.
alloy
alternator
B.C.
blast furnace
charcoal
coke
combustion
dynamo
electromagnetism
energy conservation
fossil fuel
generator
geothermal
heat engine
hydropower
industrial
Industrial Revolution
internal combustion engine
manufacture
mass
mass produced
medieval
organic
passive solar
smelt
static electricity
Stirling engine
telegraph
textile
town gas
transmit
voltage
wet-cell battery

IF YOU'VE EVER LIT A CANDLE you know that making fire is as easy as striking a match. But for our earliest ancestors, the ability to create a spark and build a fire must have been astonishing. The energy that it brought changed their lives. For the first time, they had the power to produce heat and light whenever and wherever needed. Creating fire was just the beginning of our ongoing quest to use Earth's energy resources to make our lives better.

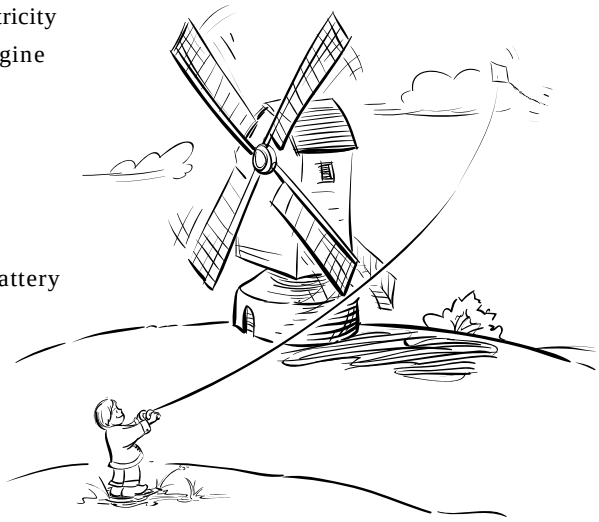
OUR FIRST ENERGY SOURCES

For most of the history of humankind, wood was (and still is for some) the mainstay of life — for shelter, for transportation on land and on water, and for heat and light when burned. Besides wood and their own muscles, people took advantage of the energy that the sun, hot springs, wind, water, and even animals could provide — to do work, to travel, and for recreation.

Ancient civilizations advanced the use of energy resources. Around 3,500 B.C. (about 5,500 years ago), Egyptians made the earliest known sailboats, harnessing the power of the wind to travel faster and further, increasing trade with neighboring lands. By 500 B.C., Greeks were building what we now call "passive solar" homes to make good use of the sun's light and warmth.

By 85 B.C., Greeks were freed from grinding grain by hand with the invention of water-wheel-powered grain mills, an early example of industrial technology. Around the same time, Romans were enjoying hot baths with water heated from geothermal hot springs.

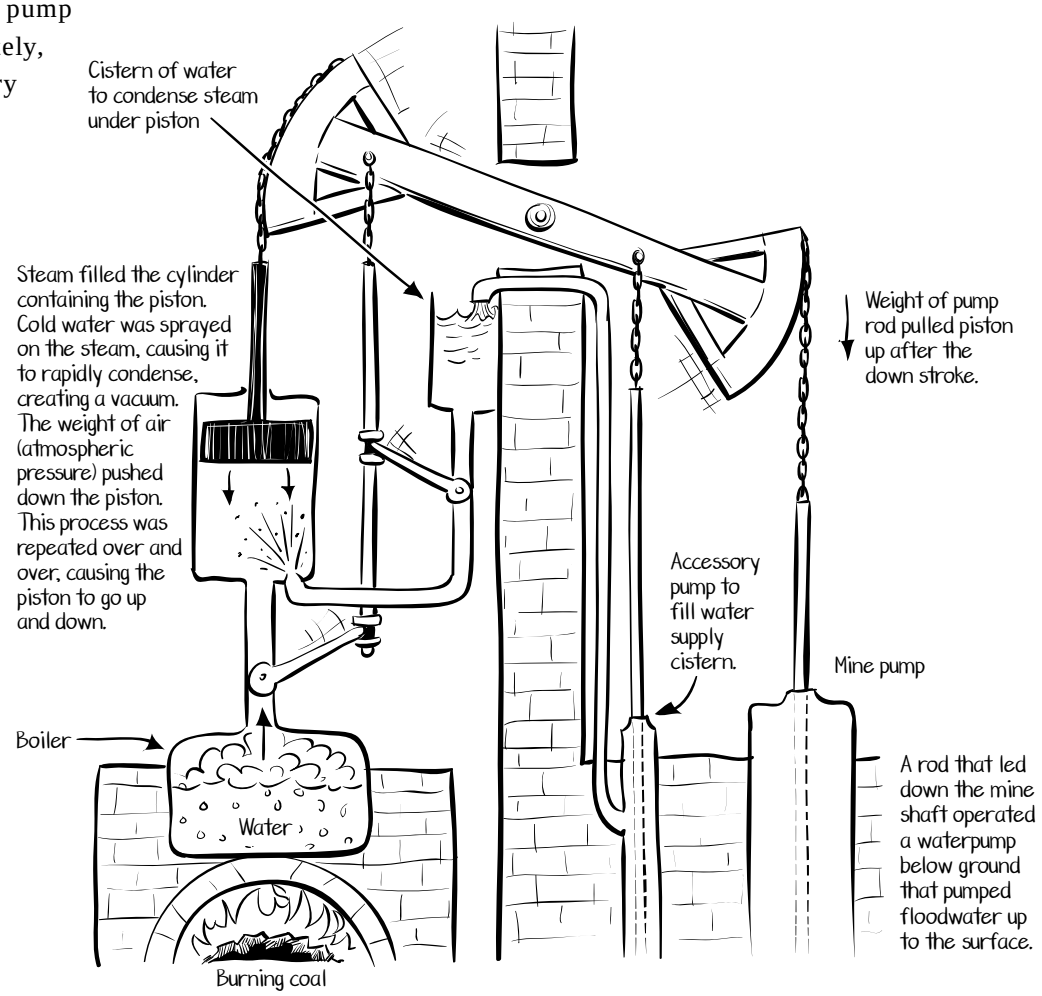
By 640 A.D., in what is now Iran, the Persians were building windmills to capture wind's power to grind grain. Europeans adopted the idea and used modified versions during medieval times.



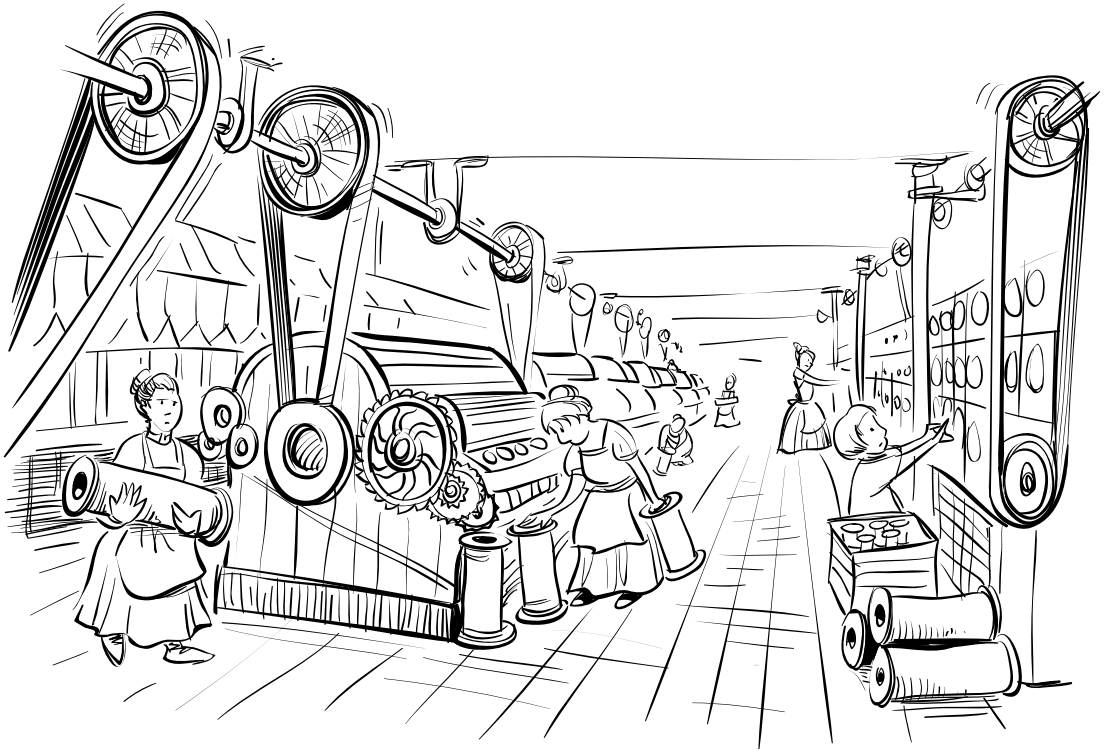
Wood was used extensively during this time. In the 1300s, Germans built the first blast furnaces to burn wood at extremely high temperatures, allowing them to produce large quantities of iron. Much of Europe's forested area was logged during the next few centuries for the production of iron and building of ships.

COAL POWERS INDUSTRY

Although people burned coal for heat at least as early as the first century A.D., it took more than a thousand years for coal to become a dominant source of energy. By the late 1600s coal had become more popular than wood in England. In fact, the British had lots of coal. But they also had flooding problems from groundwater flowing from the rock deep in the coal mines. They needed a way to pump out the water. Fortunately, in 1698, Thomas Savery invented one of the earliest workable heat engines — one that used steam to operate a water pump that solved the flooding problem. Blasts of steam from water boiled by burning coal kept the engine working whenever the pump was needed.



An early steam engine pumps water from a coal mine.



A steam-driven cotton mill in the 1700s, where machinery was powered by steam engines located in a separate room

The textile industry was also flourishing in England during this time. It, too, saw revolutionary change, as inventors developed coal-fired steam-driven machines to spin yarn and weave cloth faster and cheaper than the water wheels that powered the early factories. (Water wheels still remained popular, however, and people continued to use them — as they had for centuries — for such work as lifting water for irrigation and rotating huge stones to grind grain.)

THE INDUSTRIAL REVOLUTION STEAMS AHEAD

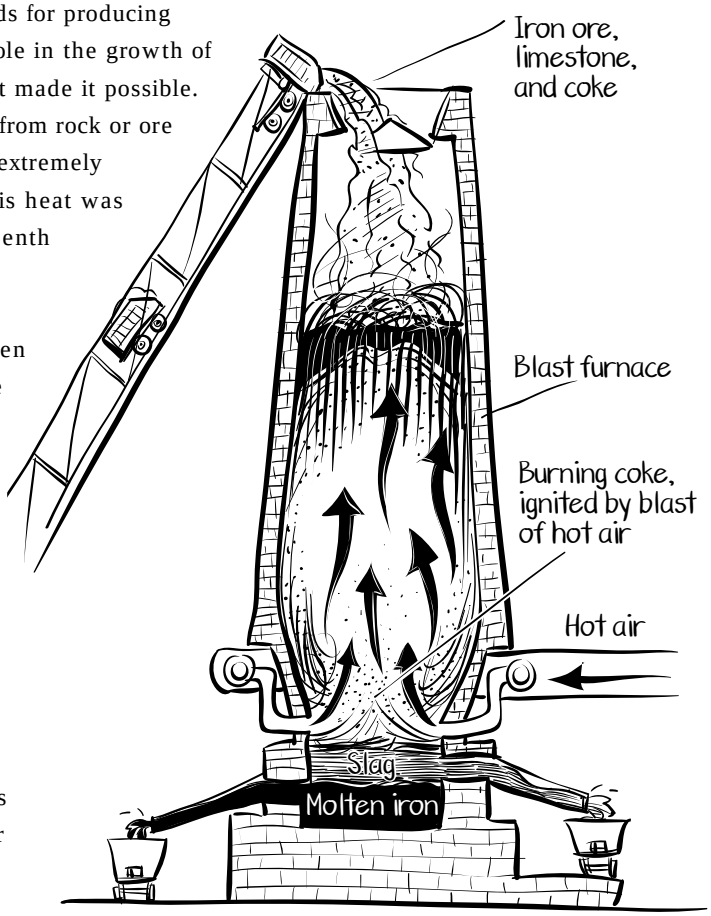
By the early 1700s, industry was booming, with improved steam engines providing power for industry to process raw materials and manufacture products. The new engines required ever-greater amounts of coal to heat water for steam, so the coal-mining industry was a big business. New opportunities beckoned, and lifelong country dwellers migrated to places where they could take jobs in factories and mines, places where people endured hardship for the promise of progress. Populations increased rapidly in areas where there was employment. The first industrial cities were born.

IRON WORKS

Of all the advances that fueled the Industrial Revolution, one of the most important was an improvement in methods for producing iron. Heavy machinery made of iron played a key role in the growth of manufacturing, and coal was the energy source that made it possible.

The process of extracting iron (or other metals) from rock or ore is called *smelting*. To smelt iron from rock requires extremely high heat. The first furnace capable of generating this heat was the blast furnace, developed in Europe in the fourteenth century. It used charcoal (made from wood) as fuel. Modified over time, blast furnaces were burning hot enough to actually melt iron ore. The melted iron then separated from the ore and ran to the bottom of the furnace, where workers could collect and shape it (producing what we still know today as cast iron).

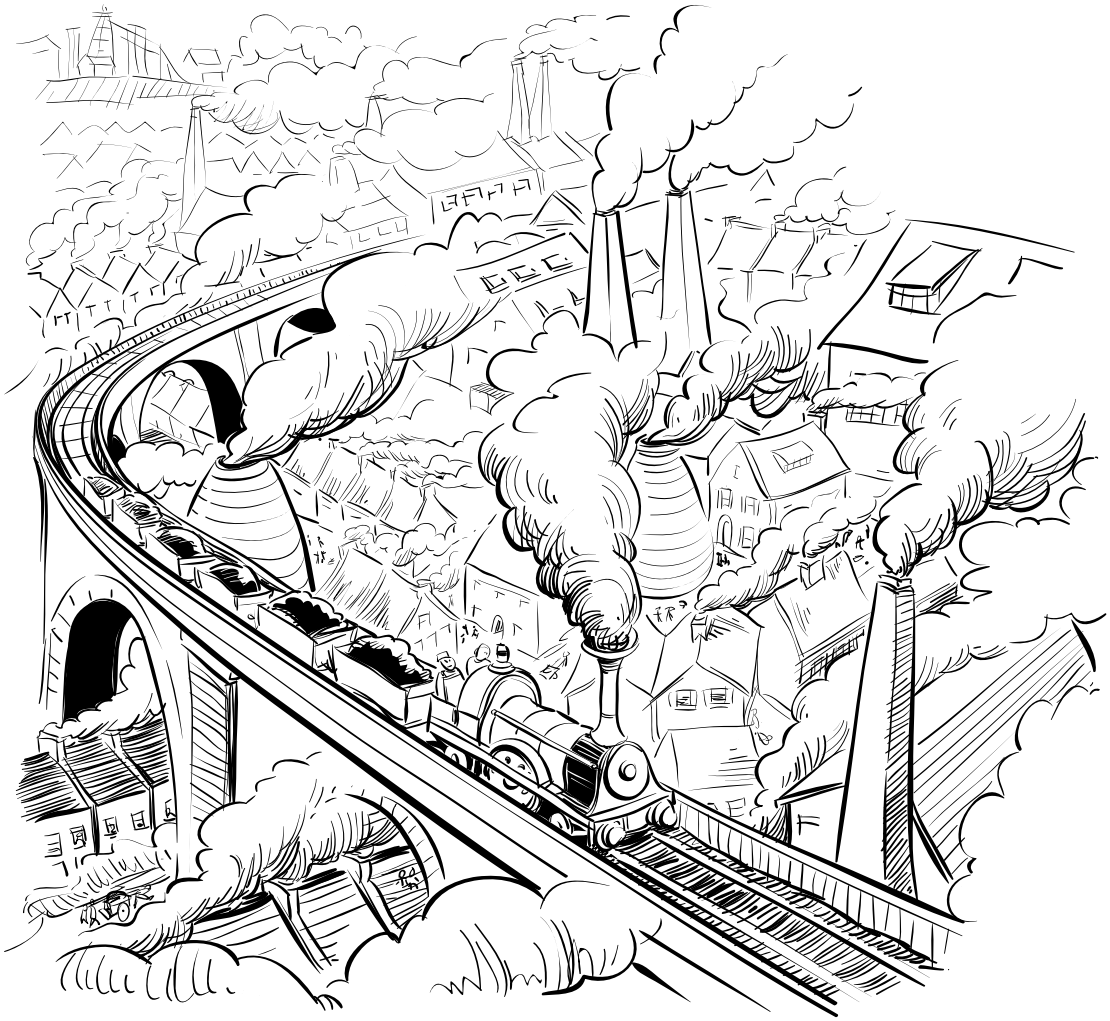
Coal was more widely available and burned hotter than charcoal. But the sulfur in regular coal made iron too brittle when smelted. In 1709, the development of coke — coal with the sulfur removed — allowed the use of coal in blast furnaces, revolutionizing the iron industry. Blast furnaces were fired up daily, churning out tons of iron and, later, a new metal, steel (an alloy, or mixture, of iron and carbon). Not only were factories burning coal products to make steam to power their machinery, blast furnaces were burning them too, to produce the metals needed for industry's machines.



Blast furnace

The development of coke, a substance derived from coal that reaches extremely high temperatures when burned, was also a major advance at that time. It allowed greater production of iron, which meant people could build even more machinery.

During the 1700s industry and machinery continued to evolve. Steam engines — now improved even more by James Watt — were put to many new uses. By 1783, the first working paddle-wheel steamboat was chugging up a French waterway. Not long after, people started using "town gas" made from coal to light streetlamps in Cornwall,



Industrial city

England. These both were big developments. Now goods and people could travel faster, and work could continue after dark.

As the next century began, steam engines had become bigger and better than ever. Fired mostly by coal, they provided five times the pressure of Watt's early engines. They were now powerful enough to drive the mighty locomotives that made history as they hurtled across continents in record time. Steam engines were puffing away in factories, with smokestacks towering above most city landscapes. Sources of energy that had once seemed so amazing had become commonplace and essential.

A "STIRLING" IDEA

Robert Stirling of Scotland designed an engine in 1816 that worked without burning a fuel. It used heat (as from the sun) to expand and contract air, causing a piston to move up and down. However, Stirling's invention was overlooked and crowded out by the already popular steam engine. Practical uses for the Stirling engine would not be developed until almost 200 years later (see page 92, Solar Dish Engines).

EXPERIMENTS WITH ELECTRICITY

Even before the end of the eighteenth century, electricity had entered the picture. In the mid-1700s, Charles Dufay, a Frenchman, and Stephen Gray, an Englishman, had both conducted important experiments investigating electricity. And, in America, Benjamin Franklin's famous kite-flying demonstration had proven that lightning is electricity.

In the early 1800s, Italian Allesandro Volta produced electricity from a wet-cell battery for the first time. And American Joseph Henry, Englishman Michael Faraday, and Danish physicist Hans Øersted began experimenting with electromagnetism.

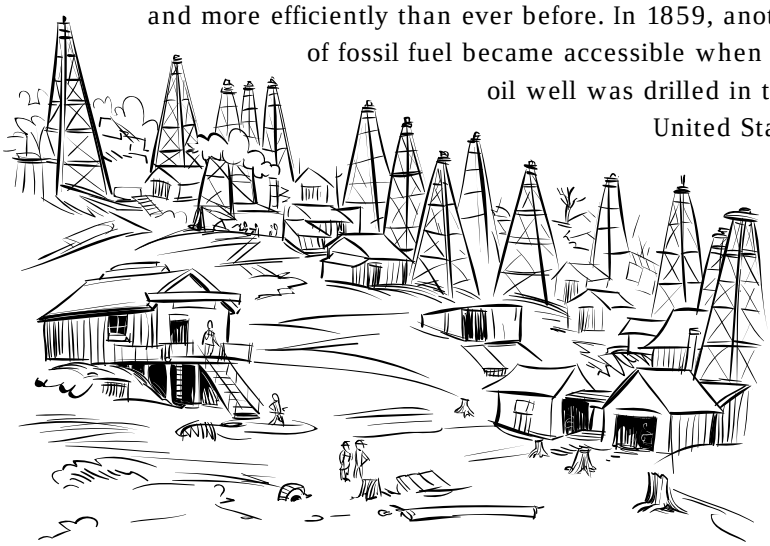
By the 1830s, scientists had demonstrated that electricity and magnetism could be converted into one another. Soon huge electromagnets were lifting weights of more than a ton (2,000 pounds, or 907 kilograms), and early generators, called dynamos, were producing electricity by spinning magnets between wire coils. Electromagnetism was used in the telegraph to tap out messages in Morse code. This first electronic communication — along wires and across long distances — was one of the first practical applications of electrical energy.

AMBER AND "ELEKTRONS"

The ancient Greeks coined the term "elektron" (meaning amber, which is fossilized tree sap) and noticed that when rubbed, amber "attracted" fluff. (We now know that this is due to the force of static electricity.)

FOSSIL FUELS POWER INDUSTRY AND TRANSPORTATION

In the mid- and late-1800s industry grew and factories spread, especially in Britain, Germany, France, and the United States. The demand for coal and other fuel increased. To meet this demand, machines were developed to extract coal from the earth more quickly and more efficiently than ever before. In 1859, another type of fossil fuel became accessible when the first oil well was drilled in the United States.



First oil derricks in the United States

The following year, in Belgium, gasoline (refined from oil) was used in the earliest working internal combustion engine, paving the way for development of the automobile.

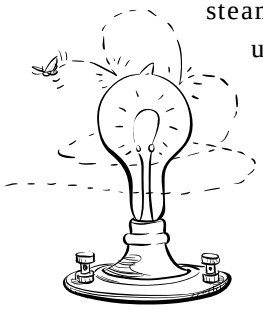
In 1885, Karl Benz unveiled the first motorcar. Made in Germany, it was a three-wheeled, gasoline-powered model. A fellow German, Gottlieb Daimler, followed two years later with a four-wheeled version. Soon after, Frenchmen Edouard and André Michelin developed the first air-filled tires, which were easier to make and to use than the original solid rubber tires. Each year automobiles became more popular and more powerful. And each year demand increased for the gasoline needed to run them.

People wanted to travel faster and further. Before long, coal became a fuel for steamships. In 1897, Englishman Charles Parsons installed a steam engine in his boat, *Turbinia*, and outran every ship in the water — even the huge three-masted clippers that, until then, had been the fastest ships at sea.

The *Turbinia*

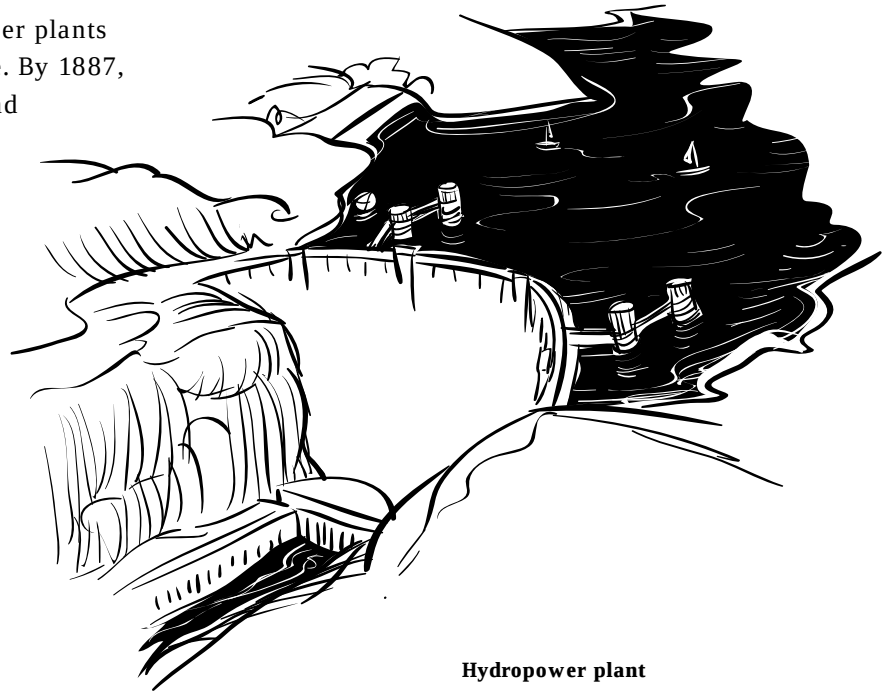
ELECTRIC POWER - A CHANGING WORLD

The period of rapid growth in the use of fossil fuels coincided with the development of electric power. By early 1870, Zenobe Gramme had perfected the dynamo, making it the first practical generator of electricity. A decade later, Parsons developed an even more efficient steam engine for driving the new generators. Widespread use of electricity was now possible.



During this time Thomas Edison developed many handy uses for electricity, including — in 1879 — the light bulb. And just a few years later Edison's first light and power operation opened in New York City.

It wasn't long before electric power plants began to dot the American landscape. By 1887, California's first hydropower plant had opened in San Bernardino. In 1896, America's earliest large-scale hydropower plant was completed at Niagara Falls, New York. Its voltage was high enough to transmit power miles away to the city of Buffalo. At that time, few people imagined that hydropower would some day provide nearly one fifth of the world's electricity.



Hydropower plant

Soon the frontier of electricity was further expanded by George Westinghouse and William Stanley, developers of the electric alternator, which made it possible to send electricity over long distances.

The appetite for convenient electric power — often provided by coal-fueled steam-driven power plants — continued to grow. Large cities were putting electricity to another use — powering trolley lines for a convenient form of urban transportation. By the end of the nineteenth century, life had changed dramatically.

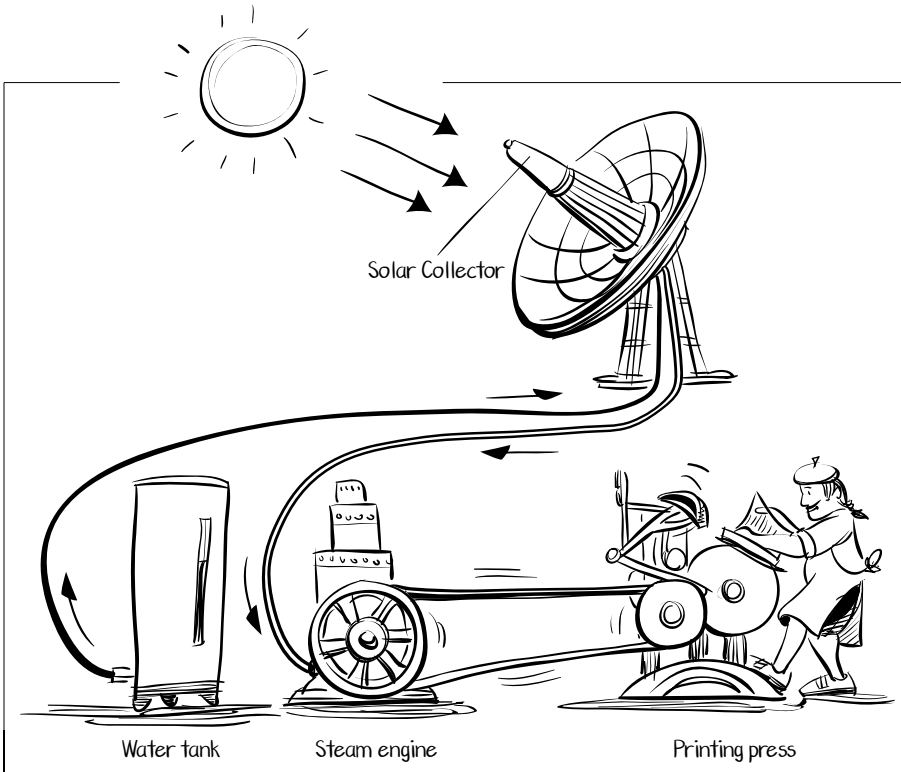
MEETING THE NEEDS OF THE TWENTIETH CENTURY

The 1900s brought even more changes. Cheap power and improved metals made mass production possible, and in 1908, the first inexpensive car — Henry Ford's Model T — rolled off the assembly line in the United States. In 1904, a pioneering power plant in Italy produced electricity using geothermal energy, and a year later, the first solar photovoltaic cells were invented.

In 1905, Albert Einstein formulated his revolutionary theory that mass is actually energy. His idea opened the door for others to later discover the process by which mass can be converted to energy, thus paving the way for the future development of nuclear power.

Just a few years into the twentieth century, hydroelectric power was producing 15 percent of America's electricity. In the 1920s, small wind turbines were also producing electricity, primarily in rural areas in the United States and France. But it was fossil fuel energy that dominated the power scene. Coal, oil, and natural gas were inexpensive and convenient, and people believed that resources were plentiful. With fossil fuels readily available, the United States led the way in manufacturing, contributing 35 percent of all the industrial goods produced in the world.

By the 1930s, automobiles swarmed over the countryside, and the total mileage of surfaced roads soon exceeded that of railroads. By mid-1940, buses and cars had replaced many trains, and thousands of miles of electric trolleys and tram lines had been shut down. Now, in highly industrialized countries, almost every home, office building, and factory had electricity.



A solar steam engine runs a printing press at the Paris Exhibition in 1878.

THE FIRST SOLAR ENGINE

In 1861, Auguste Mouchet patented the world's first solar steam engine. It used mirrors to focus heat from the sun onto a boiler to make steam for steam engines. In 1878, at the Paris Exhibition, Mouchet and fellow inventor Abel Pifre used a solar steam engine to run a printing press. Pifre, a newspaper publisher, later demonstrated how efficient the solar engine printing press was by printing 500 copies per hour of his Soleil (Sun) Journal, in a large public garden in Paris. Unfortunately, these engines were crowded out when the gasoline-powered engine was perfected. It would be decades before solar power would once again create steam to do work.

NEW SOURCES OF POWER

The late 1930s and 1940s saw the first development of nuclear technology. German Otto Hahn and Austrian Lise Meitner, along with several other scientists, unveiled the process of nuclear fission — the release of energy by splitting uranium atoms. Italian Enrico Fermi worked in the United States to design and build the earliest nuclear fission reactor. The world's first nuclear-powered electricity plant opened in 1954 in what was then the Soviet Union. Before long, dozens of nuclear power plants were providing electricity for countries around the world.

The last half of the twentieth century saw significant progress in the development of energy technologies using wind, solar, and geothermal energy. These technologies were all producing electricity without burning fossil fuels. Solar photovoltaic cells were improved in the 1950s to generate electricity reliably. Also during this decade NASA began using hydrogen fuel cells in its space programs. The first American geothermal power plant began operating in 1960, generating electricity from natural steam brought up from wells underground.

Even though new energy technologies were developed, fossil fuel use held the lead in industry, transportation, and generation of electricity. By the early 1980s, three out of every four power plants in the United States burned fossil fuels, and almost every household in America owned at least one car or used gas-powered public transportation.

WHERE DO WE GO FROM HERE?

Today, at the beginning of the twenty-first century, almost 85 percent of the energy we use in the United States comes from fossil fuels. There are growing concerns about our dependence on these diminishing resources.

Fortunately, there are alternatives to the overuse of fossil fuels. We can conserve energy, and we can take advantage of the many other energy choices we have available. We can make energy decisions that will improve our lives, the lives of future generations, and the environment in which we live.

THE ENERGY TIMES

PLANNING OVERVIEW

SUBJECT AREAS:
Language Arts, Fine Arts, Earth Science, Environmental Science, Physical Science, History, Geography, Government

TIMING:
Preparation: 30 minutes
Activity: 3-5 45-minute class periods

Summary

Students investigate past and present energy use while developing their own historical newspaper.

Objectives

Students will:

- Recognize that energy use has evolved over time to meet the changing demands of society.
- Explain why energy use is a newsworthy topic.
- Conduct research on an historical period.
- Demonstrate skills needed to publish a special edition newspaper on energy.
- Evaluate their finished product, *The Energy Times*.

Materials

Student Handout: "*The Energy Times*: Getting Out the Newspaper"

"Energy Timeline" (in Appendix)

A variety of local, state, or national newspapers

Pens, pencils, marking pens, paper

Research materials including books, encyclopedias, Internet access, library references

Tape, rulers, rubber cement, glue sticks, scissors

Optional: Tabloid-sized paper (Rolls of newsprint are sometimes available from local newspapers.)

Optional: Computers and word-processing programs

Optional: Computer graphics programs

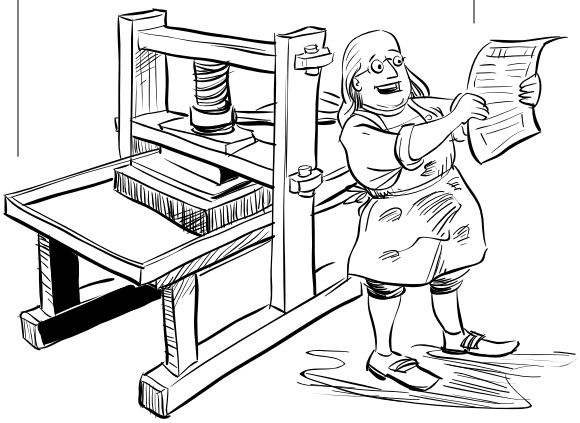
Optional: E-mail or web page software and Internet access

Making the Link

Energy affects our lives every day. In fact, there has never been a time in history when humans have not used energy. Energy use has always been a newsworthy topic, whether communicated by word of mouth, by stone tablet, or by the printed word.

The advent of practical ways to use electricity, along with the development of the internal combustion engine (such as that found in cars and trucks), brought an ease to our lives that most of us are not willing to give up. Our electrical devices and our cars are considered necessities of modern life.

Energy issues are frequently front page news. The resources we use to produce electricity and run our transportation have become very valuable commodities. The resulting problems associated with energy use (such as pollution, gasoline shortages, electrical blackouts) are also common topics of everyday life.



By studying the history of energy use, we can learn more about where we stand in the present, as well as how to plan our future.

Since energy use plays a significant role in our daily lives and in the global community, using this topic for the production of a newspaper should be an easy concept for students to grasp.

Teaching Notes

In this project the class will develop its own newspaper, *The Energy Times*, which will cover society at a chosen time in history. The focus will be on energy production and use, and will include newsworthy events and inventions as well as interviews and human interest stories.

Newspapers are collective efforts, which are excellent for developing interdisciplinary skills, including those of research, composition, word processing, hierarchical decision-making, organizing, proofreading, illustrating, and editing.

Information found in the Chapter 1 Discussion and the handouts, "*The Energy Times*: Getting Out the Newspaper" and the "Energy Timeline" will help guide the project.

Warm-up

After students have read the Discussion for Chapter 1, "A Brief History of Energy," ask them if there has ever been a time when humans have not used energy. Generate a discussion about what students know concerning energy use over time. During the discussion, make a list of various energy resources on the blackboard. Try to include as many resources as possible.

Ask students if there is ever a day in their lives when they don't use energy. If they were to create a newspaper about a day in their community, could the activities or events they describe have taken place without some form of energy use? Elicit students' views regarding pollution, transportation, space heating, and technological advances. Discuss our daily dependence on electricity (which usually only comes to mind if there is a power failure).

The Activity

1. Bring in some recent newspapers. Break students into informal groups and have each group scan a newspaper to identify and name the various sections.

2. As a class, generate a list of the different sections of the newspaper and what information each contains. After some discussion, distribute "Getting Out the Newspaper" and have students check to see what other sections might be included. Add these to the list. Tell students to keep this handout.

3. Explain that they, as a class, are going to develop their own newspaper with the theme of energy. Tell students that different groups will be responsible for various sections of this newspaper.

   Explain that their newspaper, *The Energy Times*, will not be like a daily newspaper, but will reflect a longer range of time and a particular historical period. However, it will be written as if the events were occurring in the present.

4. Discuss the different jobs involved in developing a newspaper. These include editors, reporters, photographers, artists, cartoonists, proofreaders, word processors, designers and printers. For those teachers who integrate technology into the classroom, please note the possibilities here for Internet research, word processing, design, creation and importing of graphics, and document layout.

5. Divide the class into working groups and have each group choose (or assign each group) a different section of the newspaper on which to work. Possible sections might include News and Features, Editorial, Entertainment and Leisure, Business, Sports, and Advertising.

6. Refer to the handout, "Getting Out the Newspaper" and make sure that everyone understands the jobs described. Then have each group select an editor, reporters, and any other jobs they think necessary to get the job done.

7. Hand out the "Energy Timeline" and allow groups some time to review it. Tell them to suggest a 50- to 100-year time period that they think would be most interesting to focus on as a class. Or you may wish to pick one yourself, (e.g., the era of the Industrial Revolution, which started in the early 1700s and continued to the mid-1800s).

8. Have groups brainstorm what kinds of articles, features, illustrations (or, when possible, scanned graphics) they could have in "their" section of the newspaper.

   For example, if the time period 1700-1750 is chosen, News/Features may have a description of T. Savery's steam engine being used to pump water from flooded coal mines. They might compose some interviews with coal miners and with Mr. Savery. The Entertainment/ Leisure section could have a feature on fashions made from fabric from the new textile mills. The editorial department might have a commentary on the terrible conditions in the coal mines or applaud the march of progress brought about by increased coal mining production. The business section might have a feature comparing the benefits of various water-wheel designs for factories.

   Assist each group in determining where to find the information it will need to write convincingly about its choices.

9. Give students a deadline for completing their sections. Allow class time for groups to work on research, composition, proofreading, and word processing. If possible, have each group save its work on a disk. If you have a scanner, groups may wish to scan in any illustrations or photographs they have found during their research. Editors should supervise the work, assisting in editing and proofreading as well as layout.

10. Have editors from each group assemble the newspaper. Have them refer to actual newspapers as a model for layout. They may be assisted by their group's word processor.

Wrap-up

As a class, share and evaluate the final product. You may wish to have each group present its section. Examine and discuss the various sections to see whether each reflects the theme of energy use during the selected time period. Elicit comments about the effect energy use had on lifestyle and the environment during the time period studied. Compare this to the effects energy use has had in other time periods, including the present.

Discuss the process of composing a newspaper. Compare the process of producing an "historical newspaper" with that of putting out a daily newspaper.

You might want to reproduce the newspaper in sufficient quantities to be given to other classes and taken home to family and friends. (If you are especially pleased with the product, you may wish to have your local newspaper printer publish your paper on newsprint.) If distributed beyond your classroom, you may wish to have a small student group gather feedback from others about the newspaper. This feedback could be used as part of the evaluation process.

Assessment

Have students:

- Explain why energy use is a "newsworthy" topic that affects all aspects of life at any given time.
- Demonstrate an understanding of how energy use has changed over time in order to meet the demands of progress.
- Recognize that energy use has come with a price.
- Work cooperatively to develop a section of a newspaper.
- Assume a specific task related to newspaper development.
- Evaluate the finished product.

Extensions

- Further integrate your newspaper with technology. For example, create a "paperless" product by posting your newspaper on a web page, sending it as an e-mail attachment, or copying it onto CDs to send to your "subscribers." Use PowerPoint or other presentation software to produce your newspaper.
- Brainstorm other time periods that could be covered in a future newspaper. Have each group compose its own newspaper, each representing different time periods. Compare and contrast the different time periods.
- Encourage students to read their daily newspapers and to look for energy-related topics. Have them bring in news clippings to share.

"*The Energy Times*," adapted from Project Wet, "Water: Read All About It."

THE ENERGY TIMES: Getting Out the Newspaper

Newspapers are designed to report on current events. Yet they can be considered journals that record history. They also are places where people can exchange ideas and points of view. An historical newspaper such as *The Energy Times* differs from a daily newspaper in that it is a fictionalized version of actual events from a specific time period.

Many people work together to produce a newspaper.

Reporters seek and gather information about events they are assigned to cover. Reporters write (and rewrite, if necessary) the "copy" (article, story, or column). Reporters tell who, what, when, where, why and how in an interesting, easy-to-read style. For a daily newspaper, reporters often conduct interviews to get their information. For *The Energy Times*, reporters can quote from imaginary interviews based on research.

Photographers record images that illustrate a story and capture the interest of the reader.

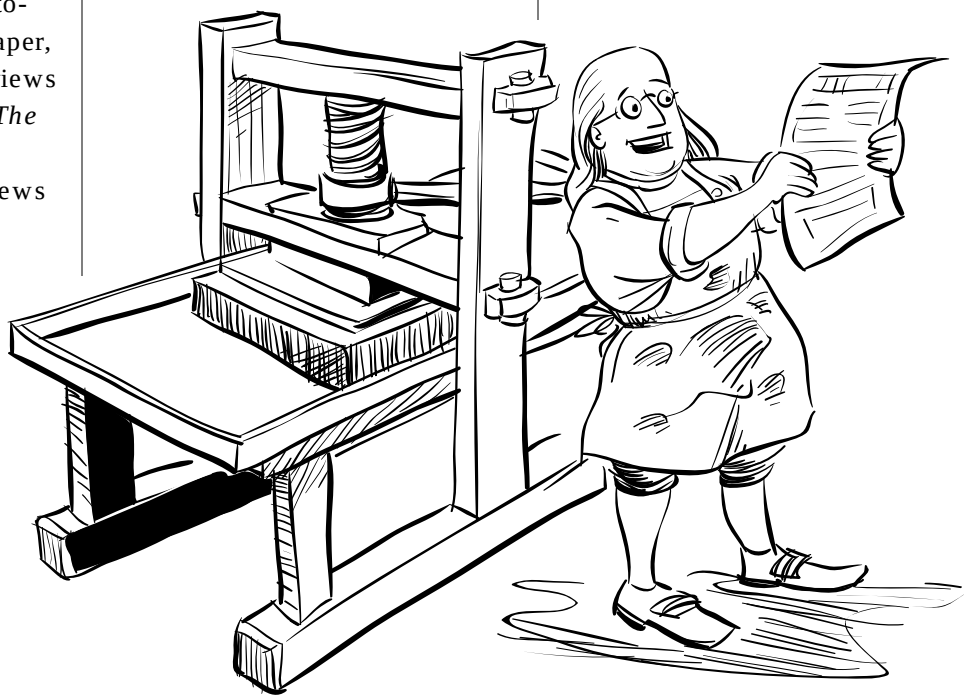
Graphic artists enhance a story and provide illustrations and images such as maps, charts, and graphs. For *The Energy Times*, graphic artists and photographers may also create illustrations or "photographs" using models with props and costumes. Actual photos and other images can be downloaded from the Internet or scanned from other public domain resources.

Editors determine, along with the rest of the staff, which stories to report and where to place them. They also review rough drafts and comment on additions or deletions that should be made. Editors for *The Energy Times* will also put the various sections together to complete the final product.

Managing editors or **page editors** lay out and arrange the stories in logical order. For *The Energy Times* the editors of each department assume this duty.

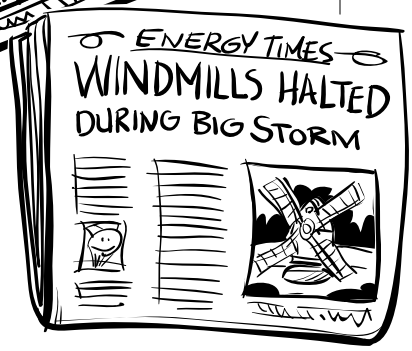
Proofreaders make detailed corrections on all written copy and graphics.

Ad managers decide which ads to use and where to place them in the paper. **Advertising copywriters** write ads, and graphic artists illustrate the ads.



Most newspapers are divided into sections.

News and Features. All the articles that the editor and staff feel are important are in this section. For *The Energy Times*, these stories will cover some aspect of life related to energy use. Some examples: "Amazing New Steam Engine Saves Drowning Coal Miners!" or "World's First Geothermal Electric Power Plant Opens."



Entertainment and Leisure. In this section, news and stories about society's leisure-time and recreational activities are found. In newspapers today, this category includes fashion, movies and television, music, art and community events. For *The Energy Times*, the time period that the class chooses will dictate the aspects of entertainment and leisure to be covered. Every attempt should be made to relate the stories to energy use in some way. Two examples: "New Fall Fashion From Factory-Woven Cloth" or "Exploring the Wonders of Steam-driven Ocean Travel."

Sports/Weather. For *The Energy Times*, depending on the time period, sports and weather may be difficult to research, especially as these subjects relate to energy. Some examples: "Stadium Lit With Modern Electric Power — More Nighttime Games Possible" or "Windmills Halted During Huge Storm." (If desired, this section may be eliminated for *The Energy Times*.)

Editorials. This section presents the opinions of the newspaper staff and contributing writers. Readers are also invited to respond with their own thoughts in the form of letters to the editor. For *The Energy Times*, students will assume the roles of editors, contributing writers, and readers, responding to hot-button energy issues of the time period chosen. Some examples: "New Factories Are Driving Hand Weavers Out of Business" or "New Steam Engine Steps Up March of Progress."

Advertising. Without people purchasing space for ads, most newspapers couldn't survive. The advertising department of *The Energy Times* can create ads that reflect all aspects of society at the time but should try to focus on those that relate to energy use. Two examples: "Don't Be the Last on Your Block to Buy the New Model T Ford" or "Feeling Under the Weather? A Visit to Saratoga Hot Springs Will Fix You Right Up!"

CHAPTER 2

ENERGY AND ELECTRICITY
How we produce most of our electricity

VOCABULARY

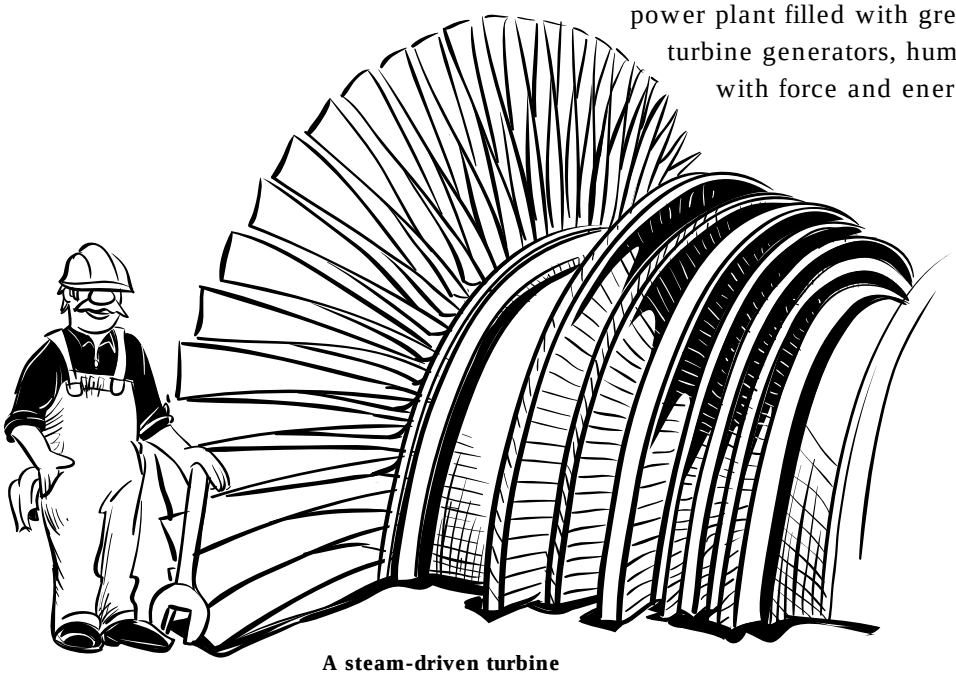
alternating current (AC)
ampere (amp)
atom
baseload power
blackout (brownout)
centigrade
complete circuit
condenser
conductor
demand
direct current (DC)
electric current
electrical energy
electron
energy conversion (transformation)
Fahrenheit
generator
grid
heat (thermal) energy
kilowatt
kilowatt-hour
magnetic field
mechanical energy
megawatt
negatively charged
neutron
nucleus
peaking power
positively charged
power load
proton
resistance
static electricity
substation
transformer
transmission lines
turbine
vaporize
velocity
watt
watt-hour

HOW OFTEN DO YOU THINK ABOUT where your electricity comes from? If you are like most of us, you don't give it too much thought. This is pretty normal, because most people in industrialized countries like the United States are often many miles of wire removed from the places where their electricity is generated. (Those of us lucky enough to have our own way of generating electricity — such as from a wind turbine or solar panels — are still the exception, at least in the United States.) Behind the scenes, energy producers are working day and night to provide us with a steady supply of electrical power.

Using improved technology and know-how, today's electricity suppliers have figured out plenty of different, and sometimes complex, ways to generate electricity. But the most common and widespread method uses an age-old apparatus, the turbine, attached to a much more modern device, the generator. For over 120 years these two seemingly simple machines have worked together in power plants to produce vast quantities of electricity, revolutionizing the way people live, work and play.

A TYPICAL POWER PLANT

Basically, a turbine, a generator, and a source of energy make up a power plant, no matter how large or small. Even a single wind turbine can be thought of as a power plant. But usually, when we think about electricity generation, we picture a huge steam-driven power plant filled with great turbine generators, humming with force and energy.



A steam-driven turbine

The Turbine

A turbine is any device with blades attached to a central rod, or rotor, that spins when a force hits the blades. This spinning motion can do a lot of useful work. Water wheels and windmills were actually our first turbines. Their wooden blades captured the power of wind or rushing rivers to lift water for irrigation or to rotate great stones to grind grain.

It wasn't until the 1880s, when the generator was first invented, that people began using turbines to produce electricity. Today we have many turbine designs. Some are small or have just a few main blades attached to the rotor (wind turbines, for example). Some turbines (such as those that use steam) are enormous, standing much taller than the average person. These very sophisticated turbines have thousands of different-sized blades attached in a complicated pattern to the central rotor. These huge turbines are the kind used in most of today's large power plants.

Turning the Blades

The force of high-pressure steam powers most of today's turbines. We usually make this steam by burning a fuel (coal, natural gas, oil, or biomass) to heat water above its boiling point. (Burning, or combustion, is a chemical reaction in which a fuel combines with oxygen and gives off heat.)

We don't always have to burn something to produce the heat needed to make steam. The heat can also come from nuclear reactions (in a nuclear power plant), from the sun (in a solar thermal plant), or from deep underground, using the earth's natural hot water and high-pressure steam (in a geothermal power plant).

Forces other than steam, such as falling or running water, the wind, and ocean waves and tides, can also spin turbines. There are even ways we can generate electricity without using turbines at all. (See Chapter 3, "Energy Sources for Electricity Generation.")

Generating Electricity Using Electromagnetism

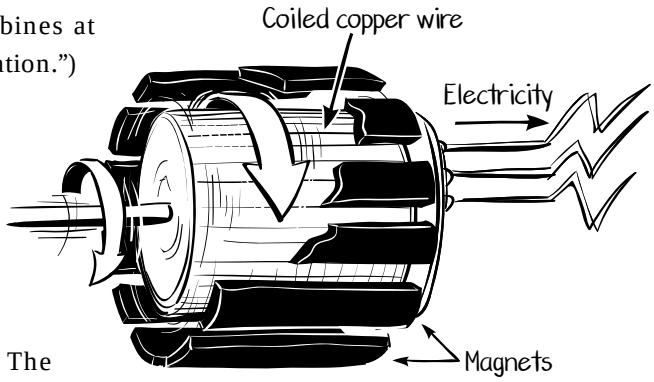
In a power plant, the sole function of a turbine is to spin a generator. A generator changes the mechanical energy of spinning to electrical energy. In a generator, coils of copper wire attached to the rotor spin inside a space surrounded by huge stationary magnets (or, as an alternate design, the magnet spins inside loops of wire). The magnetic field causes electrons in the wire to move, creating an electric current.

WHAT IS ENERGY?

Energy is the capacity to do work — to move something, heat it up, or change it in some way.

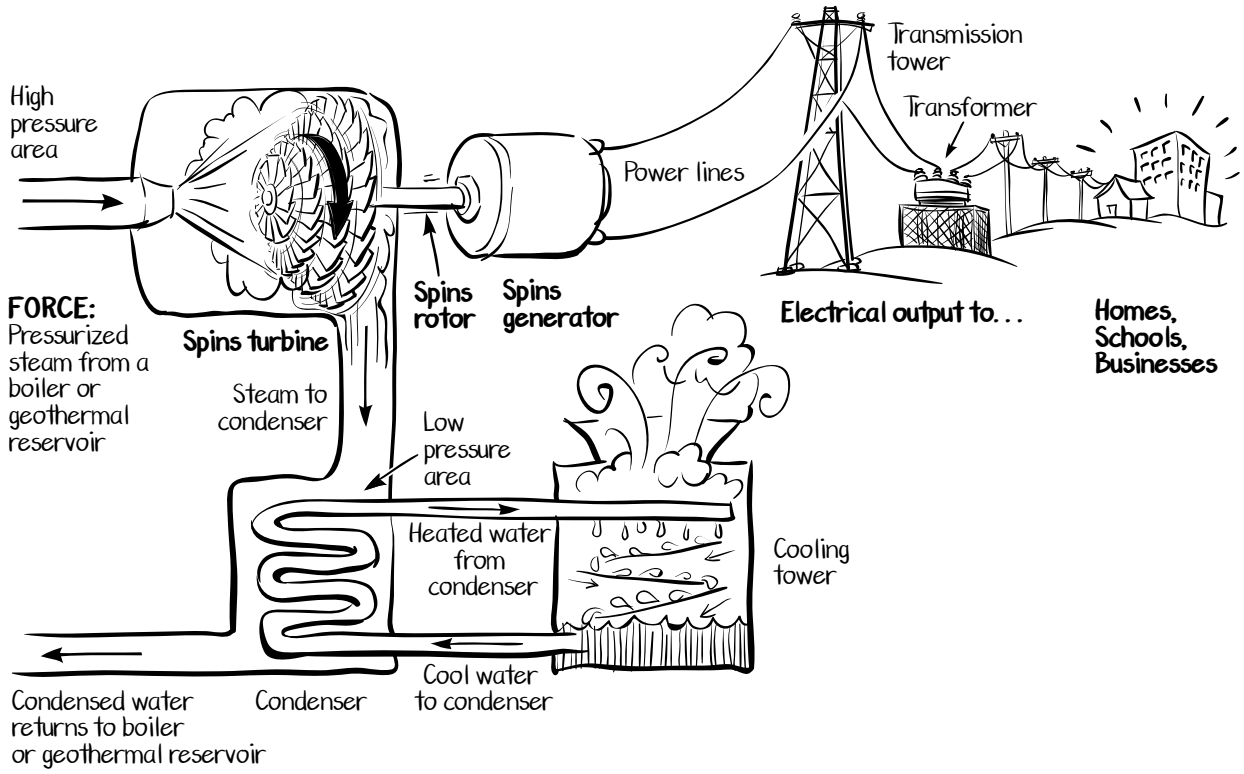
When work is being done, energy is always changing or converting. For example, when you run, your body converts chemical energy from food you've eaten into the energy of your actions (mechanical energy) and heat. Often there are several energy conversions, which are considered an "energy chain."

A steam-driven power plant has a series of energy conversions in an energy chain that goes like this: Heat energy (to make steam from water) is converted to mechanical energy (the spinning of the turbine blades); then, in the generator it's converted again to electrical energy.



A generator

STEAM-DRIVEN POWER PLANTS



HOW A STEAM-DRIVEN POWER PLANT WORKS

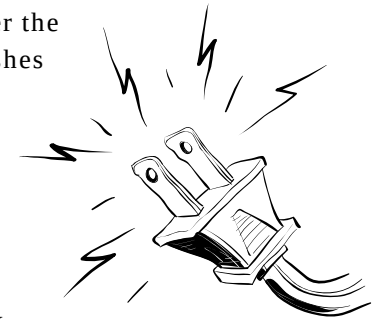
The force of steam drives most of today's power plants. A jet of high-pressure steam spins the turbine, which, in turn, spins the generator — producing electricity. The electricity speeds through transmission lines that connect with our homes, schools, businesses and industry.

How does steam get its force? Water's boiling point is 212°F (Fahrenheit) and 100°C (centigrade). When its temperature is less than this, water is in a liquid phase, with the molecules packed tightly together. But when water is heated above its boiling point, it "flashes" into steam (its gas, or vapor, phase), and the molecules separate and bounce all around. Because the molecules spread out, steam occupies a much larger space than it did as water — over a thousand times as much space! When steam is confined and not allowed to expand as it is vaporized, it becomes high-pressure (pressurized) steam.

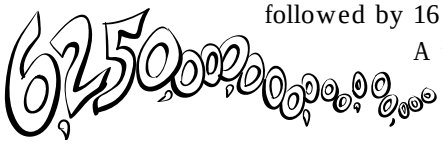
In a turbine, high-pressure steam is released from a confined space. The steam bursts out through nozzles at very high velocity. It can reach speeds over 450 mph (miles per hour) — 724 km/h (kilometers per hour) — and blasts into the turbine blades. To get even more force, low pressure is created by cooling the steam as it rushes out of the turbine. This cooling condenses the steam back to water (contracting the space occupied). The push of the high-pressure steam and the pull of the low-pressure area create that extra oomph needed to spin the turbine efficiently.

UNDERSTANDING ELECTRICAL TERMS

Electrons traveling along 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. Voltage is the force with which a source of electric current, such as a generator or battery, moves electrons. At power plants, electricity is usually generated at around 20,000 volts. By comparison, the light bulb in your desk lamp operates at 120 volts.

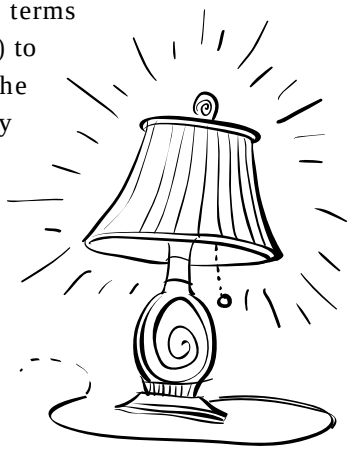


Current is the rate of flow of electric charge. It is the number of electrons flowing past a certain point per unit of time (usually one second). The amount of current flowing in a wire is expressed as *amperes*, or amps (named after Andre Marie Ampere). This is similar to describing water flow in gallons per minute. An ampere is equal to about 6.25×10^{18} electrons per second. That's a LOT of electrons — 625 followed by 16 zeros.



A *watt* (W) is a unit of power (named after James Watt). It is the rate at which work is performed. 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 kilowatt (kW) is 1,000 watts, the average amount used by homes in the U.S. One megawatt (MW) is 1,000 kilowatts (1 million watts). In the U.S., 1 MW serves an average of 1000 homes.

The electricity industry also uses the terms *watt-hour* (Wh) and *kilowatt-hour* (kWh) to measure electricity use. A watt-hour is the amount of electricity used in one hour by a device that requires one watt of power to operate. A kilowatt-hour is 1,000 watt hours. For example, a 100 watt light bulb that is left on for one hour will use 100 watt-hours of electricity. If left on for ten hours, the same bulb will use 1,000 watt hours, or one kilowatt-hour.

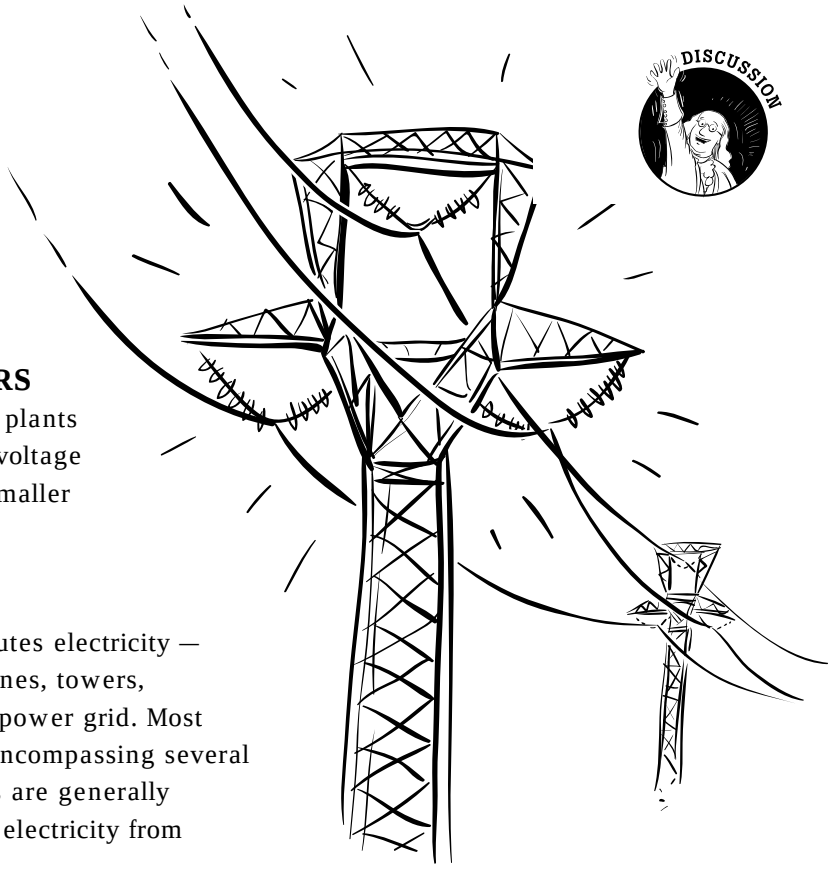


WHAT IS ELECTRICITY?

Atoms — the tiny building blocks of all matter — are electrically neutral, or uncharged. The center, or nucleus, of an atom has neutrons and positively charged protons. It is surrounded by negatively charged electrons. These charges balance each other to make the atom neutral.

However, some kinds of atoms have electrons that are loosely held. They can be attracted to move from one atom to another. The movement of these electrons over time causes an electric current (electricity). (Scientists still aren't certain what this "movement" is.)

Electricity needs a pathway to follow, called a complete circuit. The electrons flow from negative to positive along this pathway. Some types of metal wire allow electrons to flow from atom to atom more freely than other types. These are good electricity conductors because they have less resistance to the flow of electrons. Copper wire has low resistance and so it is commonly used for electrical wiring.



SENDING ELECTRICITY TO CUSTOMERS

Electricity is sent, or transmitted, from power plants along power lines. Power lines include high-voltage transmission lines and a complex system of smaller distribution lines serving communities.

The Power Grid

The entire interconnected system that distributes electricity — power plants, transmission and distribution lines, towers, substations, and transformers — is called the power grid. Most power grids cover large regions, sometimes encompassing several states. Grids operated by neighboring utilities are generally connected to each other for a smooth flow of electricity from region to region.

Increasing and Decreasing Voltage

Before the electricity leaves the power plant, the voltage is increased, or stepped up, by a transformer. Higher voltage travels better over long distances. For safety, high-voltage transmission lines are installed on tall towers or underground. You may have been close enough to one of these to hear the crackle of high voltage electricity in the wires.

As the electricity nears its destination, it goes through a substation where the voltage is lowered, or stepped down. But the voltage is still too high to be used in your home or business. So, before entering a building, the current goes through yet another smaller transformer to drop the voltage again. These small transformers are often mounted high on a utility pole near the building. Some of us can go outside and see these small transformers, which, in the U.S., normally change the voltage to 120 and 240 volts. (Some appliances need higher voltage than others.)

The lines also pass through a watt-hour meter, usually located on the outside of the building. This meter measures and displays electricity use.

SEND IN THE ALTERNATE

Electricity is transmitted in two ways: *direct* or *alternating*. With direct current (DC) the electrons flow in one direction. With alternating current (AC) the flow changes direction, oscillating back and forth in the conductor. In the United States, AC current does this 60 times (cycles) a second or 60 Hertz.

In the early days of electricity production, DC current was king. But DC current couldn't travel very far through power lines, so it limited the widespread transmission of electricity. Then, in 1885, American inventor George Westinghouse and electrical engineer William Stanley refined the process of producing AC current. AC could be transformed to a higher voltage, allowing it to travel far. Now electricity could be sent anywhere transmission lines could go.

MANAGING THE LOAD

Our electricity is billed in kilowatt-hours. Most meters track the amount of electricity we use, but not the times that we used it. The time of day that we use electricity is important — for the electricity suppliers, the grid managers, and for the electricity customers. The amount of electricity generated depends on the demand (how much is being used) at any one time.

Baseload Power

The basic amount of electricity that must be produced all the time (the amount that the grid managers know will be needed night and day) is called *baseload power*. Supplies of baseload electricity can be planned far ahead. Baseload power is traditionally supplied under long-term contracts from large power plants that operate 24 hours a day. It is the least expensive electricity.

Peaking Power

The electricity demand above the baseload is called *peaking power*. The need for peaking power can fluctuate greatly, depending on the time of day, week, or season. The highest loads are often on cold winter days when we need more heat, and on hot summer afternoons when we need the most cool air conditioning.

Peaking power is more expensive than baseload power. This is because peaking power plants are turned on only when they're needed (so they can only sell electricity part-time). And sometimes peaking power is purchased at high cost from out of the region.

Problems can occur when our demand for electricity exceeds the amount of peaking power available. If you have experienced electrical "blackouts" or "brownouts" it might have been because there wasn't enough peaking power available to cope with a sudden increase in demand where you live.

ELECTRICITY CHOICES

In the following chapters you will learn about different ways we can meet our electricity needs. We have some choices to make — about how much electricity we use, when we use it, and the energy resources we use to generate it. These choices are becoming more important every day.

GOING FOR A SPIN:
Making a Model Steam Turbine

PLANNING OVERVIEW

SUBJECT AREAS:
Physical Science, Math, Language Arts

TIMING:
Preparation: 30-60 minutes
Activity: 1-2 45-minute class periods

Note: "Going for a Spin" and "Getting Current" are best done in conjunction with one another.

Summary

Students explore how various energy sources can be used to cause a turbine to rotate.

Objectives

Students will:

- Recognize how the force of wind, falling water, and expanding steam can be used to do work.
- Create a model of a turbine and cause it to spin using the forces of wind, falling water, and expanding steam.
- Create a steam device that simulates some of the conditions of a steam-driven power plant.
- Use the scientific method to write up their work, including hypothesizing and drawing conclusions.
- Assess the ability of the turbine model to actually generate electricity.
- Use diagrams and narratives to describe how their apparatus worked and why.
- Compare their models to an actual power plant.

Materials

Per student group:

2 aluminum pie pans

Metal funnel, 4 inches (10 cm) in diameter

Scissors

Compass (for drawing circles)

Ruler

Pencils

Several plastic straws (the long soda type is best, but regular sized straws can be used)

Push pins

Small, thin washer (optional)

Small cooking pot, no bigger than 5 or 6 inches (13-15 cm) in diameter

Student Handout, "Going for a Spin," pages 36-39

Copy of Chapter 2 Discussion, "Energy and Electricity"

Student Handout, "Scientific Method Form," page 185

For all groups to share at a "central station":

Hot plate(s) or other heat source(s)

Oven mitts

Source(s) of falling water, such as a faucet and sink, or a large jug or bottle of water and a bucket or tub

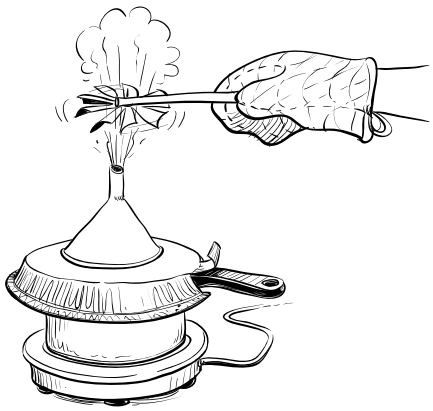
Towels for clean-up

Teaching Notes

Please review with your students all safety rules for working with heat and steam, particularly if you must use an open flame. Remind students to take care when cutting the aluminum pie plates.

This activity is intended for use in conjunction with the activity, "Getting Current." Each represents the two main functions of many typical power plants. However, each activity is designed to stand alone, if necessary.

The turbine model in this activity is not powerful enough to generate electricity, but it will successfully show students how different energy sources cause a turbine to spin. In "Getting Current" students will demonstrate how electricity is produced using electromagnetism. Though the two activities cannot be "connected" to produce electricity using the turbine model, students should be able to make a mental link between the two devices.



If you wish to do a more complicated project that shows a student-made turbine causing a generator to produce electricity, see the Tennessee Valley Authority materials listed in the Teacher Resources section of the Appendix.

Important Note: There are many different scientific method formats. The one suggested here is very basic and you may prefer to use your own format. If your students are not familiar with the steps of the scientific method, then you may wish to explain the method further.

Warm-up

Ask students if they have tried to wade across a rushing river or into ocean waves. Perhaps some have stood near a large waterfall. Ask students to describe these experiences. Have students connect the force of moving water with the idea of using it to do work.

Next ask students about the power of steam. It may be more difficult for kids to picture how steam can be forceful enough to make something move. Have students relate their experiences with steam (steamy showers, tea kettle, geyser, or natural steam vent). Students may think of steam as a wispy vapor that is not very powerful.

Review Chapter 2, especially the idea that we can produce and harness steam in a particular way that makes it very forceful — enough to spin a turbine that can be used to do work.

Tell students that in this activity they will be exploring how we use wind, water, and steam to turn turbines. Remind students that in the generation of electricity, the sole purpose of making a turbine rotate is to spin a generator.

The Activity

1. Gather the necessary materials and set up your classroom to accommodate the activity. Refer to the Student Activity page for the specific procedure. Develop a plan for use of a "central station," if needed.

2. Use the Chapter 2 Discussion information to discuss turbines and the various ways we can cause them to turn (wind, water, and steam).

3. Explain to students that power plant turbines are highly engineered devices that are designed to make the best use of the force of wind, water, or steam. In this activity, students make very simple turbines that will spin when blown on ("wind"), placed under falling water or held up to the homemade steam device.

   Remind students that most power plants today use steam to spin their turbines, and review how steam-driven power plants work. Emphasize that in order for the steam at a power plant to hit the turbine with enough force, it must be confined, creating high-pressure steam, and then released through a small opening, bursting out and expanding at great velocity.

4. Distribute copies of the Student Activity page for "Going for a Spin" and review the procedure. Organize student groups and give out all needed materials. Explain, if needed, that some materials are shared and that groups will be taking turns using the heat source at the "central station."

5. Once students have had a chance to look over the directions for constructing the turbine model and the steam device, and have a general idea of what they both look like, go over the instructions for using the Scientific Method Form on page 185.

6. Once finished with all three tests of the model turbine, tell students to write up the activity. Have students stay in their groups for discussion and support, but ask each individual to write up his or her own description. Consult Student pages 36-39 for exact directions.

Wrap-up

Gather the entire class together and have groups share their experiences with their turbines and the three different energy sources. Discuss ways they adapted the turbine model to make it work best. Talk about whether the angle of the blades or the distance from the resource needed to be adjusted for different energy sources and why.

Have students share their predictions regarding whether the turbine model could actually produce electricity. Ask if they changed their predictions after working with the model. Discuss why they thought the turbine in this activity is being called a "model."

Relate the use of their "wind" and water to turn their turbine models to the use of actual wind and water resources for the production of electricity. Explain that in this unit they will be learning about the many interesting ways we can use different energy resources to produce electricity without having to burn fuels. Remind students that there are also ways to produce electricity without using a turbine at all, such as with solar (photovoltaic) cells or hydrogen fuel cells, but that in this activity we are concentrating on turbines — the most common method in use today.

Ask students to explain why the steam device worked the way it did. (In the steam device, the steam is confined in a small space and so is constrained from expanding in all directions. This creates high-pressure steam that forces its way out through the small opening of the funnel. When it bursts out of the small opening of the funnel, it rises and expands with great force.)

Ask groups how far from the opening they held their turbines to get the most spin. Guide the discussion to the idea that the expanding steam hits the blades of the turbine, causing them to turn. There is a certain point above the opening where the most expansion occurs, thus causing the most spin.

Next, review the various ways we can produce steam to turn a turbine. Direct the discussion beyond burning fossil fuels (the most common way). Points to include are the use of fuels such as biomass (students may first think of wood, but explain that there are many other types of biomass), of steam that comes directly from the earth (geothermal), and of the sun's heat to boil water (as in the process of solar thermal).

If any students have completed the extra credit, have them share their descriptions. To carry this further, you might facilitate the building and testing of any of these student designs, or suggest it as extra credit homework, or as a science fair project.

Assessment

Students will have had the opportunity to:

- Create and test a model of a turbine as well as a steam-producing device.
- Draw conclusions regarding the use of wind, water, and steam as energy sources.
- Use the scientific method, including hypothesizing and drawing conclusions.
- Relate turbine models being driven by various energy sources to an actual power plant.
- (Optional) Suggest a "home-made" turbine design that would be useful for generating a small amount of electricity.

Permission was granted by the Tennessee Valley Authority to adapt portions of their junior high curriculum unit, "The Energy Sourcebook," for use in this activity.

GOING FOR A SPIN:
Making a Model Steam Turbine

In this activity you will demonstrate how different energy sources can be used to spin a turbine. Remember that the sole purpose of spinning a turbine at a power plant is to rotate an electrical generator. The turbine in this activity is not strong enough to operate an electrical generator; however, you can still experience how the force of wind, water, and steam are used to make a turbine spin.

You will also be constructing a device that produces steam in a manner similar to that used at a steam-driven power plant. You will recall from the Chapter 2 Discussion that the actual steam production technology at a power plant is extremely sophisticated and produces steam at very high pressures. However, this activity works well enough to get the point across.

Be sure to review all the safety instructions found in the Student Preface before you begin this activity.

Materials

Per student group:

2 aluminum pie pans

Metal funnel, 4 inches (10 cm) in diameter

Scissors

Compass (for drawing circles)

Ruler

Pencils

Several plastic straws (the long soda type is best, but regular sized straws can be used)

Push pins

Small, thin washer (optional)

Small cooking pot, no bigger than 5 or 6 inches (13-15 cm) in diameter

Copy of Student Activity, "Going for a Spin"

Copy of Chapter 2 Discussion, Energy and Electricity

Copy of "Scientific Method Form," page 185

For all groups to share at a "central station":

Hot plate(s) or other heat source(s)

Oven mitts

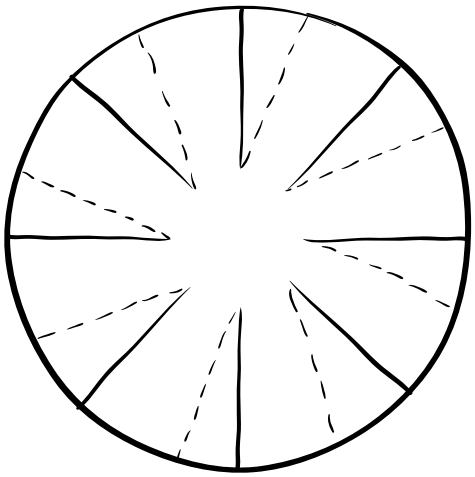
Source(s) of falling water, such as a faucet and sink, or a large jug or bottle of water and a bucket or tub

Towels for clean-up

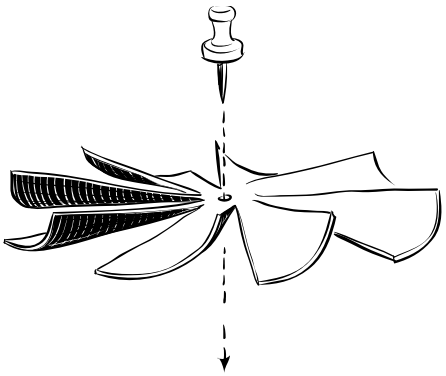
Procedure

THE TURBINE

1. Using your compass, measure and draw a 3.5 inch (approximately 8 cm) diameter circle with a pencil on one of the aluminum pie plates. Divide the circle into halves, then fourths, then eighths (marking the divisions by drawing your pencil down the straight edge of the ruler). As shown in the diagram, cut the circle into 8 blades by cutting along the 8 divisions on the solid lines, to within ¾ inch (2 cm) of the center. Make sure not to cut all the way to the center.

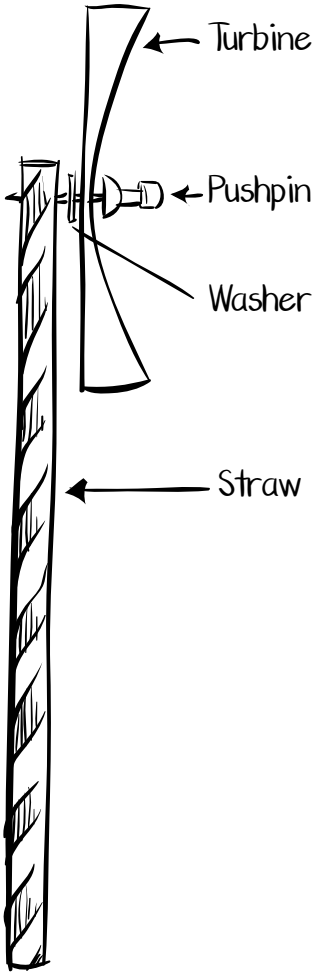


2. Taking each blade, bend one side gently up (along the dashed lines) so that all blades are curved up the same direction. (Pick a direction, such as clockwise, and stick to it all the way around). Don't overwork the blades at this point. You may need to make adjustments to the bend of the blades when you start using your turbine.



3. Using a push pin, attach the turbine to a straw at one end (illustration at right). Leave space (or insert washer, if needed) between the straw and the turbine, so it spins freely.

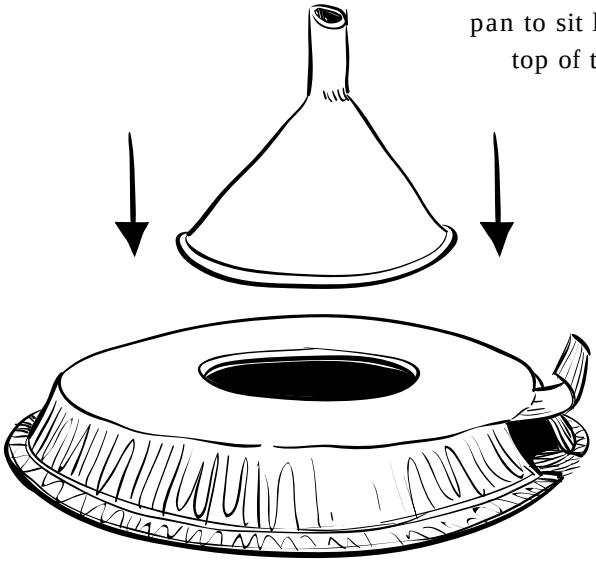
4. Next, construct your steam device (illustration at right), so that you will be ready when it's your turn to use the heat source(s) at the "central station."



THE STEAM DEVICE

1. Trace the circumference of the funnel onto the center of one of the aluminum pie pans. Using scissors, poke a hole in the center of the pan. Cut from the center out toward the edge of the traced circle, but stop about ¼ inch (almost 1 cm) from the circle itself. The line you traced is where the funnel will sit on the pie pan. The hole you are cutting must be smaller than this, so cut the circle about 1/4 inch (almost 1 cm) inside from the traced circle. This way your funnel will sit on the pie pan without falling through and will cover the gap so that steam won't escape.

2. If necessary, cut a place on the edge of the pie pan where the cooking pot handle will go, allowing the pie pan to sit level on top of the pot.



THE SCIENTIFIC METHOD FORM

Before testing your turbine model and steam device, complete Steps 1 through 3 that follow. Remember that each student should do his or her own write-up, though you are doing the experiment in a group.

1. You will be using the Scientific Method Form provided with this activity unless your teacher tells you to use a different experiment write-up form.

2. For the Research section, unless your teacher indicates otherwise, you may summarize what you have learned from reading and discussing Chapter 2 about power plant turbines. Be sure to credit this book as the source of information.

3. For the Hypothesis, you should address the following:

   a. Predict how well your turbine model will perform using the three "resources": water, "wind" (your breath), and steam. For example, will the shape of the blades and/or their angle in relationship to the force of the resource affect the turbine's performance? When using steam, will it matter how far you hold the turbine from the opening that releases the steam? Will there be an optimal amount of "wind" to get the best spin? Does it matter how far the water falls or at what angle you hold the turbine blades in the stream of water?

   b. Predict whether you think this particular turbine model would actually be able to produce a small amount of electricity if it were connected to a small generator.

4. As you work on constructing and testing your devices using the directions in "Testing the Turbine (see page 39)," fill out the Procedure and Data sections of the form.

   Since the directions are lengthy, be sure to summarize them for the Procedure.

   For the Data sections, draw pictures showing your turbine using the three different resources (wind, water, steam). Make notes about how the turbine performed using different variations, such as varying heights of water, varying "wind" speeds and distances from your mouth when blowing, different angles of holding the blades, and alterations to the shape of the blades.

   For the steam test, be sure to include the height at which your turbine spun the fastest.

5. For the Conclusion portion of the form:

   a. Compare the actual performance of the turbine to your predictions (hypothesis) regarding how the turbine worked with each resource. Make any other comments on what you learned while doing the tests, based on your notes from the Data section. Comment on why the authors have been referring to the turbine as a "model."

   b. Reassess your thinking in your original prediction as to whether the turbine could actually generate electricity.

TESTING THE TURBINE

1. Test your turbine by blowing on it, to simulate the energy of wind. Gently make adjustments to the turbine blades to get the most spin. Try varying the distance from your mouth or the force of your breath.

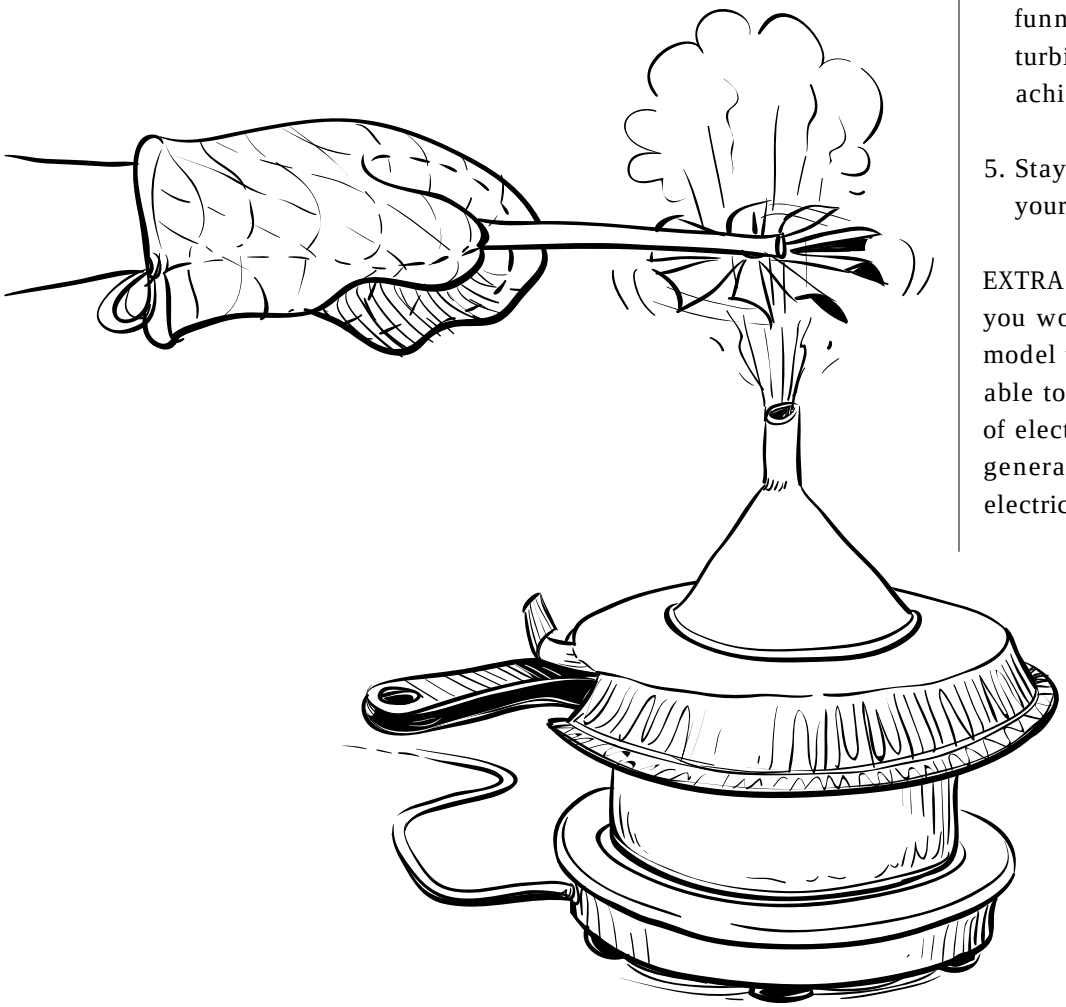
2. Test your turbine with a stream of falling water, making any needed adjustments for optimum spin. See how fast you can get the turbine to spin. Try varying amounts of falling water and varying heights from which the water falls before it hits the turbine.

3. Test your turbine using steam. Using the heat source, fill the cooking pot ¼ full of water and bring to a boil. Wearing oven mitts, place your steam device on top of the pan. Make sure that the funnel fully covers the opening in the middle of the pie plate. Steam should be issuing only from the funnel opening.

4. Wearing an oven mitt, hold your turbine "face" down over (but not directly on) the funnel opening. Remove the turbine and gently adjust its blades, if needed, to ensure optimum spin. Hold the turbine over the funnel opening again and raise and lower it slowly to see at which height it will spin fastest. Using the ruler, make an estimated measurement of the height from the funnel opening at which your turbine's top speed was achieved.

5. Stay in your groups to finish your experiment write-ups.

EXTRA CREDIT: Describe how you would design a turbine model that would actually be able to generate a small amount of electricity using a very small generator. If it worked, what electrical apparatus could it run?



GETTING CURRENT:
Generating Electricity Using a Magnet

PLANNING OVERVIEW

SUBJECT AREAS:
Physical Science, Math, Language Arts

TIMING:
Preparation: 30 minutes
Activity: 1-2 45-minute class periods

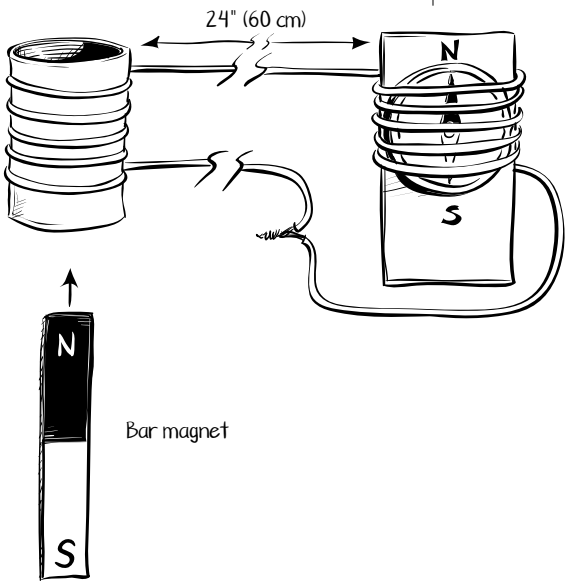
Summary

Students investigate how generators produce electricity by using electromagnetism.

Objectives

Students will:

- Hypothesize what will happen and why when a bar magnet is passed in various ways through coils of wire.
- Construct and use a model that demonstrates the actions of an electricity generator.
- Prepare a brief summary of the activity, including a description of the set-up and what occurred when it was tested.
- Draw a conclusion comparing their hypotheses to what was observed in the activity.
- Compare their models to an actual electricity generator.
- Propose explanations relating magnetism and electricity.
- Recognize that the main reason for making an electrical turbine spin is to turn a generator.
- Compare both models to an actual power plant turbine and generator (if "Going for a Spin" was also done).



Model generator

Materials for Warm-up

(Optional)

Iron filings

Stiff paper

Strong bar magnet

Materials for Student Activity

Per student group:

Student handout: "Getting Current"

Copy of Chapter 2 Discussion, Energy and Electricity

A directional compass

A strong bar magnet with north and south poles

13 feet (4 m) insulated copper wire

Cardboard toilet paper tube

Transparent tape (optional)

At least one for the entire class:

Wire stripper/cutter

Teaching Notes

Ensure that students understand that the activity setup is just a demonstration of the idea that moving a conductive wire in a magnetic field can create an electrical current. The setup in this activity does not look like a power plant generator, but both use coiled wire and strong magnets. The model works using the same principle.

Remind students to keep magnets away from computer disks, audio or video tapes, etc.

Since this activity is a simple demonstration, the full scientific method outline is not called for here. Rather, certain key elements of the method are used, including hypothesizing, describing the activity, gathering data, and drawing conclusions.

If students have trouble with their models, have them try making more coils. If this doesn't produce an electric current (move the compass dial), you may need stronger magnets.

Items in the materials list can be found at hardware, electronics, or school supply stores. You can also order them from a science supplier such as Sargent-Welch, Edmund Scientific, or Nasco Science. If you can't find iron filings, show the magnetic field illustration (also in the student handout) to your students. Discuss it using information in the Warm-up section, or have students view a video or CD-ROM that discusses magnetic fields.

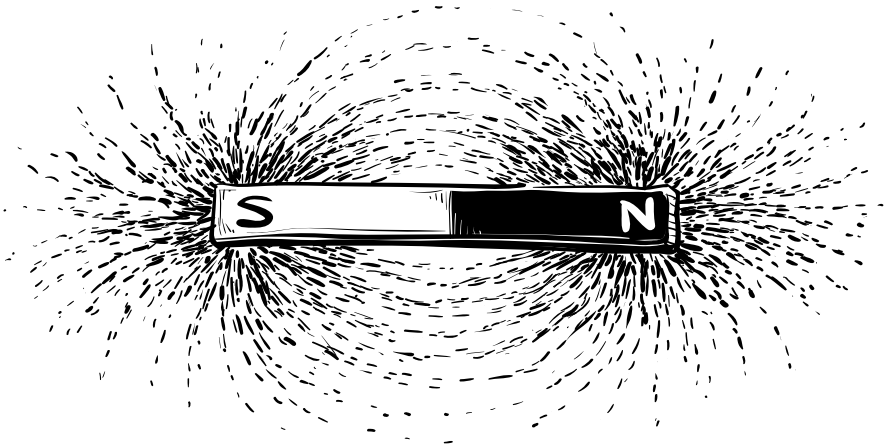
Warm-up (Optional)

If you were able to find some iron filings, try this with your students: Place a stiff piece of paper over a bar magnet that is resting on a flat surface. Sprinkle some iron filings on the piece of paper. Ask students to observe what happens. The interesting pattern that results is due to the magnetic field surrounding the magnet.

Explain that any magnetic field is actually invisible to us. The iron filings are lining up in reaction to the magnetic field, and show the lines of magnetic force — the "attraction" that occurs between the two opposite poles (north and south) of the magnet. The lines of force in a magnetic field travel from north to south — much the same way electric current flows from negative to positive (opposite charges attract).

In this activity, the magnetic field of the bar magnet interacts with electrons in a wire to create an electrical current.

Note: Students may ask what causes magnetism in the first place. Tell students that until recently, the cause of magnetism was not well understood. In fact, not long ago, the *Encyclopedia Britannica* stated: "Few subjects in science are more difficult to understand than magnetism." Recently scientists have begun to unlock magnetism's mysteries, but the answers are very complex, having to do with "spin" of electrons on their own axis as they buzz around the nucleus of an atom.

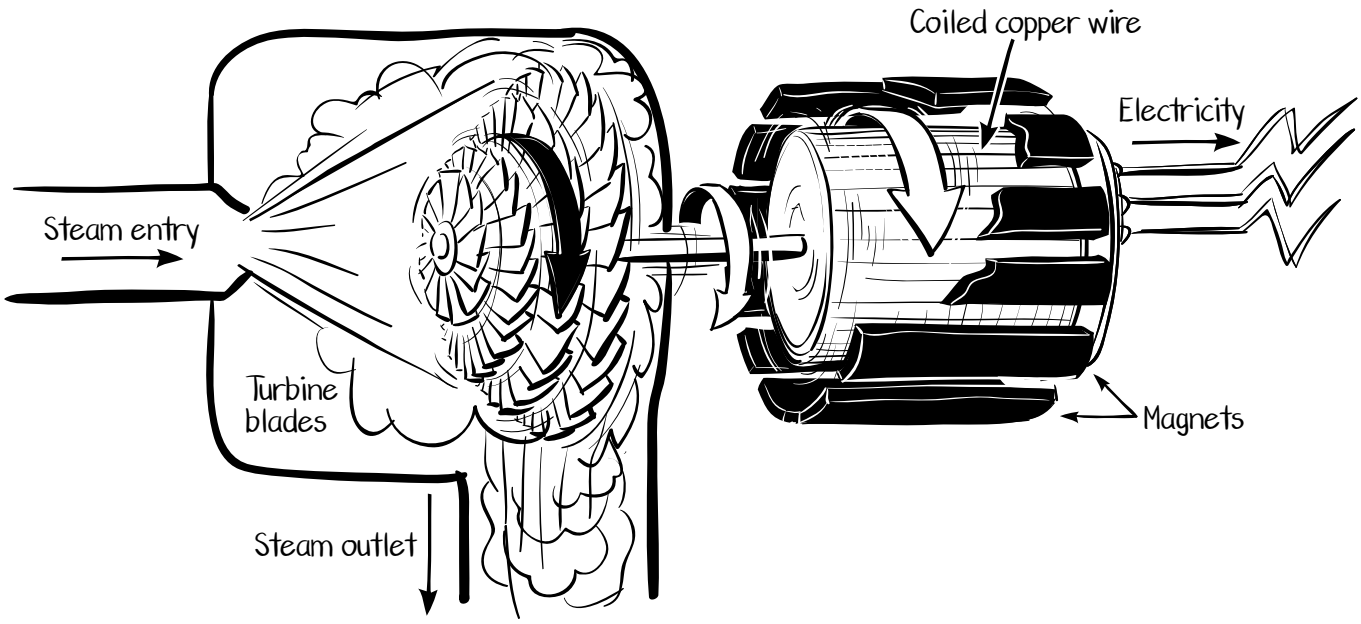


Iron filings showing magnetic fields

The Activity

1. Gather the necessary materials and set up your classroom to accommodate the activity. Refer to the Student Activity page for the specific procedure.

2. Use the Chapter 2 Discussion to talk about how a power plant generator works. Using the graphic of the typical steam-driven power plant on page 29, discuss how the power plant turbine provides the spinning force that turns the generator. While this diagram does not show the inner workings of the generator, it does illustrate the interconnection of the turbine and the generator.



Inside a turbine generator

3. Next direct the students' attention to illustration, "Inside a turbine generator" (also in the student handout). Explain that in generators the rapid spinning of wire coils between the two poles of strong magnets produces an electrical current.

4. Point out that in most power plant turbines the wire coils are moving and the magnets are stationary. However, it can work the other way around. We can move a magnet in and out of wire coils (as demonstrated in this activity) and still generate an electric current.

5. Review with the class the outline they must prepare to write-up the activity. The specific directions for doing so are found in the Student Handout for this activity. Tell students that they will be working in groups to do the activity, but each will do his or her own write-up.

6. Organize students into groups. Pass out materials and copies of the Student Activity pages.

7. Have students look over the activity directions, then reflect on what they've learned so far about generators and electromagnetism. Then ask them to fill in the Hypothesis portion of their outline (see page 45). Explain that they need to predict what they think will happen when they do the activity and why.

8. Have students create and test their own model generators. Allow time for them to also do their activity write-ups. Remind them that the background information they need to help explain how their experiment works was included in your discussion of this activity, and is also found both in the Chapter 2 Discussion, as well as in their student handout, "Getting Current."

9. Have the class get together after groups have tested their model generators and have done their write-ups. Ask students to use what they've learned from studying Chapter 2 and their experiences with both activities to write a brief narrative, on separate paper, comparing both the turbine model and the generator model to an actual power plant turbine and generator. If you did do "Going for a Spin," then have students explain how their generator model compares to an actual power plant generator.

Wrap-up

Call the class together to discuss their findings. Ask students to explain why they think generators work the way they do.

Ensure that students are able to make the connection between electricity and magnetism and have a general understanding of electromagnetism.

Next conduct a discussion connecting this activity (and that of "Going for a Spin" if you have done it as well) to an actual power plant that uses turbines and generators.

Referring back to the Warm-up, remind students that magnets create a magnetic field around them. This field causes electrons to move in the conductive wires that are spun inside the magnetic field. If these wires are connected in a complete pathway, or circuit, an electric current will then course through the wires.

Explain that the compass in their activity set-up serves as a "galvanometer," a device that indicates electric current. The very small current produced by the passing of the magnet through the coils of wire causes the compass needle (which is magnetized) to turn aside, or deflect. This is a property of electromagnetism.

Extension

As a follow-up, students may also wish to look up power plant generators in reference books or on the Internet to learn more about how they work. Other interesting topics to pursue are the electromagnetic force and the history of the compass (this one may appeal to both history and science buffs alike).

Assessment

Students will have had the opportunity to:

- Create and test a model generator.
- Prepare a write-up of the activity, including using hypothesis, description, and conclusion.
- Develop an activity write-up that includes diagrams and labels and tells why the activity worked the way it did based on what they have learned about electricity and magnetism.
- Produce a brief narrative description comparing an actual power plant generator to their turbine models from the first activity and their generator models from the second activity.

Permission was granted by the Tennessee Valley Authority to adapt portions of their junior high curriculum unit, "The Energy Sourcebook" for use in this activity.

GETTING CURRENT:
Generating Electricity Using a Magnet

Generators use magnets and wire coils to produce electricity. The electricity is produced by the rapid rotation of wire coils between the two poles of strong magnets (or the spinning of magnets surrounded by wire coils). Turbines — driven by a force such as pressurized steam, moving water, or forceful wind — provide the spinning power.

Magnets are surrounded by a magnetic field that can cause electrons to move in wires turning inside this field. If these wires are conductive (allowing electrons to flow easily), and if they are connected in a complete pathway (called a circuit), an electric current will then run through those wires.

While most generators operate by rapidly turning wire coils inside the two poles of a magnet, it also works the other way around — we can move a magnet in and out of wire coils to generate an electric current. In this activity, you will demonstrate this concept using a compass (which has a magnetized pointer that acts as a current detector) to show that electricity has been produced.

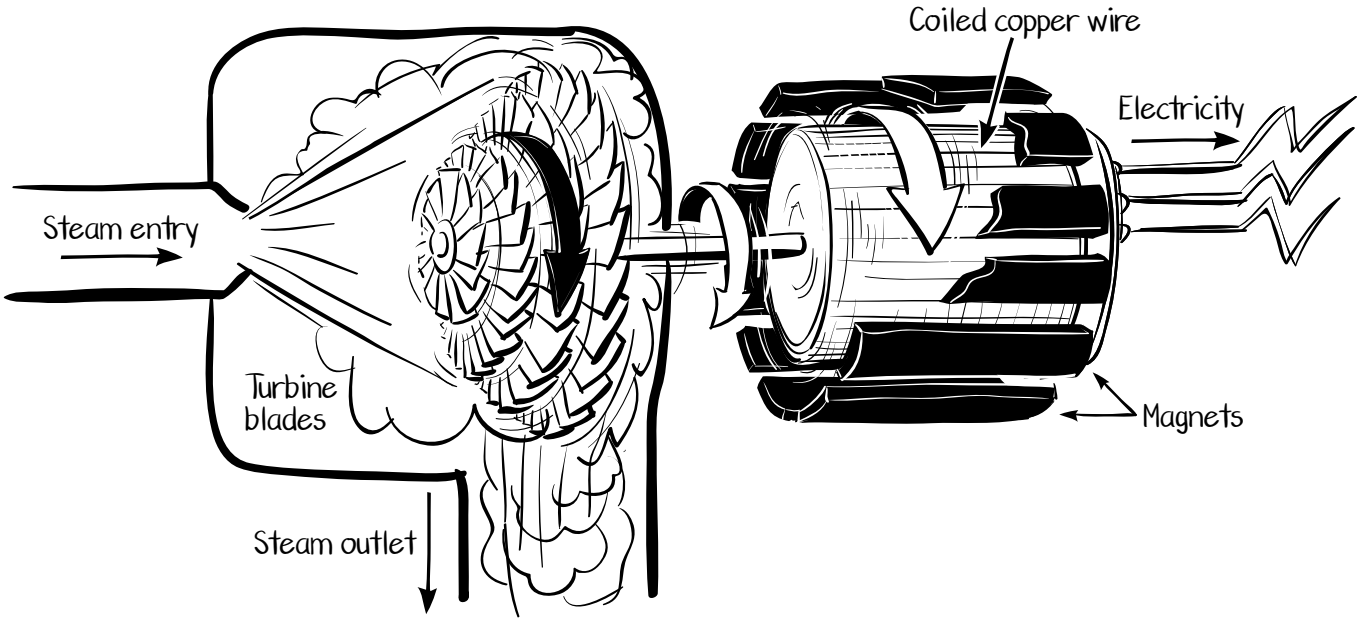
Materials

Per student group:

- A compass
- A strong bar magnet with north and south poles
- 13 feet (4 m) insulated copper wire
- Cardboard toilet paper tube
- Transparent tape (optional)

At least one for the entire class:

- Wire stripper/cutter



Inside a turbine generator

Prepare Write-up Outline

Make an outline, leaving room to write in each section, using the format below. Be sure to title your paper and include name, group name or number, and date.

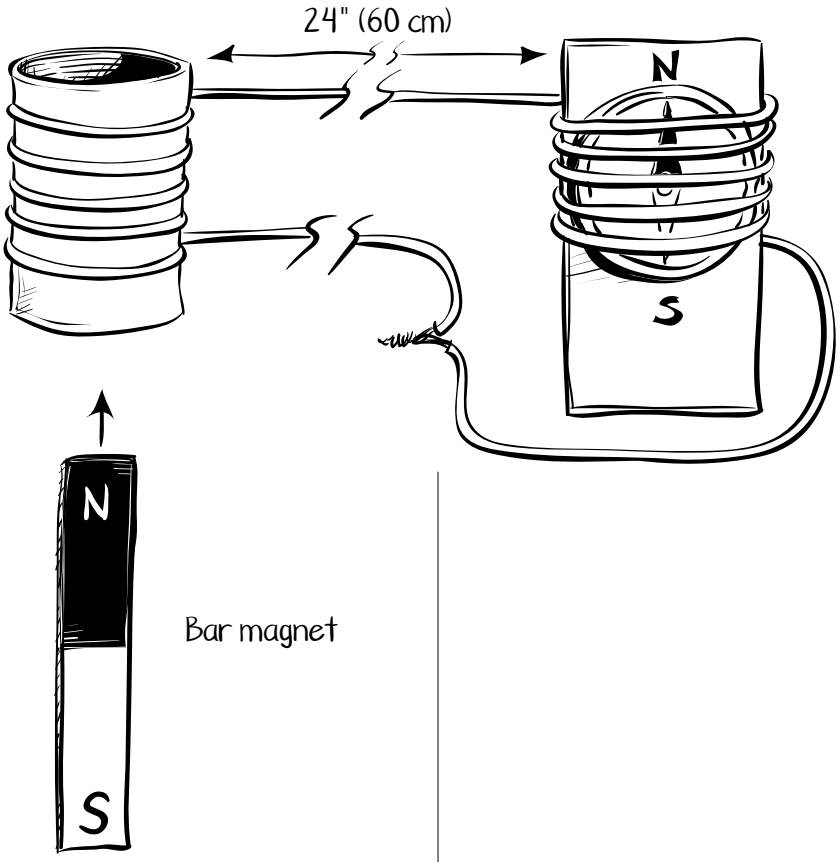
1. Hypothesis. Predict what will happen.

2. Activity Description/Data. Describe the set-up and what happened when you tried all the variations suggested.

3. Conclusion. Revisit your hypothesis. Tell whether or not it was correct, and why.

Next, review what you have learned so far about generators and electromagnetism, and study the directions for the activity. Based on this information, pose a hypothesis predicting how you think the generator model will work and why.

When everyone in your group has completed his or her hypothesis, move on to the Procedure.



Model generator

Procedure

1. Remove about ¾ inch (2 cm) of insulation from each end of the wire.

2. Wrap one end of the wire around the compass five times as shown. Be sure to position the compass so that the needle is directly underneath the wire wrapped around it. CAUTION: Ends of wire are sharp.

3. Extend the other end of the wire out about 24 inches (about 60 cm) from the compass and then wind the remaining length around the cardboard tube five times. The bar magnet will pass through these coils.

4. Run the remainder of the wire back to the compass. Twist the two exposed ends of the wire together. If desired, secure the wire to the compass with transparent tape.

5. Have one group member pass the magnet back and forth through the coils. If nothing happens disconnect one side of the wire and add more coils to the tube, then reconnect. Keep the compass at least 20 inches (50 cm) from the magnet so that the magnet itself does not cause the needle of the compass to be deflected.

6. Other group members should watch the compass closely to observe and record what happens.

7. Change the direction of the magnet by inserting it from the opposite end of the tube. Observe and record what happens. Next turn the magnet around (inserting the other pole first). Observe and record what happens.

8. Stay in your groups to finish writing up your activity. Group members should share insights and give each other support, but each person should write his or her own.

   Include your three observations based on the three different ways you tested the model. Using the Chapter 2 Discussion, your classroom instruction, and the information on this worksheet, explain why the compass reacted the way it did in your conclusion.

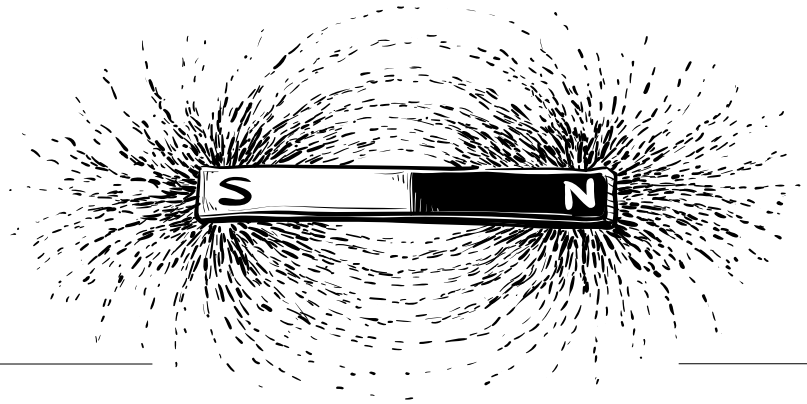
9. Be prepared to discuss your findings with the class.

UNLOCKING SOME OF MAGNETISM'S MYSTERIES

Although we can't see magnetism, we've all seen its effects. We know that magnets have a force that can attract certain materials (or another magnet). The force of a magnet can also cause another magnet to move away. We use magnetic forces everyday, from refrigerator magnets holding up memos to magnetic poles in common devices such as motors and telephones.

Most of us are also familiar with the terms north pole and south pole. This is something you usually can find marked on a bar magnet. (The labels north and south pole are arbitrary names given by scientists who first studied magnetism.) All magnets have north and south poles — no matter what shape they are. Magnets have the most force at the poles. However, magnetic lines of force actually extend all around the magnet, creating a magnetic field.

Scientists are still exploring what causes these lines of magnetic force. They do know that most atoms actually act like microscopic magnets, each with its own tiny north and south pole. When atoms are all jumbled up — as they are in most materials — we don't notice the atoms' magnetic force. But, in certain materials (mostly some metals), the atoms all line up, creating a collective north pole at one end and a south pole at the other. This results in magnetism at each pole strong enough to attract a material such as iron.



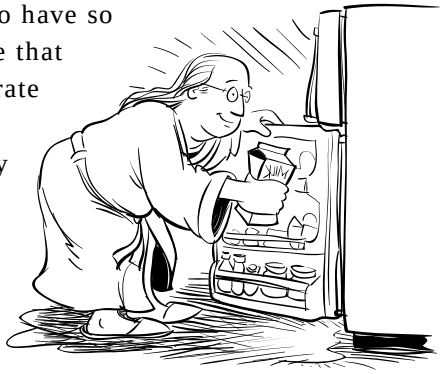
ENERGY SOURCES FOR ELECTRICITY GENERATION

How we use different energy sources to produce electricity

VOCABULARY

alternative energy
biomass
capacity
deplete
green energy
hydrogen gas
nonrenewable energy
nuclear fuels
regenerate
renewable energy
solar energy
sustainable

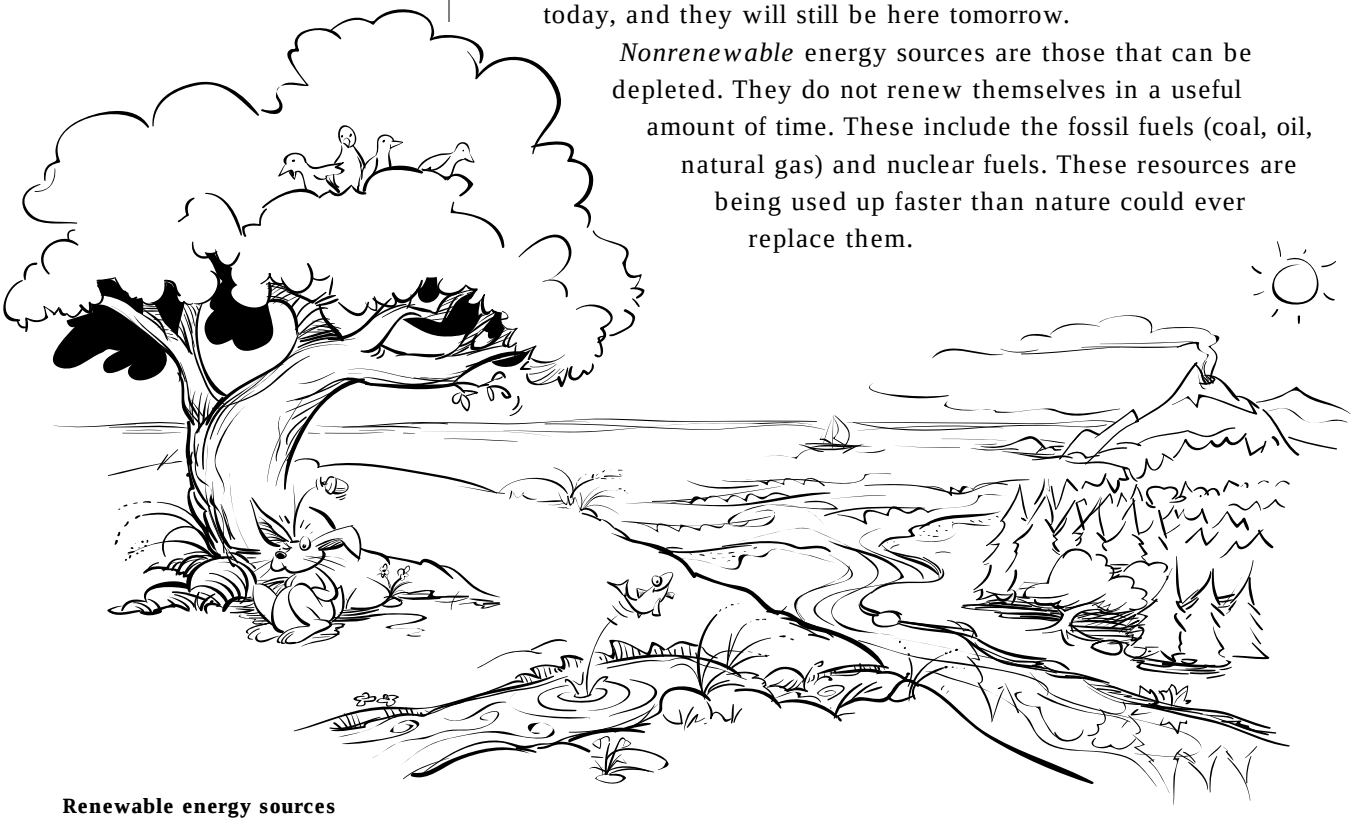
IT'S EASY TO TAKE our seemingly plentiful supply of electricity for granted, especially in the United States. We can flick on our lights or get a cold drink from our refrigerators just about anytime we want. Since we seem to have so much electricity, we might conclude that the energy sources we use to generate this electricity are also found in abundant quantities; but this is only partially true. Renewable energy sources will always be available, but others, the nonrenewables, are being used up.



RENEWABLE AND NONRENEWABLE ENERGY SOURCES

Renewable energy sources are those that naturally regenerate, or renew, themselves within a useful amount of time: wood and other substances produced by living things (biomass), natural heat from the earth's interior (geothermal), moving or falling water (hydropower), the ocean, the wind, and the sun. We can use these resources today, and they will still be here tomorrow.

Nonrenewable energy sources are those that can be depleted. They do not renew themselves in a useful amount of time. These include the fossil fuels (coal, oil, natural gas) and nuclear fuels. These resources are being used up faster than nature could ever replace them.



Renewable energy sources

Energy Resources for Electricity Generation

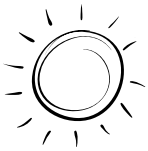
Renewable Energy Resources

Biomass: Plant material (including wood) or organic waste

Geothermal: The natural heat inside the earth

Hydropower: The force of moving water from rivers or storage reservoirs

Ocean: The mechanical energy of ocean tides, currents, and waves, and the sun's heat energy stored in the ocean



Solar: The radiant energy from the sun

Wind: The force of moving air

The Renewable and Nonrenewable Resource

Hydrogen: Hydrogen gas produced from other natural resources

Nonrenewable Energy Resources

Fossil Fuels: Coal, oil (petroleum), and natural gas

Nuclear Fuels: Elements with unstable nuclei, such as uranium

RENEWABLE? CLEAN? GREEN?

We sometimes read or hear the terms "clean energy," "green energy," "sustainable energy" and "alternative energy," along with the term "renewable energy." Some people use these terms interchangeably, which can be confusing.

Clean or green energy usually refers to energy that is environmentally friendly. When we generate electricity with these resources, very few pollutants, if any, enter our air or water.

Sustainable energy usually refers to a process, system, or technology that does not deplete resources or cause environmental damage. It means preserving meaningful choices for future generations.

When people use the term alternative energy, they are usually speaking of alternatives to the conventional energy sources — fossil fuels, "large" hydropower, and nuclear. Alternative energy can certainly include renewables. Most often, though, the term alternative is applied to transportation fuels — any fuels other than gasoline and diesel, such as ethanol, biodiesel, and hydrogen.

ENERGY RESPONSIBILITY, ENERGY CHOICES

Electricity has contributed greatly to our comfort and to our society's development, but we are using up valuable and irreplaceable energy resources. Since the beginning of the Industrial Revolution our use of energy sources, particularly the fossil fuels, has increased with each passing year. In the last 30 years alone, their use has tripled.

Our choices about energy use and energy sources have consequences for us and for all who live, or will ever live, on this planet. Responsible citizens:

- Understand the many energy sources available to generate electricity
- Are informed about the methods used to generate electricity
- Make the best use of each of the sources we have

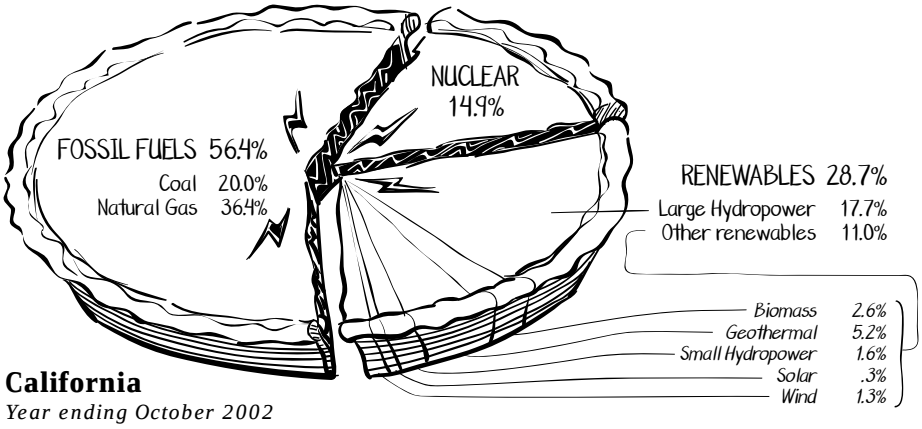
SIZING IT UP

In this chapter, power plant sizes (in kilowatts and megawatts) are given for each energy resource. A power plant's size is the amount of electricity that its turbine(s) can produce at any one time. This is known as a plant's "capacity." But power plants do not always operate at full capacity. The amount of electricity actually produced over time depends on many factors. Some of these factors are addressed in the "Considerations" near the end of each resource discussion.

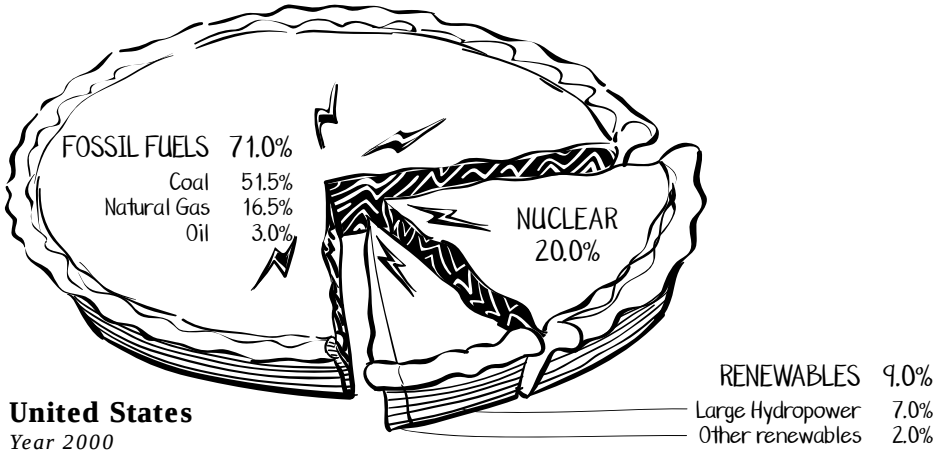
The percentages in the pie charts on the next page are from actual electricity produced.

RESOURCES BEING USED TO GENERATE ELECTRICITY

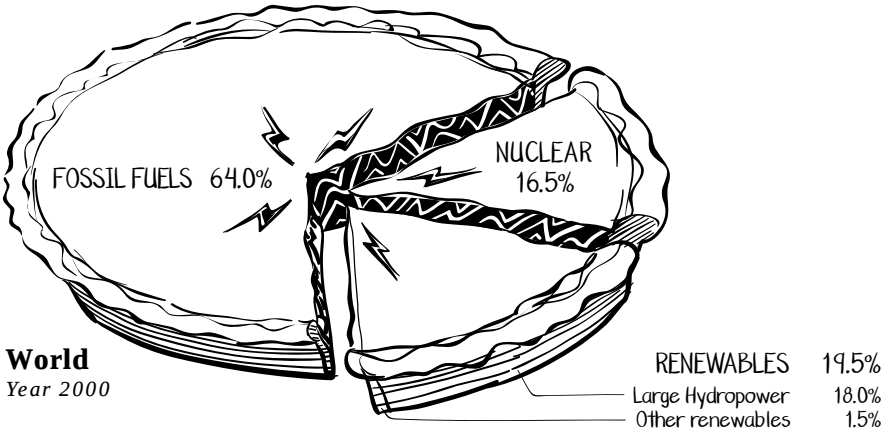
These pie charts show the percentages of electricity produced from different energy resources in California, the United States, and around the world.



California
Year ending October 2002

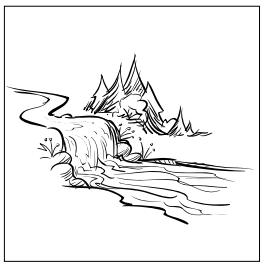


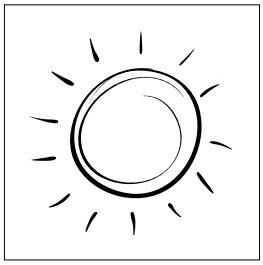
United States
Year 2000

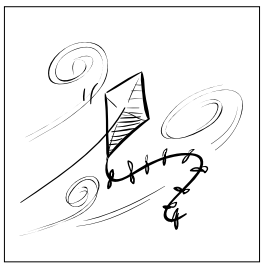


World
Year 2000

Renewable Energy Sources



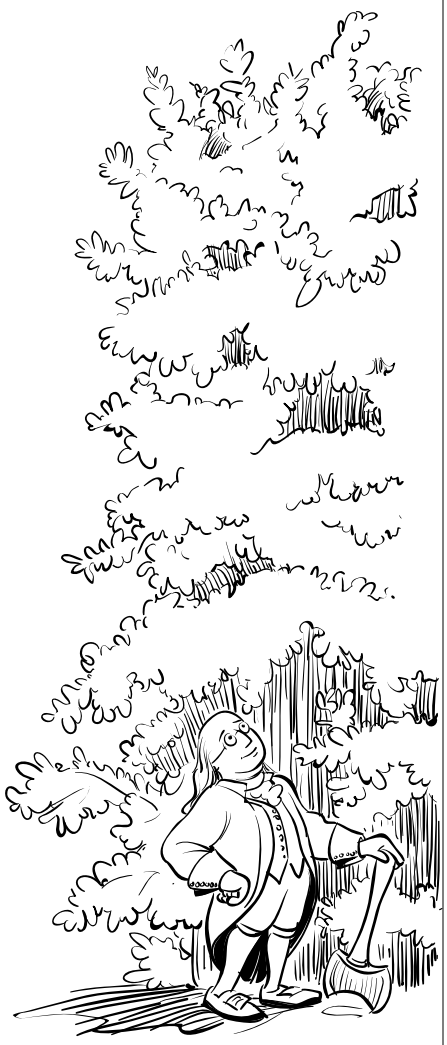




Renewable Energy Source: BIOMASS

VOCABULARY

- byproduct
- carbon cycle
- decompose
- energy farm
- gasification
- green waste
- methane gas
- microbe
- soil erosion



Fast-growing trees are ready to be harvested for use in a biomass power plant.

BIOMASS IS ONE OF THE FIRST energy resources ever used by humans. A natural collector of the sun's energy, biomass includes anything that is or was once alive. Ever since the discovery of a way to create fire, humans have been burning wood and other organic material to create heat and light.

In the United States, biomass, mostly from trees, was the premier energy source until the 1830s. It was displaced by fossil fuels (mainly coal) when the Industrial Revolution took hold in America. Recently, however, the use of biomass, in a widening range of forms, has begun to increase. Today it is an important energy source for many processes, including generation of electricity.*

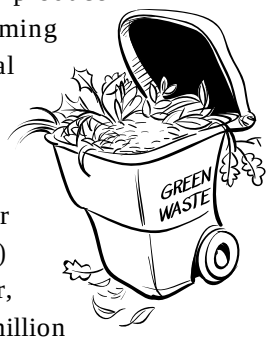
THE BIOMASS RESOURCE

Most living things receive and store energy from the sun. This energy is released when the organic material is digested, burned, or decomposed (naturally broken down over time). This released energy can be used to produce electricity. Today, many kinds of biomass are used as energy resources.

Solid Biomass

Solid biomass is anything organic that has not yet broken down into a gas or a liquid. There are many kinds of solid biomass. Chipped wood, whole trees, energy crops, and agricultural wastes are examples. Other important solid biomass sources are trimmings from forests and orchards; wastes from building construction, food processing, and paper industries; animal manure; and plain old garbage.

At home and at work people produce tons of waste each year, much of which is organic. For example, many of us produce a lot of waste just from cutting our lawns and trimming our trees and bushes. Some of us even have special trash containers for this green waste.

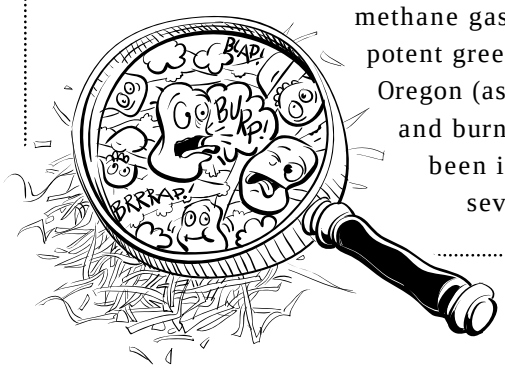


Until recently, all garbage (including organic waste) was dumped in landfills or burned without any pollution controls. Today, many biomass power plants (complete with pollution controls, if needed) use solid biomass to produce electricity. Every year, California biomass power plants consume over 7 million tons of waste wood alone. Much green waste is now trucked directly to biomass power plants rather than to landfills.

**Biomass can also be used for space heating, factory processing, and to produce liquid transportation fuel, such as ethanol.*

POWER SKETCH: Munching Microbes

Picture a landfill teeming with rotting, long-buried waste. Microbes gobble this decaying quagmire of leftover stuff that originally came from living things. As the microbes munch, they burp methane gas. Methane gas is normally released into the atmosphere and is a potent greenhouse gas (see Glossary). However, at a landfill near Eugene, Oregon (as at many others around the United States), the gas is collected and burned for heat to generate electricity. This biomass power plant has been in operation since 1992 and continues to send electrical power to several thousand homes.



Biofuels and Biogas

We can produce both liquid and gas fuels from solid biomass. This is not a new idea. The production of biomass gas, called gasification, is based on a method developed in the early 1800s to produce gas from coal for town streetlights in both England and the United States. And since the 1940s, in over a million homes in India, people have used gas fuel made from biomass for cooking in small gasifiers.

Today, gasifiers use high-tech processes to produce a gas from solid biomass by heating it under very controlled conditions. This gas can then be converted to a liquid, if desired, in a separate process.

WASTE TO ENERGY

A biomass power plant in Shasta County, California, processes about 90 tons of waste from timber mills, forests, and orchards every hour, producing enough electricity to power 50,000 homes. Each day at a biomass power plant in Vermont, about 200 tons of waste wood from local forests are converted to gas to produce "homegrown" electricity.

Gasification facilities can be large or small. In Vermont, a biomass power plant that can produce 50 MW of power is using gasification to change wood chips into a gas fuel.

Some biomass gas occurs naturally. Leftover biomass will decompose on its own, producing gases such as methane (a colorless, flammable gas). These gases can be collected for use in a biomass power plant. Some of these plants are located at landfills to burn the gas right as it is formed. Landfill power plants now operate in dozens of communities throughout the United States. Denmark has solved its livestock manure problem by turning most of it into a biomass gas fuel for heating and generation of electricity.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

Energy Farms

Sometimes specific crops and trees are grown just for biomass power. These are often referred to as energy farms. Hybrid willow and poplar trees as well as switchgrass are the crops most widely used today. They grow quickly, help keep loose soil from eroding, and thrive in a variety of growing conditions. Hybrid willows and poplars can be cut and used for energy as often as every three years, as they regrow quickly from the cut stumps.

For many years, farmers have been growing switchgrass as a side crop for livestock feed and to control soil erosion. Now, some of these farmers are growing switchgrass as their main crop — an energy crop. For example, in Alabama, farmers are successfully raising switchgrass energy crops in soil once depleted and eroded by the over-harvesting of cotton.

Besides providing a local, abundant, and "green" energy source, growing energy crops can also revitalize the economies of rural areas. It has been estimated that the United States has sufficient available land to grow enough biomass to supply one fourth of our current energy needs.

Switchgrass, a biomass energy crop, swiftly grows to 10 feet high.

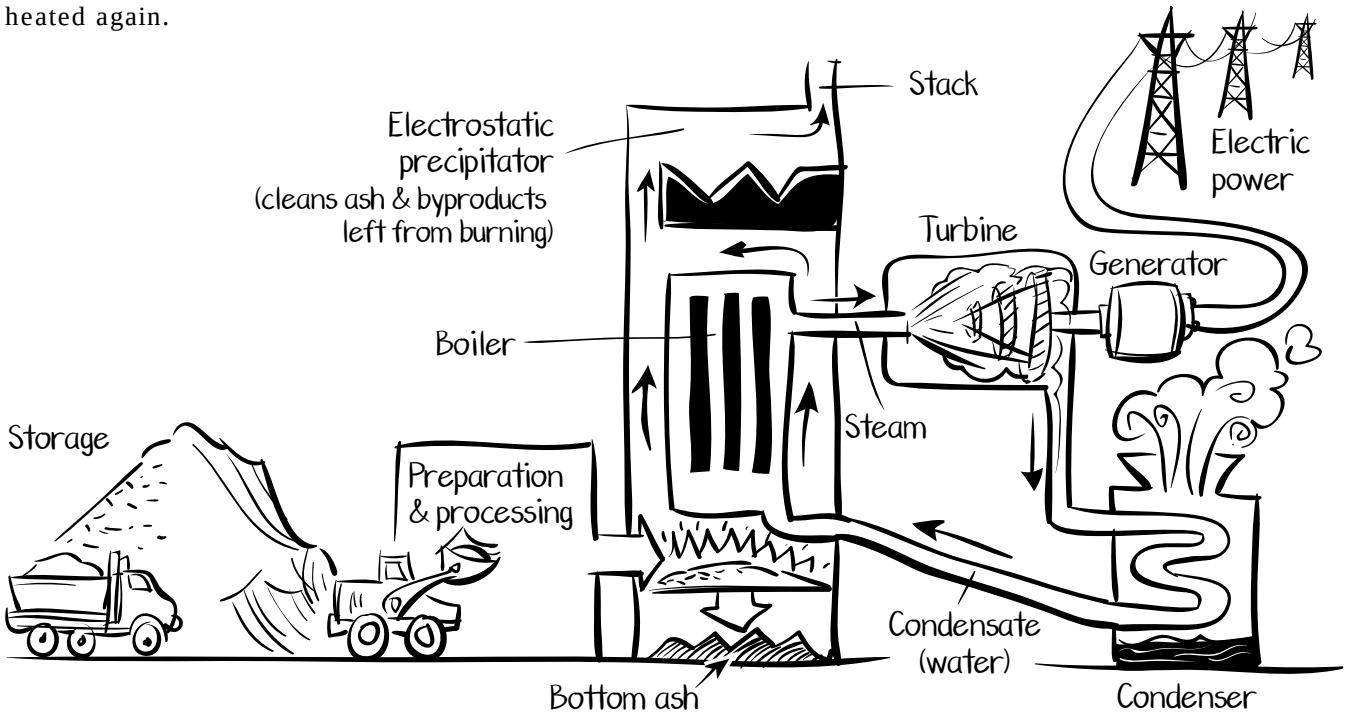
GENERATING ELECTRICITY FROM BIOMASS RESOURCES

Biomass Power Plants

Biomass power plants usually work by burning organic matter or a biofuel to produce heat to boil water for steam to drive a turbine generator. These power plants vary in size.

Large Biomass Power Plants. Large-scale biomass power plants often resemble traditional steam-driven plants, such as those that run on fossil fuels. In a biomass plant, however, the energy production process includes the preparation and processing of the biomass for burning. If it's wood, it might be chipped. If it is garbage, non-burnable materials are removed, and sometimes the remainder is formed into pellets. At other biomass plants, the biomass is converted into a gas or liquid fuel before it is burned.

The processed biomass is then burned in enormous furnaces. The resulting heat boils water for steam that is used to drive turbine generators. Biomass power plants have special technologies that clean most of the ash byproducts and smoke produced from burning before they are released into the atmosphere. Like most other power plants, they have condensers that cool the water and recycle it to be heated again.



Large-scale biomass power plant

Small Biomass Power Plants. Small biomass power plants are often found in rural areas and in the villages of developing countries. These little powerhouses can deliver electricity to a single facility or to a limited number of nearby users. They usually make use of locally generated biomass. For example, one Midwest dairy farmer uses cow manure to produce methane gas. This gas drives a biomass power plant that generates enough electricity for his farm and for fifty of his neighbors.

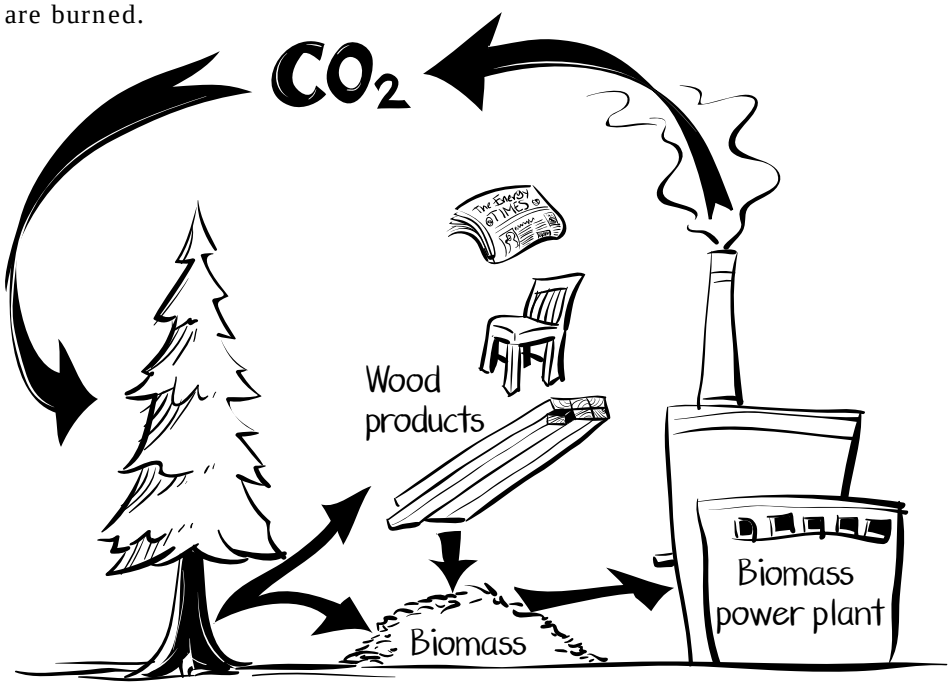
Cofiring. Biomass can also be burned along with another type of fuel, such as coal, in a process called cofiring. This can be done using existing equipment in a traditional coal power plant. The addition of biomass at these power plants reduces the amount of pollutants produced. Since most of the electricity in the United States is currently produced from coal and other fossil fuels, adding biomass has a positive effect on the process. Some coal power plants even dedicate a portion of their operations to burning only biomass.

IT'S A GAS!

While biofuels are often burned to heat water for steam-driven electrical generation, they can also produce electricity without creating steam. Biofuel gases themselves are sometimes used to drive gas turbines. Gas turbines are driven by heated and pressurized gas instead of by steam (see page 121).

CONSIDERATIONS

- Biomass energy crops are beneficial to the environment because they take in carbon dioxide as they grow. This can offset CO_2 — a greenhouse gas — given off when they are burned.



CO_2 from biomass power plants is offset by growing trees and crops.

CONSIDERATIONS (continued)

- Use of orchard and forest trimmings, along with other green waste for biomass fuel, can reduce waste disposal and landfill costs.
- Anything that is burned gives off some byproducts (ash and gases, for example). Power plants that use solid biomass have special equipment to prevent most of these pollutants from going into the atmosphere.
- Gases produced from decomposing organic material in landfills are pollutants and, if highly concentrated, are toxic. Collecting and processing these gases for fuel helps solve this problem. Biofuels burn efficiently and so produce fewer pollutants.
- When transported or stored for use as a combustible material, solid biomass can take up a lot of space.
- Some people think that thinning overgrown forests and collecting fallen branches and tree trunks from the forest floor for biomass fuel protects forests from catastrophic wildfires and contributes to a healthier forest ecosystem. Others fear that, if not done correctly, this practice can adversely affect animal habitats and/or disrupt fragile ecosystems.
- Biomass is a renewable resource if we don't harvest the organic materials faster than crops or forests can be cultivated or naturally regenerated.
- Today, solid biomass power plants generate mostly baseload electricity. Biogas plants can be either baseload or peaking plants.

DATA FILE: Biomass

California

- Over 1.4 trillion pounds of biomass are burned annually for the production of electricity in California.
- Almost 3 percent of California's electricity — around 600 MW — is produced from biomass.

United States

- Over 100 biomass power plants are generating more than 1,700 MW in the United States.
- The states producing the most electricity from biomass are California, Maine, and Michigan.

Worldwide

- Some of today's most active users of biomass for electrical generation are western Europe, China, Mexico, Brazil, India, and Russia.

Data available in 2003

Renewable Energy Source: GEOTHERMAL

VOCABULARY

binary power plant
conduction
crust
dry steam power plant
fissure
flash power plant
fumarole
geothermal reservoir
(hydrothermal aquifer)
groundwater
heat exchanger
hot dry rock
hydrogen sulfide
magma
mantle
modular
mud pot
porous
subducting
tectonic plates
wastewater

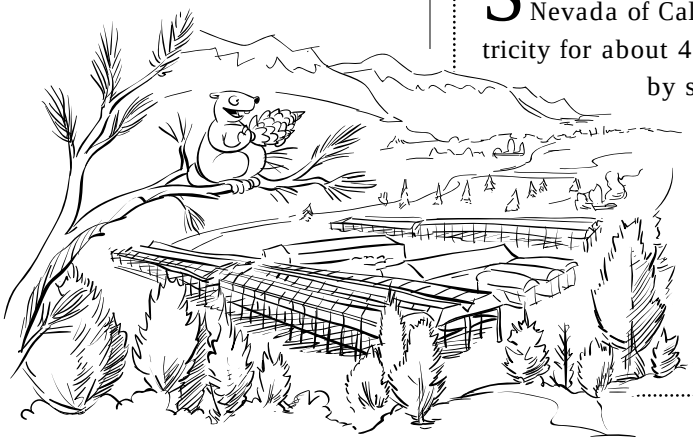
PEOPLE HAVE ALWAYS BEEN FASCINATED with volcanoes and their fiery displays of nature's power. Many ancient societies once thought volcanoes were homes to temperamental gods or goddesses. Today we know that volcanoes result from the immense heat energy found in Earth's interior. This heat also causes hot springs, steam vents (fumaroles), and geysers.

Over the ages, humans have benefited from Earth's geothermal energy by using the hot water that naturally rises up to the earth's surface. We have soaked in hot springs for healing and relaxation, and have even used them as instant cooking pots. Hot springs have also been an important part of cultural life, especially in Japan and Europe.

Today we drill wells deep underground to bring hot water to the surface. We use this geothermal energy to heat buildings, to speed the growth of plants and fish, and to dry lumber, fruits and vegetables. We use the really hot water to generate electricity.

POWER SKETCH: Good Neighbor

Set amidst the open vistas and forests of the eastern Sierra Nevada of California, a power plant churns out enough electricity for about 40,000 homes. The natural setting is not marred by smoky emissions, because there are none. This geothermal power plant uses hot water resources from an underground geothermal reservoir to power its turbine generators. Many tourists and residents of nearby Mammoth Lakes don't even realize the power plant is there beside the main highway. Those who do know say it is a good neighbor indeed.



Mammoth Lakes geothermal power plant

THE GEOTHERMAL RESOURCE

Geo means earth and *thermal* means heat. So geothermal energy is the heat energy of the earth.

Heat Energy from the Inner Earth

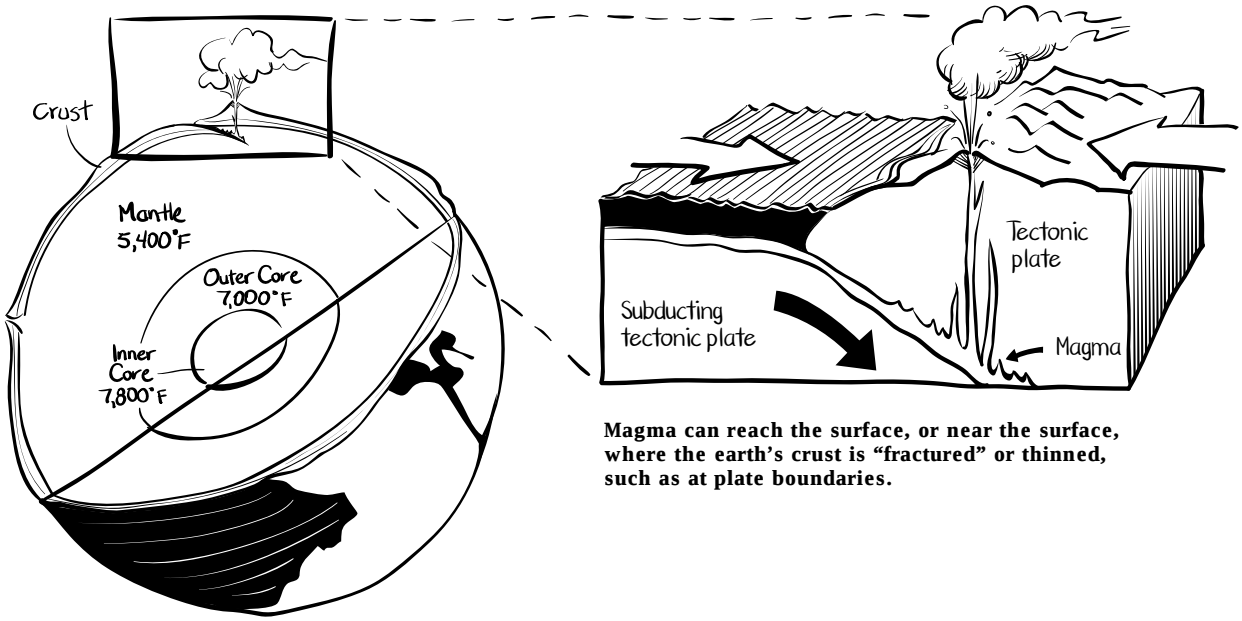
Billions of years ago our planet was a fiery ball of liquid and gas. As the earth cooled, an outer rocky crust formed over the hot interior, which remains hot to this day. This relatively thin crust "floats" on a massive underlying layer of very hot rock called the mantle. Some of the mantle rock is actually melted, or molten, forming magma.

The heat from the mantle continuously transfers up into the crust. Heat is also being generated in the crust by the natural decay, or breakdown, of radioactive elements.

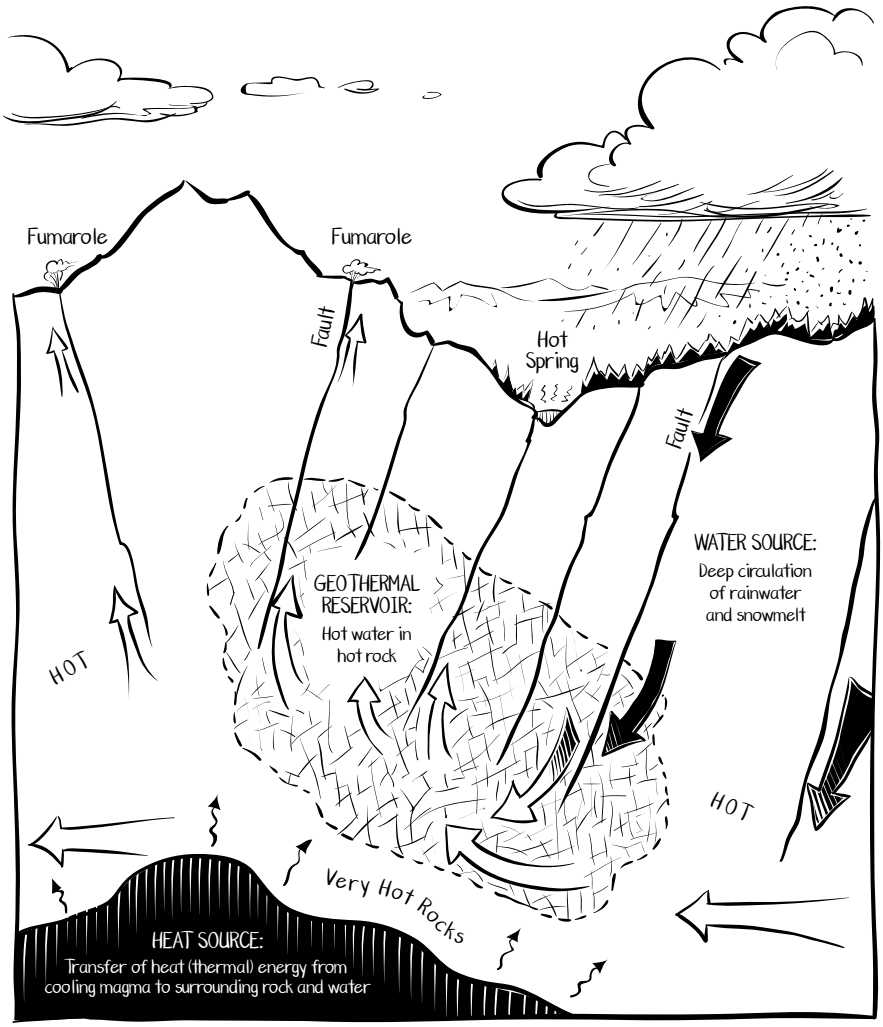
The crust is broken into enormous slabs — tectonic plates — that are actually moving very slowly (at the rate your fingernails grow) over the mantle, separating from, crushing into, or sliding (subducting) under one another. The edges of these huge plates are often restless with volcanic and earthquake activity. At these plate boundaries, and in other places where the crust is thinned or fractured, rising magma can travel up the many cracks and fissures. Sometimes the magma emerges above ground — where we know it as lava. But most of it stays below ground where, over time, it creates large regions of hot rock.

HOT LOCATIONS

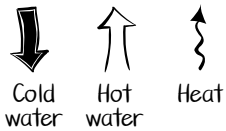
The edges of the continents that surround the Pacific Ocean (the Pacific "Ring of Fire") are prone to earthquakes and volcanoes and have some of the best geothermal resources in the world. This includes the western part of North, Central, and South America; Japan; the Philippines; and Indonesia. Some of the other prime geothermal locations include Iceland, Italy, New Zealand, the Rift Valley of Africa, and Hawaii.



Magma can reach the surface, or near the surface, where the earth's crust is "fractured" or thinned, such as at plate boundaries.



A geothermal reservoir is a large underground area of hot permeable rock saturated with superheated water.



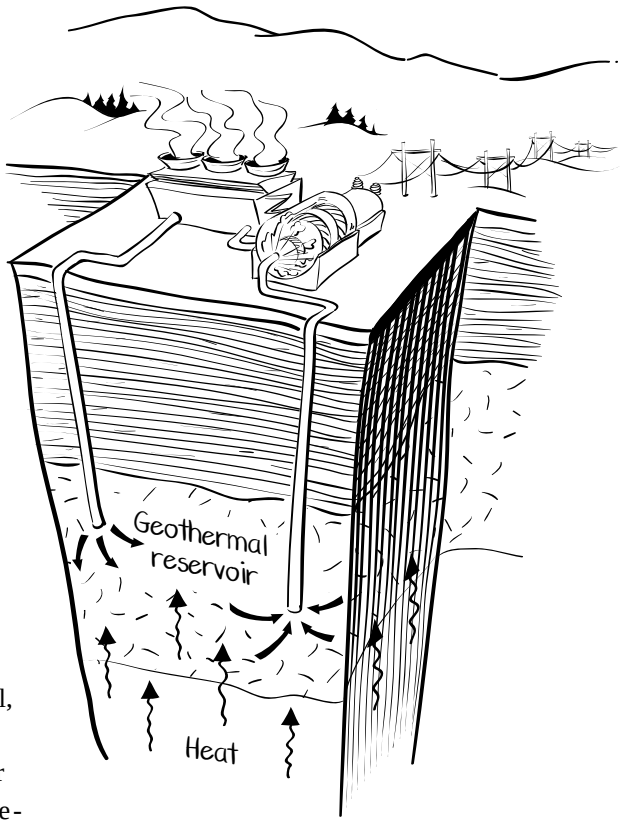
The Geothermal Reservoir

Rainwater and snowmelt can seep miles underground, where it absorbs heat from the hot rock. This water can get really hot. It can reach temperatures of 500°F (260°C) or higher — way above boiling.

Sometimes this hot water will work its way back up (hot water is less dense than cold and so tends to rise). If it reaches the surface it can form hot springs, steam vents (fumaroles), mud pots, or geysers. If it gets trapped deep below the surface, it can form a "geothermal reservoir" of hot water and steam. A geothermal reservoir is an underground area of cracked and porous (permeable) hot rock saturated with hot water. The water and steam from these superheated reservoirs are the geothermal energy resources we use to generate electricity.

GENERATING ELECTRICITY FROM GEOTHERMAL RESOURCES

Geothermal reservoirs can be found from a few hundred feet up to two or more miles below Earth's surface. We drill wells to reach them. After the wells are drilled, steel pipe (casing) is inserted. Now with an open passageway to the surface, the hot geothermal water or steam shoots up the well naturally or is pumped to the surface. From here it's piped into a geothermal power plant.

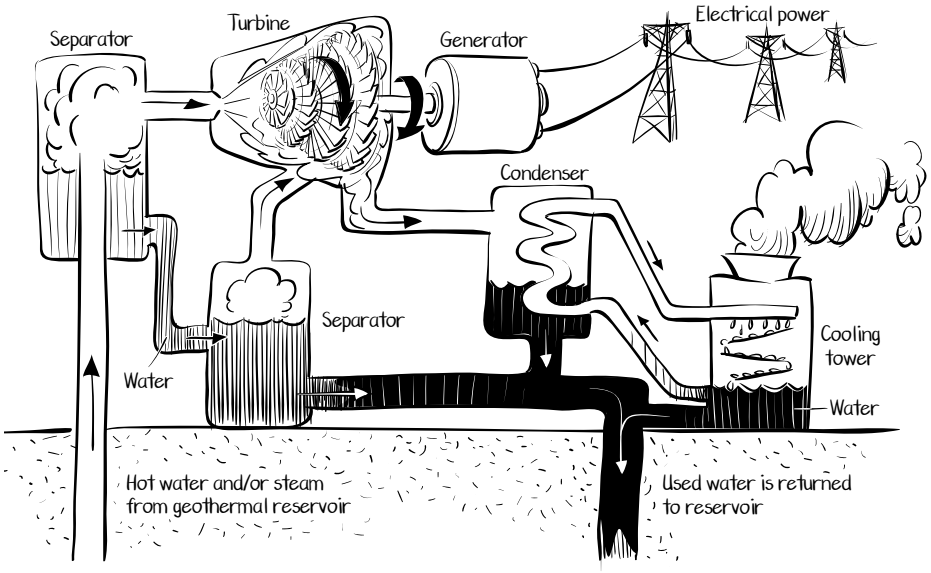


Hot water or steam from deep underground shoots up a geothermal well, spins the turbine-generator, and is returned to the reservoir.

Geothermal Power Plants

There are different kinds of geothermal power plants, because there are different kinds of geothermal reservoirs.

Flash Steam Power Plants. Flash steam plants use really hot geothermal reservoirs of about 350°F or higher. From the well, high-pressure hot water rushes up pipes into a "separator," where the pressure is reduced. This causes more of the water to vigorously "flash" to steam, the force that drives the turbine-generators. After the steam does its work, it is condensed back into water and piped back down into the geothermal reservoir so it can be reheated and reused. Most geothermal power plants in the world today are flash plants.

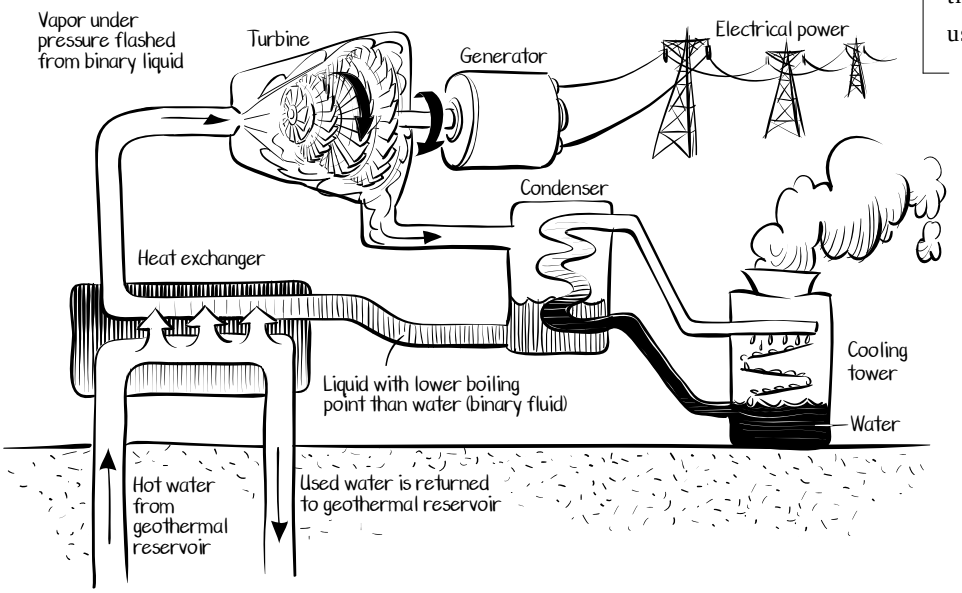


Flash steam plants can include one steam/water separator or, more commonly, two separators (shown here).

Dry Steam Power Plants. A very few geothermal reservoirs are filled naturally with steam, not water. This means that the wells will produce only steam. The power plants that run on this steam are called "dry steam" power plants. Here, the steam blasts right into the turbine blades (they do not need separators), then is condensed to water and piped back into the reservoir. Though dry steam reservoirs are rare, they have been important to the development of geothermal power, especially in California, Italy, and Japan.

Binary Power Plants. In moderate-temperature geothermal reservoirs, the water is hot (over 200°F, or 93°C), but not hot enough to produce steam with the force needed to efficiently turn a turbine-generator. Electricity is generated from these reservoirs, however, using binary (*bi* means two) power plants.

In the binary process, the geothermal water is used only for its heat, not to produce steam. In a heat exchanger, the heat transfers to a second liquid. This second liquid flashes to vapor and drives the turbine. Once used, the geothermal water is pumped back into the reservoir. Moderate-temperature reservoirs are more common than high-temperature reservoirs, so the use of binary power plants is expanding worldwide.



Binary power plant

HEAT EXCHANGERS

Heat exchangers are used in electricity generation when the heat source is hot, but not quite hot enough to bring water to a boil to create forceful steam.

A heat exchanger transfers (moves) heat (thermal energy) from a hotter liquid to a cooler one without letting the two liquids mix together. An arrangement of metal pipes or plates keeps the liquids separate, so only the heat is conducted through the metal from the first liquid to the second.

Sometimes the second liquid is water, which flashes to steam to drive the turbine. Sometimes it is a liquid with a boiling point quite a bit lower than water, so it flashes to vapor at a lower temperature.

Like steam, the force of rapidly expanding vapor drives the turbine blades. Often the steam or vapor is then condensed back to a liquid and used over and over again.

Sizes of Geothermal Power Plants

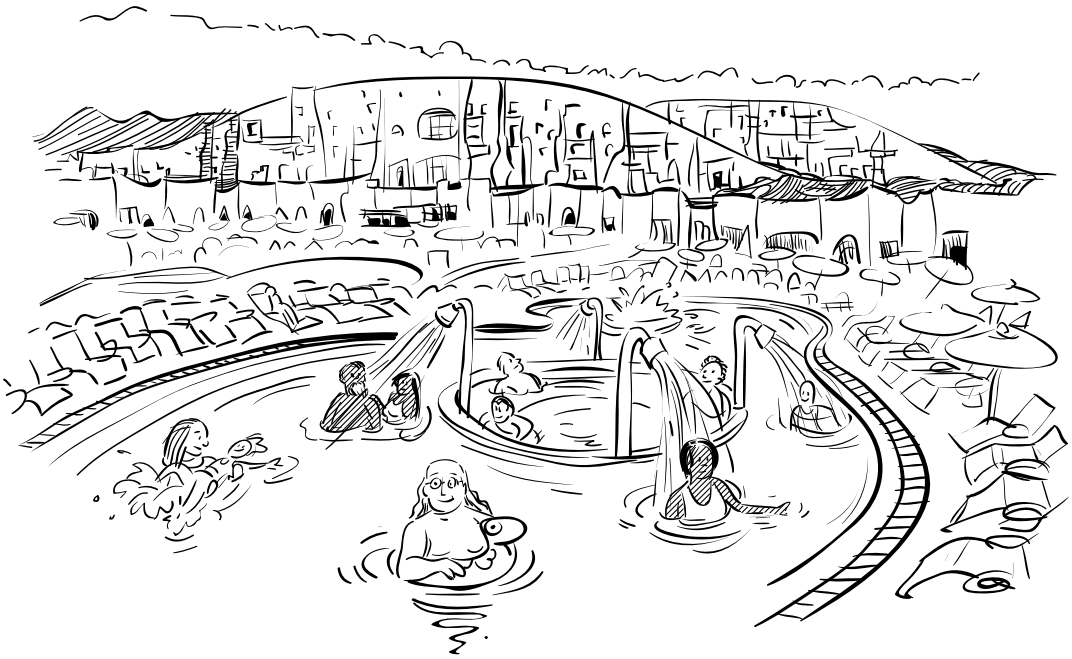
Geothermal power plants come small (300 kW to 10 MW), medium (10 MW to 50 MW), and large (50 MW to 100 MW and higher). A geothermal power plant usually consists of two or more turbine-generator "modules" in one plant. Extra modules can be added as more power is needed.

Binary plants are especially versatile because they use relatively low reservoir temperatures. Small binary modules can be built quickly and transported easily . These little power plants are great for use in remote parts of the world, far from transmission lines. One interesting plant is installed in the rugged mountains of Tibet (People's Republic of China). At a soaring 14,850 feet (4,526 meters), it is the highest geothermal power plant in the world.

Small binary plants are also popular for hot spring spas and health resorts. They add the convenience of electricity while maintaining an environmental and healthful appeal. For example, an artistically designed hot springs resort in Austria is using a small binary geothermal power plant for its power.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts
1 megawatt serves about 1,000 homes in the United States.



A hot springs resort in Austria powered by geothermal energy

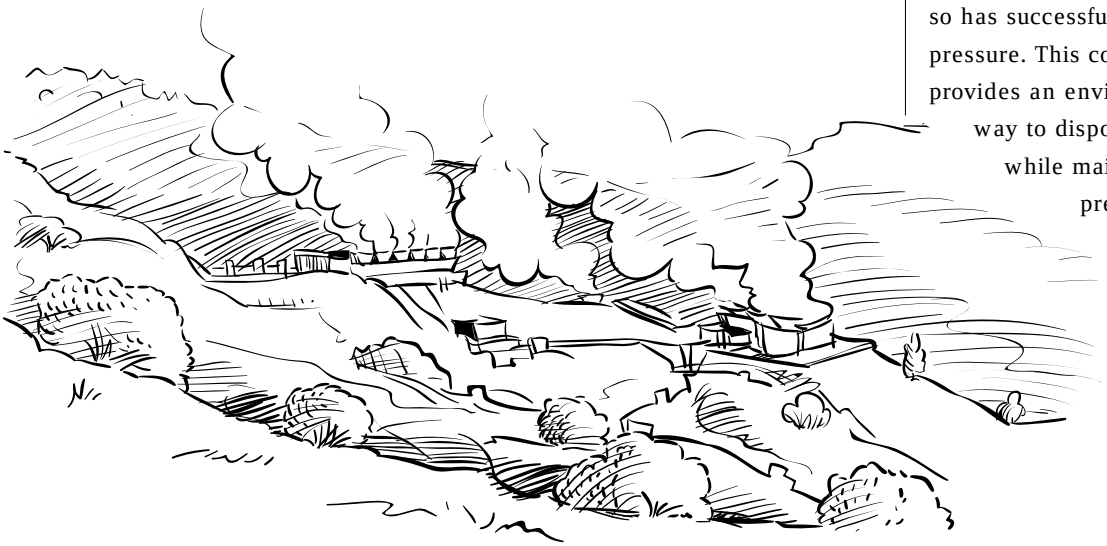
Geothermal at Work around the Globe

California produces electricity from nearly 50 geothermal plants, up and down the state. Northern California has 21 plants at "The Geysers," and more are planned in the Cascade Mountains. Central California has a plant near Mammoth Mountain; and Southern California has plants in two regions. One is in the intensely agricultural southern tip of the state. The other, on the China Lake Naval Air Weapons Station, is so successful that the Department of Defense wants to develop geothermal potential at its other western bases.

Three other states in the U.S. now produce geothermal-powered electricity: Hawaii, Nevada and Utah. To increase geothermal use, the U.S. Department of Energy has an active program called "GeoPowering the West." It targets a total of 19 western states, each with good prospects for geothermal production.

Geothermal generates about one-fifth of the electricity in the Philippines, making this country the second largest user of geothermal electricity in the world (after the United States). Italy was the site of the world's first geothermal plant, still operating at one of the few "dry steam" fields in the world. Other places using geothermal energy include Mexico, Indonesia, Iceland, New Zealand, Japan, and several Central American countries.

Geothermal industry experts have identified 39 countries that could be powered 100 percent by geothermal energy.



Geothermal power plants at The Geysers in California

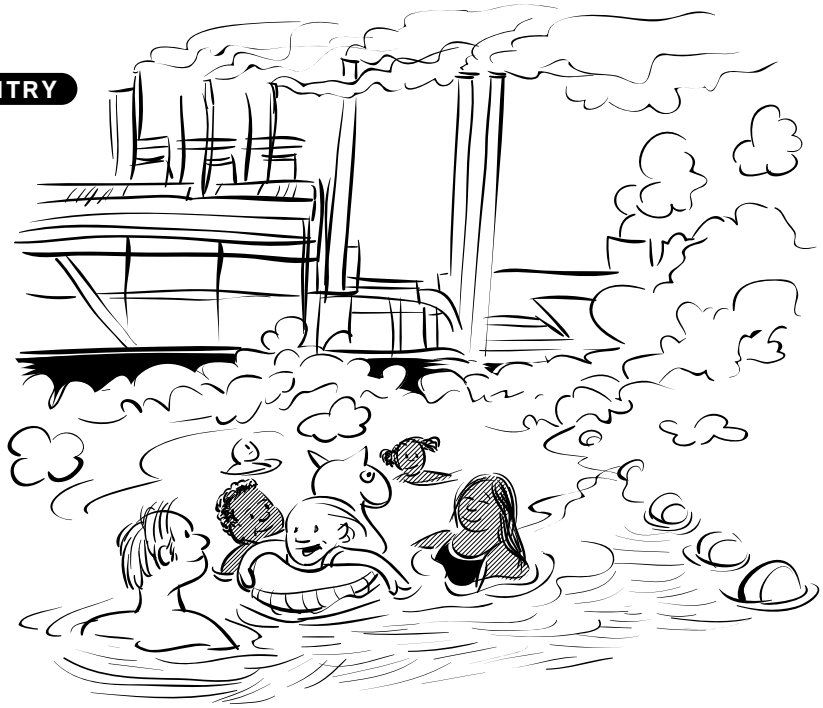
A WINNING SOLUTION

A geothermal area in northern California is named "The Geysers." It once was the site of a famous resort — attracting the likes of Jack London and Teddy Roosevelt. Today it is the world's largest producer of geothermal electrical power. Even its reservoir is unique, being one of the few in the world to produce steam (rather than mostly water). Today, after 40 years of production, the steam field reliably generates enough electricity to power a city the size of San Francisco.

In the 1980s, the reservoir began to lose steam pressure, reducing the amount of electricity that could be produced. Today, cities in Lake and Sonoma Counties are piping their cleaned wastewater many miles to The Geysers and injecting it deep into the geothermal reservoir. Doing so has successfully boosted steam pressure. This cooperative project provides an environmentally safe way to dispose of wastewater, while maintaining steam pressure for electricity production. Everyone wins!

HOT ENERGY FOR A COLD COUNTRY

Iceland is such an active geothermal area that hot springs occasionally bubble up right into people's living rooms! People in this cool-weather country really make good use of their abundant geothermal energy resource. They use it for everything from heating homes, offices, and greenhouses to warming swimming pools and generating electricity. Even in the middle of winter, it is not uncommon to see people soaking in the steamy hot pool found right outside a geothermal power plant.



Some spas in Iceland are located right next to geothermal power plants.

New Reservoirs from Hot Rock

With today's technology we use the water and steam in geothermal reservoirs to carry Earth's heat to the surface. But there are many places underground where the rock is very hot, yet doesn't naturally contain much water. Researchers are working on ways to pump water down into the hot rock so the water can carry the geothermal heat, as in a natural geothermal reservoir. Sometimes called "hot dry rock," this method involves drilling a well down into the hot rock, cracking it, and then injecting water down into the fractured rock. The now-heated water is then pumped up a separate well where it can be used to generate electricity in a binary power plant.

A U.S. project at Los Alamos, New Mexico, first demonstrated that hot dry rock power plants can work. Japan, France, Germany, Switzerland, Australia, and several other countries also are working on this method. In the United States and elsewhere, similar processes are being adapted to boost the production of already-developed, natural geothermal reservoirs.

CONSIDERATIONS

- Geothermal power plants have no smoky emissions. What we see coming out of a geothermal plant cooling tower is steam (water vapor). Flash and dry steam plants produce only a small fraction of air emissions compared to fossil fuel plants. Binary power plants have virtually no polluting emissions.
- Geothermal power plants use very little land compared to conventional energy resources and can share the land with wildlife or grazing herds of cattle. They operate successfully and safely in sensitive habitats, in the middle of crops, and in forested recreation areas. However, they must be built at the site of the geothermal reservoir, so there is not much flexibility in choosing a plant location. Some locales may also have competing recreational or other uses.
- Geothermal wells are sealed with steel casing, cemented to the sides of the well along their length. The casing protects shallow, cold groundwater aquifers from mixing with geothermal reservoir waters. This way the cold groundwater doesn't get into the hot geothermal reservoir and the geothermal water doesn't mix with potential sources of drinking water.
- Geothermal water contains varying concentrations of dissolved minerals and salts. Sometimes the minerals are extracted and put to good use. Examples are silica (used in cement), and zinc (for electronics and for making alloys such as bronze and brass). At reservoirs with higher concentrations, advanced geothermal technology keeps the salty, mineralized water from clogging up and corroding power plant equipment.

(continued)

DATA FILE: Geothermal

California

- In California, geothermal is the second largest source of renewable electricity (after hydropower), contributing about 5 percent of the state's electricity.
- The Geysers in northern California is the world's largest single source of geothermal power, generating 900 MW of electricity.

United States

- Geothermal resources suitable for electricity production occur mostly in the western states.
- The U.S. has about 2,400 MW of geothermal power plants — more than any other country.

Worldwide

- Around the world there are about 9,000 MW of geothermal power plants in 22 countries, including the U.S., Italy, the Philippines, Japan, Indonesia, New Zealand, and Mexico.

Data available in 2003

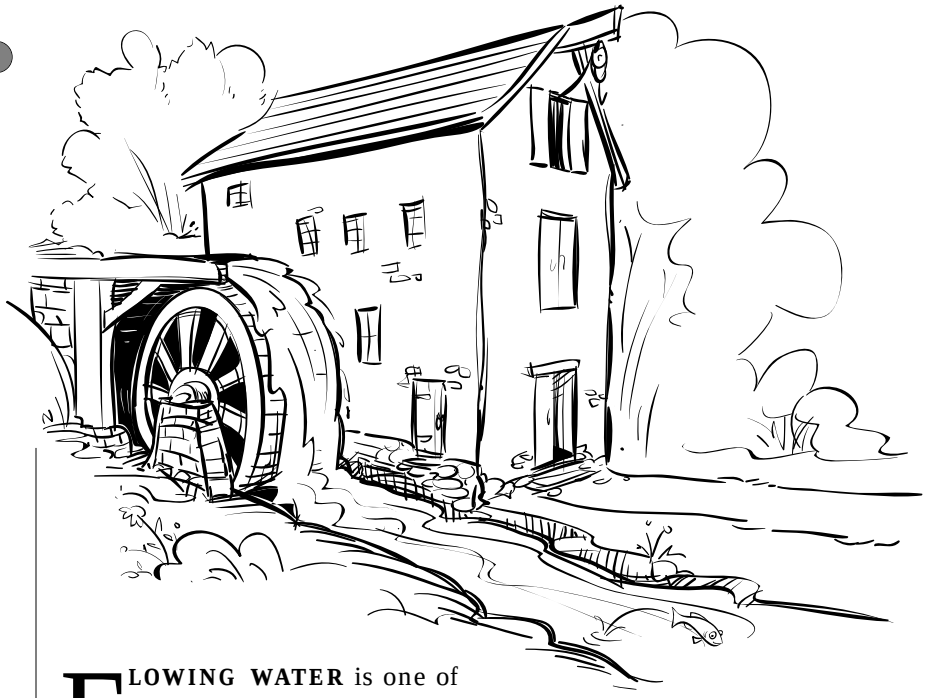
CONSIDERATIONS (continued)

- Some geothermal aquifers contain dissolved gases such as hydrogen sulfide. This gas smells bad (like rotten eggs) and is toxic at high concentrations. Modern geothermal technology ensures that geothermal power plants capture these gases before they go into the air. The gas removal processes can produce sulfur for use in fertilizers.
- Geothermal reservoirs must be carefully managed so that the steam and hot water are produced no faster than they can be naturally replenished or supplemented.
- Geothermal power plants provide very reliable baseload electricity. Some plants can increase production to supply peaking power. But geothermal plants can't be used solely as peaking plants; if geothermal wells were turned off and on repeatedly, expansion and contraction (caused by heating and cooling) would damage the well.

Renewable Energy Source: HYDROPOWER

VOCABULARY

flow
head
horsepower
impoundment
penstock
pumped storage
run-of-river (diversion)
tailrace
water cycle



FLOWING WATER is one of nature's most powerful forces. Humans began harnessing this energy force several thousand years ago. By the first century B.C., waterwheels were working in many parts of the world, including Greece. In fact, the term hydro comes from an ancient Greek word for water. For centuries waterwheels provided the energy to grind grain and saw lumber. By the 1700s, more than 10,000 waterwheels were hard at work in colonial New England alone.

During the Industrial Revolution, waterwheels were also used to run textile mills and other factories. By the mid-1800s water turbines were driving a new device – the generator – to produce electricity. In 1878, the world's first commercial water-driven electrical station opened at Niagara Falls, New York, and the era of hydroelectric power was born.

THE HYDROPOWER RESOURCE

The hydropower resource is the energy in flowing water, provided to us naturally by the earth's water cycle and by gravity. Moving water has a great deal of force. In fact, the force of the flow of a medium-size river is equal to several million horsepower. (One million horsepower, if converted to electricity, would equal the power of 746 MW.) You can imagine how easily this much force can be put to work driving waterwheels or water turbines.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
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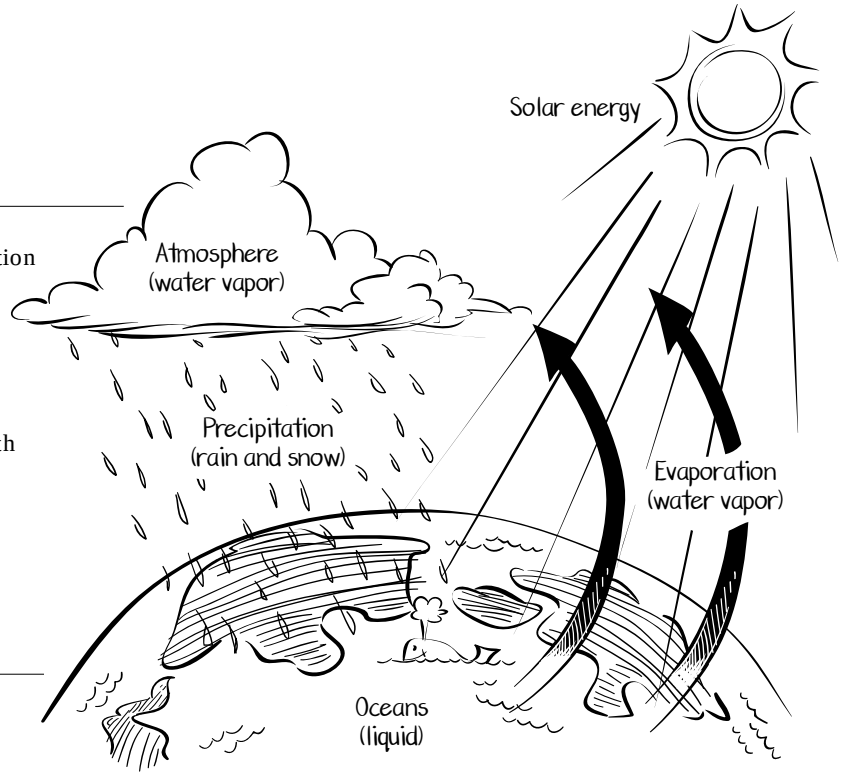
1 megawatt serves about 1,000 homes in the United States.

DISCUSSION

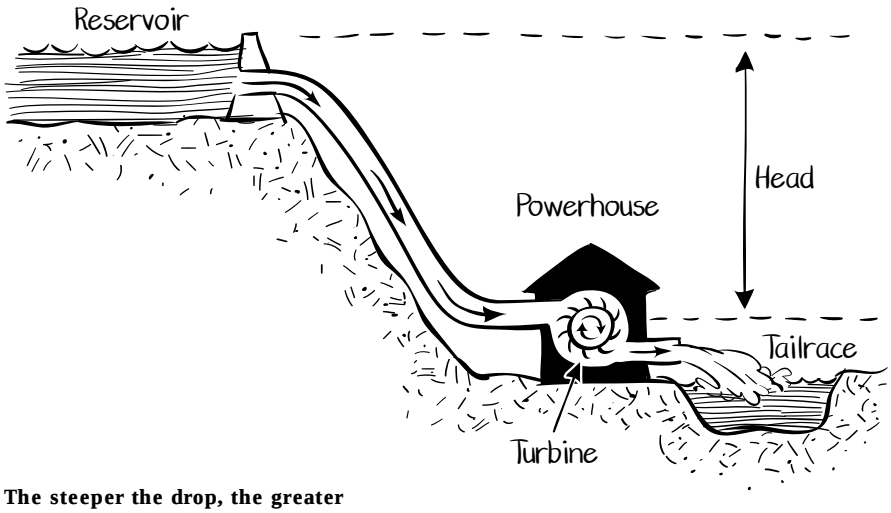
THE WATER CYCLE

Energy from the sun causes evaporation of water from the land and from the oceans, rivers, and lakes. This puts water vapor into the atmosphere where it can condense to form clouds, which then return the water to the earth as rain, snow, and ice. Water runoff is pulled down by gravity to form streams and rivers, which flow to lakes and to the sea. The cycle of evaporation and precipitation is continuous.



The Steeper the Better

The amount of force that water can impart depends on two factors: the head, the vertical distance the water falls; and the flow, the volume (amount or mass) of the water. The greater the head and the flow, the more water energy is available. So hydropower systems work best with a steep drop (high head) and a large flow. One gallon (3.8 liters) of water falling 100 feet (30 meters) per second can generate about 1 kW of electric power. No wonder waterfall areas, with their naturally steep drops, were chosen as the sites for the world's first hydroelectric power plants.



The steeper the drop, the greater the force of falling water

GENERATING ELECTRICITY FROM HYDROPOWER RESOURCES

All hydropower plants, large or small, use a water turbine and a generator to produce electricity. The water turbine is at the heart of any hydroelectric system. Resembling its cousin, the waterwheel, it is far more streamlined and spins much faster. The first model, the Francis turbine (also called a Pelton wheel), is still in wide use. Its curved paddles are enclosed in a shell into which the water flows. Today's water turbines are designed for maximum efficiency. They come in many shapes and sizes to work with varying conditions of head and flow. Hydropower generators resemble those found in many other types of electric power plants.

Most hydropower systems use some type of water passageway, pipe, or channel, to send the water to a turbine. The passageway not only directs the water where it is needed, but also concentrates the water's force by increasing the volume in a specific area of flow.

Most have a powerhouse enclosing the turbine(s) and/or generator(s) to protect the equipment and to make maintenance possible. Water leaving the turbines is channeled back to the river downstream of the power facility.

HARD-WORKING WATER

The ambitious Big Creek hydropower project in California, begun in the early 1900s, now sends the water of Big Creek through a series of dams, lakes, tunnels, and powerhouses — all built into the steep mountainsides of the Sierra Nevada between Yosemite and Sequoia national parks. Nine powerhouses have been added, which altogether generate over 1,000 MW of electricity, prompting some to call this river system the "hardest working water in the world."

POWER SKETCH: Power in Paradise

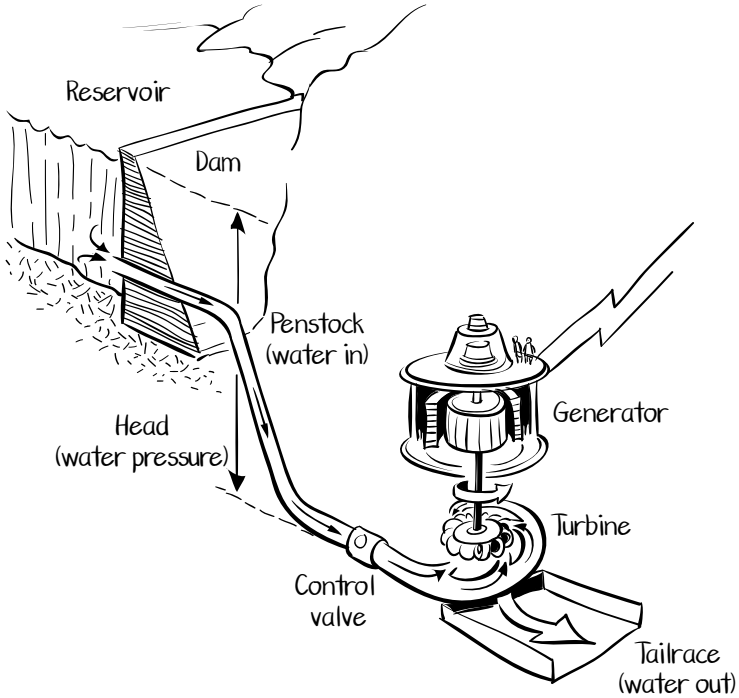
Members of a family living in the hilly rainforest many miles from Quito, Ecuador, have always treasured their lush, natural environment. After many years of roughing it, they wanted to enjoy a few conveniences that required electricity. But they lived far from power plants and transmission lines. They solved this dilemma by installing a small hydroelectric system near the waterfall on their property. This "run-of-river" system does not disrupt the flow of the river feeding the waterfall and pool below. It does generate enough electricity to run a small refrigerator and electric lights. It even provides power to run a computer, which is used for their exotic plant-seed business. The forest has almost covered the power-generating equipment with foliage, so they enjoy the convenience of electricity without disturbing the beauty of their little piece of paradise.

Two Common Hydropower Systems

There are basically two ways that hydropower facilities use the force of flowing water.

Storage Hydropower Systems. The hydropower plants we're most used to seeing are called "storage" hydropower plants. These plants use a dam, an impoundment that holds water back to create an artificially steep drop (high head). The dam is placed across a river, causing it to back up into a reservoir or lake. The water is held back until it is needed. When released, it falls down through pipes, or penstocks, to turbines in the powerhouse far below. Once used, the water usually flows through tailraces (pipes or channels) to the downstream river.

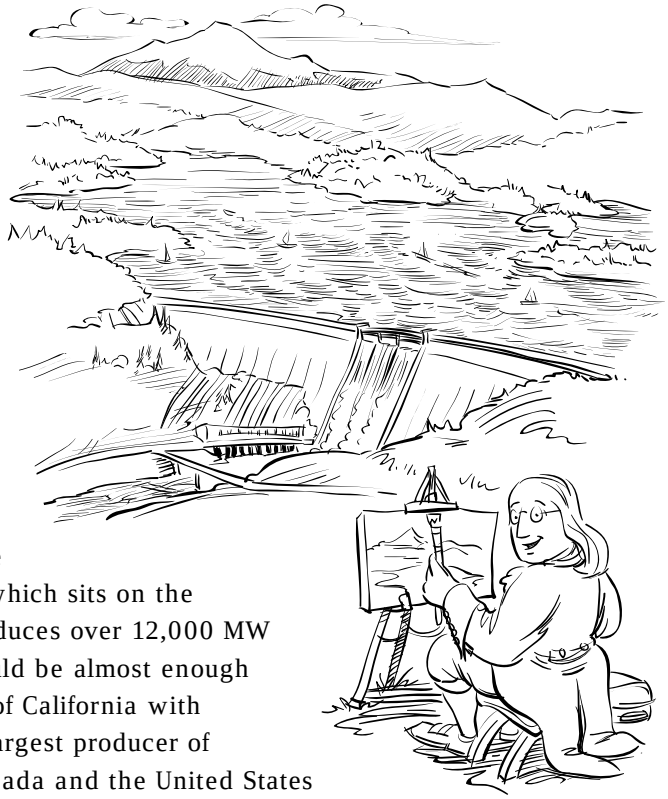
In 1887, California hosted the first hydropower plant in the western states, the High Grove Station in San Bernardino. A number of other pioneering hydro plants were built in California, including Folsom Dam, which began generating electricity from its powerhouse in 1895. After several upgrades, the Folsom Dam is still in operation today. As with a number of other hydropower projects, Shasta Dam was originally planned as an irrigation and flood control project. It began generating electricity in 1944 and is still a significant source of hydropower in California.



Inside a storage hydroelectric plant

STORE NOW, USE LATER

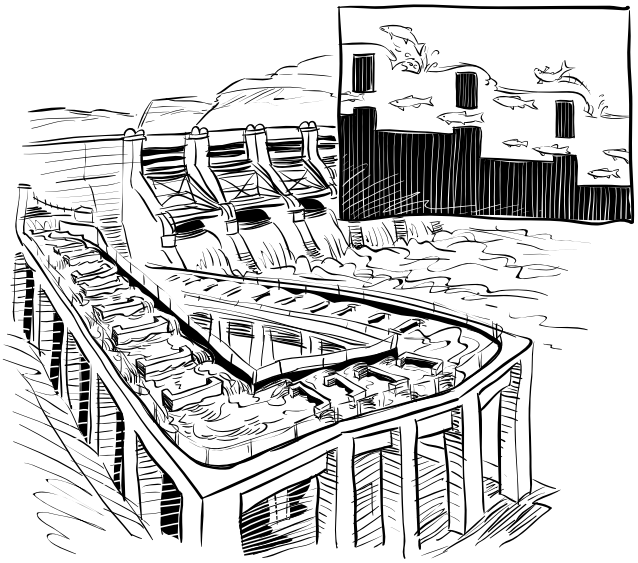
Some dams use a pumped storage system to move water between an upper and a lower reservoir. During times of high demand (great need) for electricity, water is released from the upper reservoir to generate electricity and ends up in the lower reservoir. When electricity is plentiful, and this plant is not needed, the electricity is used to pump the water back to the upper reservoir. An example of this type of system is the Eastwood powerhouse in the Sierras of California.



The largest storage hydroelectric facilities in the United States are located along the Columbia River in the Pacific Northwest. These include the Chief Joseph, John Day and Grand Coulee Dams. In fact, the Grand Coulee is the largest dam in the United States and the third largest in the world. It produces over 6,000 MW of power and holds back a lake 150 miles (241 kilometers) long.

The largest hydropower plant in the world is the Itaipú hydropower plant, which sits on the border of Brazil and Paraguay and produces over 12,000 MW of power. (The power it generates would be almost enough to supply about one third of the state of California with electricity!) In fact, Brazil is the third largest producer of hydroelectricity in the world. Only Canada and the United States generate more. China, India, Malaysia, and Vietnam are planning large-scale hydro projects. China has begun a huge hydropower project on the Yangtze River that will control flooding while producing an anticipated 18,200 MW of electricity. Europe, Japan, and Russia are also top hydropower producers.

CHUTES AND LADDERS

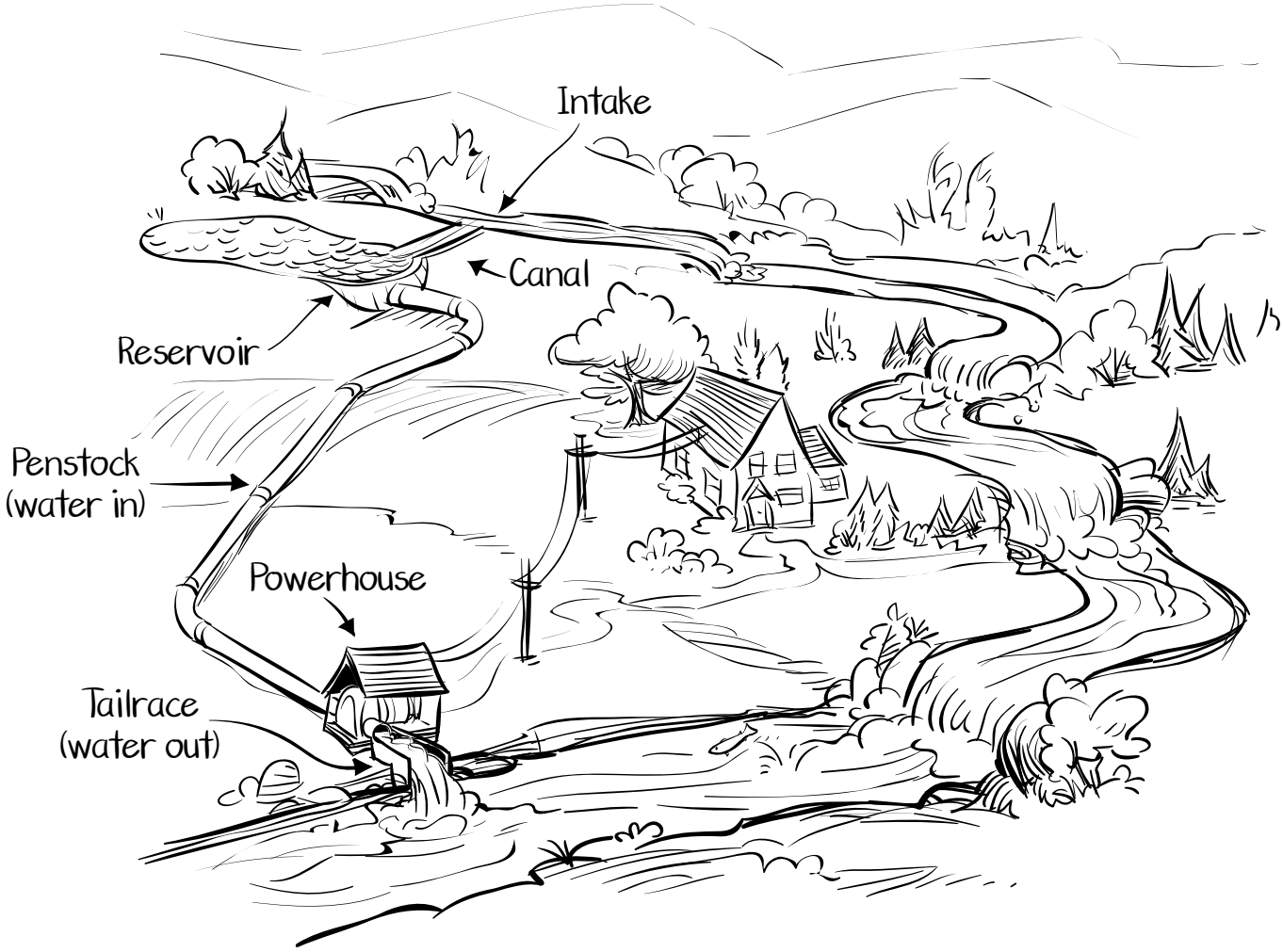


There are a number of ways to avoid damage to fish caused by large storage hydropower plants. Innovative methods include fish ladders for adult salmon migrating upstream to spawn, flashing lights to alert night-migrating fish, screens to shield turbines, and surface collectors that guide juvenile fish through chutes that go around the project.

Run-of-River (Diversion). Run-of-river systems are today's hydropower systems of choice, because they are designed to maintain the natural flow of a river and are fish-friendly.

With these systems, the river generally continues to run its natural course while some of its water is directed off, or diverted, through a pipe or channel and often is held (usually for a short period of time) until needed. Once the diverted water has done its work, it is sent back to join the river through a tailrace. There are a number of ways this is accomplished.

In one type of facility, a pipe runs down an upriver slope to a downriver powerhouse at a lower elevation. In another system, water is diverted from a river into a small holding bay and then channeled down to a powerhouse as needed.



A diverted run-of-river system

A third method creates a channel through rock that runs alongside a steep drop. Nothing on the surface is disrupted as most of the system is placed underground. The Tazimina Hydroelectric Project near Anchorage, Alaska, was installed in a steep gorge that has turned a tumbling river into a 120-foot (37-meter) waterfall. Some of the upper river's flow is diverted through a vertical pipe installed in the cliff alongside the waterfall. The water rushes down the pipe to turbines in a powerhouse below and then it rejoins the river's main flow.

Run-of-river hydropower is useful in many places. It limits disturbance to the natural setting. Also, it can provide electrical power for people living far from transmission lines.

In the Gold Rush country of California's Calaveras County, there is a small run-of-river power plant called Murphy's Powerhouse, on Angels Creek. The name of the powerhouse refers back to Murphy's Camp, where water was originally diverted to assist the miners who were washing gravel to look for gold.

Sometimes storage and run-of-river systems are combined. For example, at Bishop Creek Hydropower Project in California's Eastern Sierra Nevada, spring runoff from melting snow is collected in two reservoirs, built to prevent flooding of the Bishop Creek area below. Throughout the year, a moderate amount of water is released into Bishop Creek, where it eventually spills through four run-of-river powerhouses. These were originally built to provide electrical power for gold and silver mining in the early 1900s and still provide plenty of electricity today.

There are a number of run-of-river projects in the United States. Many are hailed for preserving a river's flow while providing electrical power. One project is located just off the Mississippi River near Vidalia, Louisiana. It maintains the flow of the "Mighty Mississippi" (a main artery for transportation), helps control flooding, and supplies electricity. A project on the Quinebaug River in Connecticut has recently been awarded a coveted "low impact" certification for producing hydropower without disturbing the local environment. Several other facilities have also received this award, including one at Falls Creek, in the Willamette National Forest of Oregon.

Worldwide, there is great interest in run-of-river projects for both remote areas and for grid-connected localities. For example, mountainous Nepal, criss-crossed with over 6,000 rivers, is interested in using these systems to provide rural villages with electricity. China has plans to provide up to 75 million people with diversion projects. Many hilly areas in Europe are already dotted with run-of-river hydro systems.

Project Size

Today's hydropower systems range from those that provide energy for one home to mammoth, multi-megawatt installations. In California, a large-scale hydropower facility is considered any project that generates more than 30 MW of electricity. Most large-scale hydropower installations use a storage system, which creates the greatest environmental concerns (See Considerations).

Small-scale hydropower projects are often divided into small-scale hydro and micro-hydro. Small-scale projects range from 100 kW to 30 MW, while micro-hydro projects usually produce 100 kW or less. Small-scale projects can be run-of-river or storage-type facilities. Most, but not all, small-scale hydropower systems are run-of-river, considered easier on the environment.

Most experts say that our hydropower facilities in the future will be small-scale and/or run-of-river facilities. Many potential locations exist for these types of power producers. Also, some older small-scale hydro projects that were shut down in the 1960s and '70s have recently been reopened. For example, a small hydro facility operated by Cornell University at Fall Creek in Ithaca, New York, was recently reopened after a 30-year shut-down. It is once again supplying 2-4 MW of power to the university, a small but eloquent testimonial to the value of using a local, renewable energy resource.

CONSIDERATIONS

- Hydropower produces no air pollution. It is very efficient, reliable, and — once installed — inexpensive. Hydropower systems can provide both baseload and peaking power. Run-of-river systems, especially, can be turned on and off very quickly.
- The main drawback of run-of-river systems is that the flow in the rivers and streams fluctuates by season, and in low rainfall or drought years, less electricity can be produced. Low rainfall can also lower electricity output of storage systems.
- Run-of-river hydropower systems are considered by many to be the preferred hydropower technology because they are easy on the environment. Run-of-river projects could contribute a significant amount of electricity worldwide.
- Large-scale storage hydropower projects are expensive to build, but can provide many megawatts of electricity to an area.
- The installation of a dam across a river for a large-scale storage project can cause the river water to back up over hundreds of acres, swallowing up towns and fertile land. There are also impacts to water quality, fish, and wildlife. The flooding can also ruin important cultural, religious, and archeological sites. Flooding an area can displace hundreds or even thousands of people. For example, the large Yangtze project in China will create a lake 400 miles (644 kilometers) long and will require the relocation of 1.2 million people.
- Currently, a number of large projects around the world have been canceled or placed on hold due to public concern about the environmental impacts of the dams. In recent years, some consideration has been given to removing dams in highly sensitive areas. For example, some smaller, older dams in sensitive areas of the U.S. Pacific Northwest have already been removed.

DATA FILE: Hydropower

California

- California has over 380 hydroelectric facilities that can produce more than 14,000 MW of electricity.
- About 19 percent of California's electricity comes from hydropower.

United States

- The United States gets between 7 and 12 percent of its electricity from hydropower.
- Washington, Oregon, California, and New York are the states producing the largest amount of hydroelectricity.

Worldwide

- One-fifth of all the world's electricity is generated by hydropower.
- Twenty-four countries get about 90 percent of their electricity from waterpower, including Norway, Brazil, Paraguay, Ethiopia, Ghana, and Zambia.

Data available in 2003

Renewable Energy Source: OCEAN

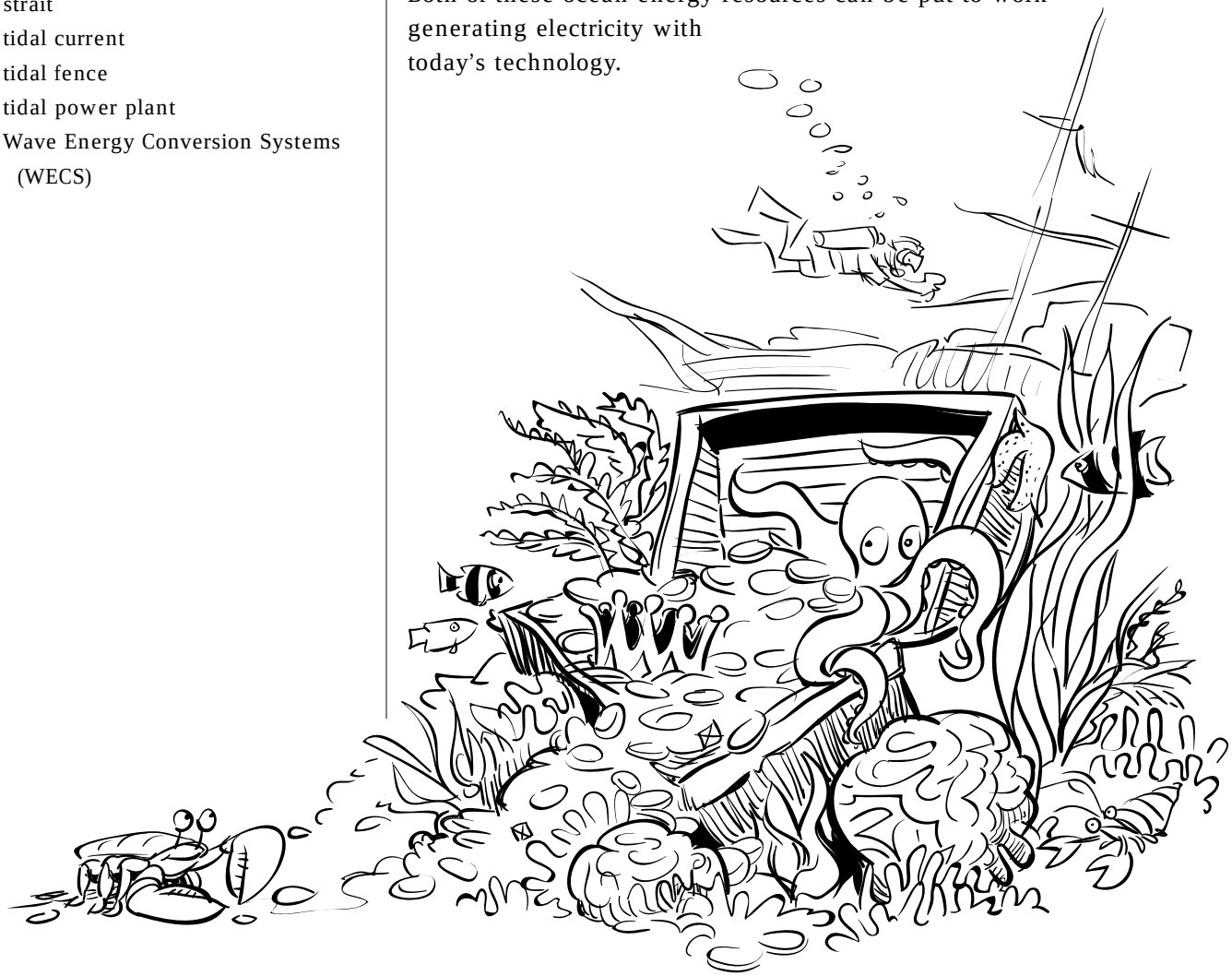
VOCABULARY

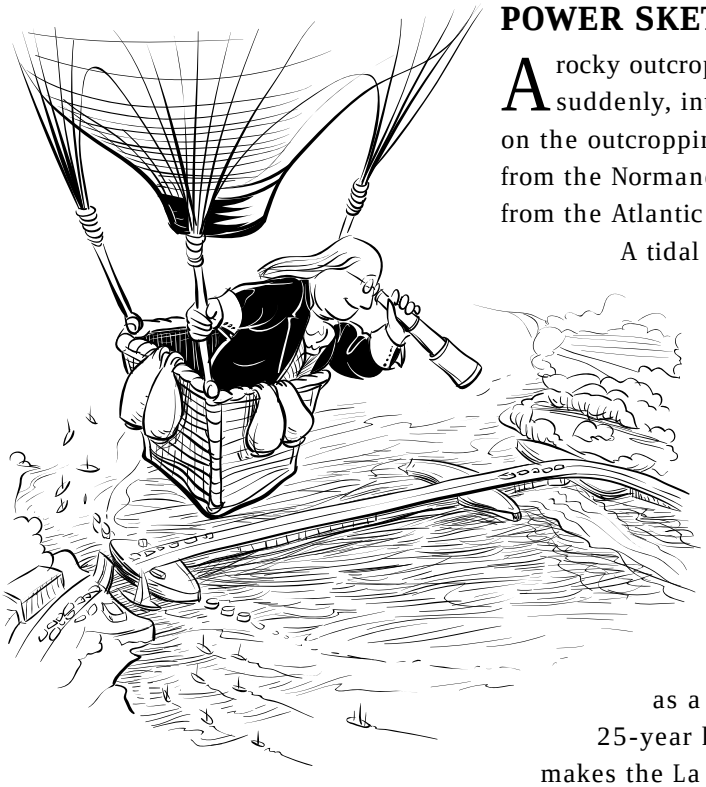
aquafarming
barrage
current
ebb
estuary
high and low tide
marine current
Ocean Thermal Energy Conversion (OTEC)
one-way marine current
sluice
strait
tidal current
tidal fence
tidal power plant
Wave Energy Conversion Systems (WECS)

SINCE EARLIEST TIMES, the ocean has been a vast resource for travel, food, pearls, minerals, oil, and much more. Some say that the ocean is the last remaining frontier on earth. Much of the deep seafloor, with its many marvels, remains to be probed. And there's the lure of undiscovered shipwrecks and the riches they might contain. However, there is yet another ocean frontier that some think is much more valuable than buried treasure. This is the ocean's energy frontier, one that we are just beginning to understand and put to work.

THE OCEAN RESOURCE

The movements of ocean waves and currents have tremendous energy. And a vast amount of heat energy from the sun is stored in our seas. Both of these ocean energy resources can be put to work generating electricity with today's technology.





POWER SKETCH: Vive La Rance

A rocky outcropping of France's Atlantic coast is transformed, suddenly, into an island. Twice a day the single structure on the outcropping, the abbey of Mont-Saint-Michel, is cut off from the Normandy mainland by the tide, which sweeps in from the Atlantic to the La Rance estuary.

A tidal power plant here captures energy from the dramatic rise and fall of the sea. Built in 1966, the plant at La Rance supplies about 240 MW of electricity to French homes and workplaces. The facility uses a dam stretched across the opening of the estuary. Inside the dam's powerhouse are 24 hydroelectric turbines, specially engineered to capture the force of both incoming and outgoing tides.

The crest of this dam doubles as a roadway, and the reservoir behind it serves as a recreation area. This, combined with a 25-year history of reliable electricity generation, makes the La Rance power plant an energy-wise winner.

Marine Currents

There are two kinds of marine current energy: energy from two-way marine currents, which are also called tidal currents, and energy from one-way currents.

Two-way currents are the ocean tides, caused by gravitational pull of the moon and sun. Each heavenly body pulls on the part of the ocean nearest to it, causing bulges in water height. As the earth rotates, those bulges move in relation to the world's coastlines, pulling water onto and away from the shore. So the turning of the earth causes a moving pattern in the ocean: at every coast in turn, the level rises and falls, resulting in two high tides and two low tides daily.

One-way currents are like massive "rivers" of ocean water flowing within the ocean for hundreds — sometimes thousands — of miles.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

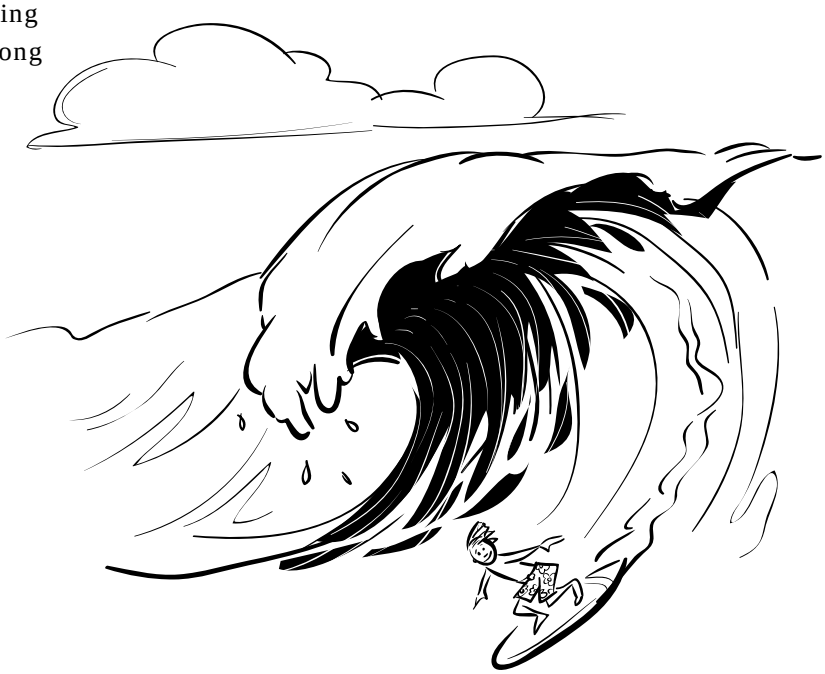
Found close to the surface or deep within the ocean, one-way currents occur because of differences in ocean temperature, water density, and topography from area to area. Some one-way currents are also driven by winds and the earth's rotation. One well known example is the Gulf Stream, which carries warm water from the Gulf of Mexico to the northerly shores of Europe.

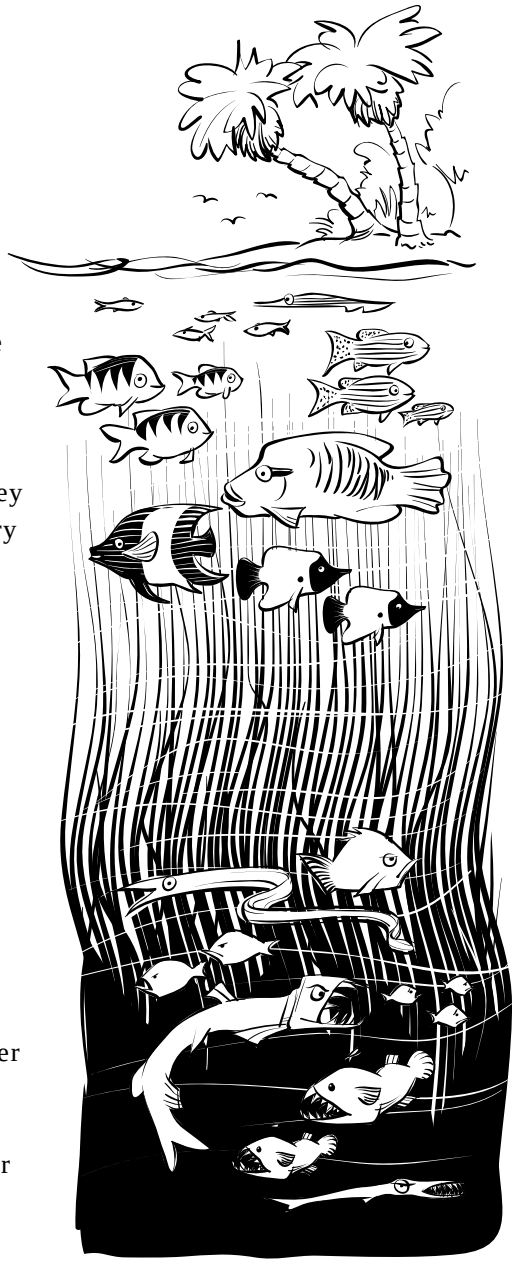
Both two-way and one-way marine currents can be used to generate electricity. The key is a site with a forceful flow of ocean waters. Strong flows tend to occur within straits, between islands, and at entrances to large bays and harbors. In North America, promising locations are found in the northern part of both coasts. Worldwide, high-energy marine current sites are in the United Kingdom, Italy, Australia, India, Russia, Argentina, the Philippines, and Japan.

Waves

Wind force creates ocean waves. Each wave can travel a long distance without losing much energy. Wave energy is remarkably powerful, something that can be confirmed by anyone who has ridden a big wave (or been knocked down by one) as it breaks onto shore. Strong, steady winds will produce waves that travel up to 35 miles (56 kilometers) per hour. Storms, of course, produce the most dramatic waves, some of which tower over 100 feet (30 meters).

Wave energy systems can use the moving force of these waves in the open sea or along coastlines. Experts estimate that wave energy has the potential to provide up to 10 percent of the world's electricity (including about 2-3 million MW of electricity just from the coastline areas). They also think the best spots could produce up to 65 MW per mile of coastline. These high-energy wave locations are generally on western coastlines facing the open sea, including parts of North America, South America and northern Europe.





The Ocean's Stored Heat

Much of the sun's radiation falls on the world's oceans, where it is absorbed and stored as heat (thermal) energy. Our oceans cover more than two-thirds of the globe, so you can imagine how much heat energy is stored in these vast waters. This heat energy is found in the upper surface waters. The sun's rays are not able to penetrate extremely deep water, but down to about 200 feet (61-90 meters) they can be an effective warming source. Deeper water, by contrast, is very cold — near freezing at depths greater than 3,000 feet (914 meters).

The temperature difference between sun-warmed surface and near-freezing deep waters is great enough to be used to produce electricity. The difference needs to be at least 36°F (22°C), so some of the best global locations are the sun-drenched ocean surfaces of the tropics. That includes Hawaii, Florida, and many other places, including island nations such as those of the southern Pacific and Indian oceans.

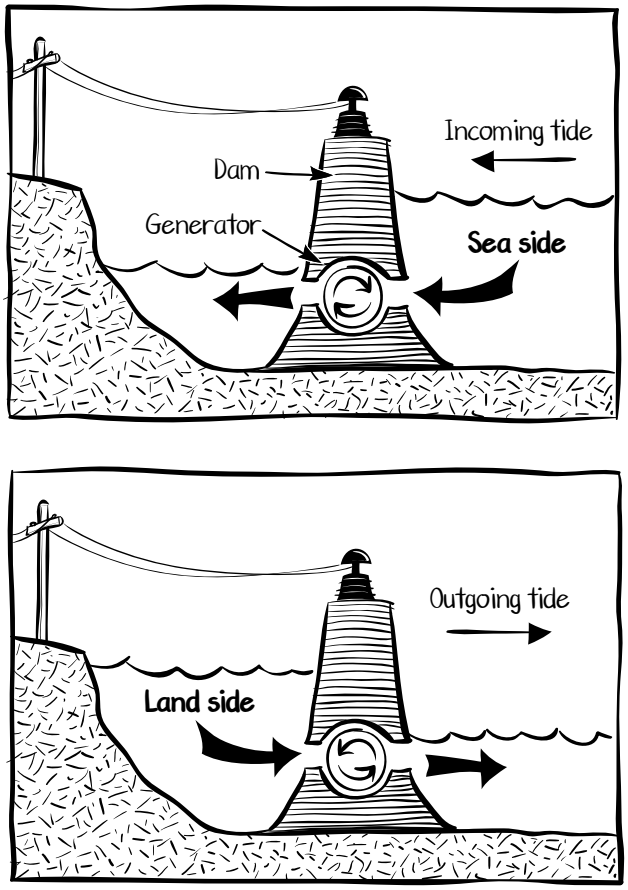
GENERATING ELECTRICITY FROM OCEAN RESOURCES

Marine Current Energy Systems

Some marine current systems aren't new. As long ago as the Middle Ages (1200-1500 A.D.), farmers built ponds to trap advancing seawater from rising tides. They would then use the moving water to power their mills when the tide flowed back out. Today, some tidal power plants use a dam, or barrage, stretched across the opening of a bay or strait. At high tide, water rushes through openings, or sluices, into a reservoir, bay, or estuary. The water is held there until the tide drops (ebbs), and then is let out through turbines that drive electrical generators. A variation of this technique is a system that uses generators working at both low (outgoing) and high (incoming) tides. This second type is what makes the La Rance facility work. (See "Power Sketch," page 80, and illustration, page 83.)

Other types of marine current technologies are still in the research stage. One is a tidal fence, like a row of giant turnstiles, set up in any type of channel — between two islands, for example. Another is a tidal turbine that works like an underwater wind turbine. Mostly submerged in the sea, these systems can also be grouped into undersea "energy farms."

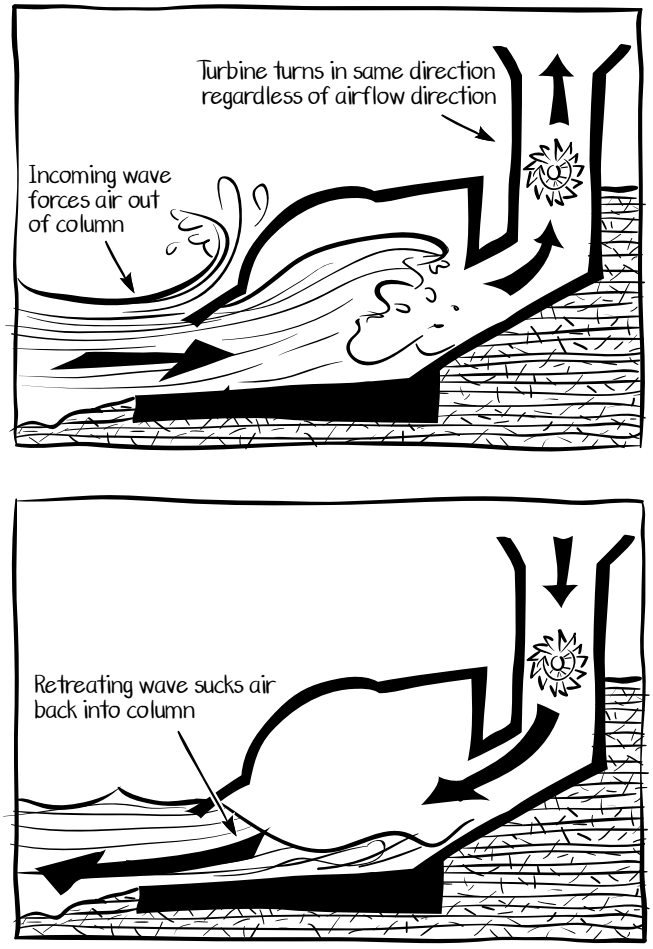
A number of countries have been investing in marine current energy. China began using tidal power in the mid-1950s and at one point as many as forty small power plants were generating electricity. Most of these became outdated and were closed, but China still has at least seven tidal power stations that altogether generate about 11 MW of power. A power plant located on the Bay of Fundy in Nova Scotia has been generating around 20 MW of tidal power since 1984. Norway has recently installed a windmill-like turbine and has plans to add 20 of these "sub-sea" turbines by 2004. In the United Kingdom, several research groups are exploring various marine current energy technologies. One of these, the "Stingray," uses huge horizontal flaps or wings that move up and down in the marine current. Another is the world's first offshore marine current system, which employs windmill-like rotors and produces up to 300 kW of electricity. Other countries looking at the use of marine current energy include India, Korea, Russia, Australia, the Philippines, and the United States.



A tidal generation power plant that works at both high and low tides

Wave Energy Conversion Systems

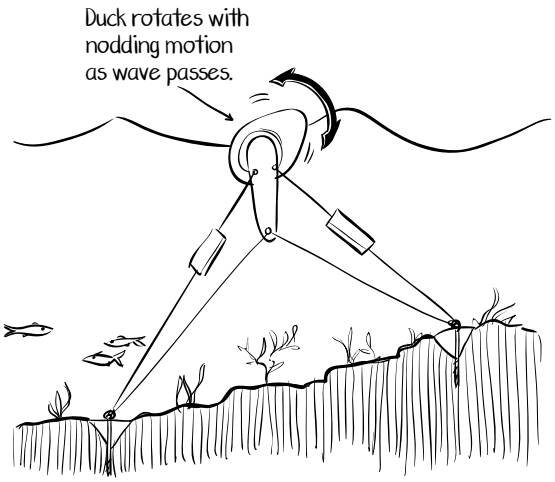
Shorelines that experience steady, powerful wave action are good places for stationary Wave Energy Conversion Systems, or WECS. One type uses forced air to spin a turbine. Waves enter a column and force air past the turbine, making it spin. When the waves recede, the air pressure drops, also causing the turbine to spin. So electricity is generated as the waves enter the column and again as they recede. (See illustration next page.) Scotland has the world's first forced-air type of wave power plant, capable of producing 500 kW of electricity. Another type of shoreline wave energy system uses a reservoir built into the bottom of a cliff along the shoreline. Waves are channeled into a reservoir. This captured water can then be released through a turbine to produce electricity as needed.



A forced air Wave Energy Conversion System

Other types of wave energy conversion systems are offshore floating devices. Many of these dot the ocean's surface, attached to the seafloor with anchors. The bobbing motion of the waves causes pumps or pistons to move up and down, converting the force to spin the turbines. In other systems, the turbines are powered by the surge of the waves as they pass through. Some floating wave systems can also be grouped together, creating a "wave energy farm."

A wide variety of floating wave energy designs have been researched, with interesting names such as the "Clam" and the "Nodding Duck." One wave system resembles a moving sea serpent. Another is named "Archimedes," after the Greek scientist who researched flotation in ancient times. Many wave energy systems have been developed in Northern Europe, which experiences strong wave activity. The U.S. Navy is planning to install a prototype of a wave energy conversion system that uses a series of submerged buoys attached to an electrical generator on the ocean floor. This system will supply the Kaneohe Marine Corps Base in Hawaii with electricity via an underwater cable. Other places investigating wave energy include Australia, China, India, Japan, Portugal, Indonesia, Canada, and mainland United States.



Nodding Duck

Ocean Thermal Energy

The difference between warm surface water and cold deep seawater is put to work in Ocean Thermal Energy Conversion (OTEC) power plants. These can be located along the shoreline or on floating offshore platforms. There are two main types:

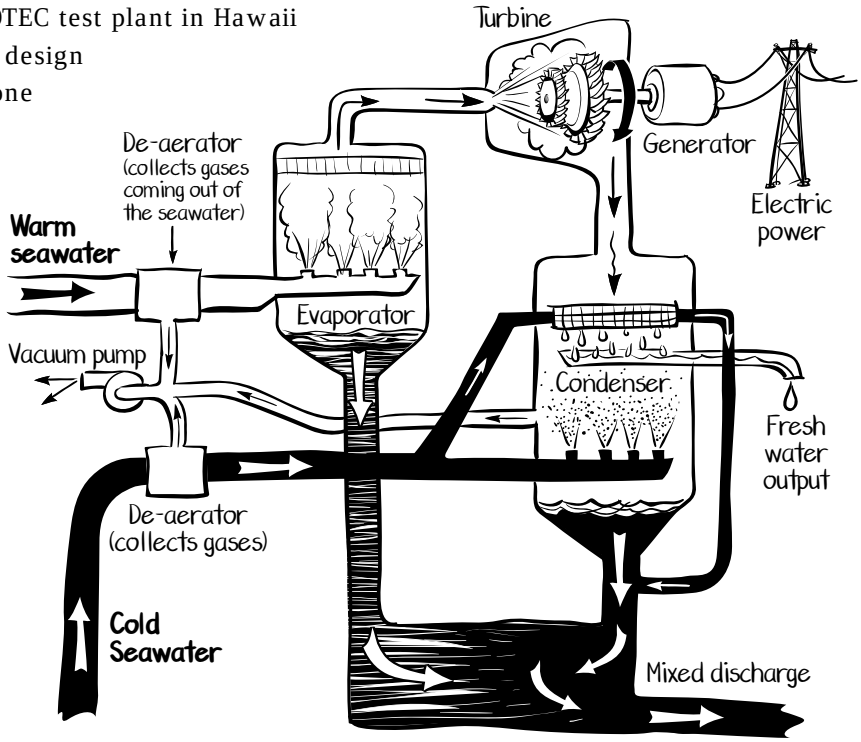
Closed Cycle OTEC. Warm ocean water is piped into a heat exchanger that causes another liquid with a lower boiling point (the "working" liquid) to instantly "flash" to vapor, or vaporize (see "Heat Exchangers," page 63). The force of the rapidly expanding vapor drives a turbine. Cold water from the ocean depths is brought up in a different set of pipes to cool the vapor, causing it to condense back into a liquid. This system's name comes from the fact that the working liquid is contained in a closed pipe system.

Open Cycle OTEC. In this system (illustrated on this page), the warm seawater itself is the working liquid. It is piped into a chamber in which the pressure has been reduced by creating a partial vacuum. The lower pressure allows the warm water to boil and flash to steam. Cold seawater is used to condense the steam after it has passed through the turbine. An open cycle OTEC test plant in Hawaii successfully ran from 1993-1998. Its design reflected input from years of work done by several U.S. agencies and a university in Japan.

Closed cycle OTEC is most useful for producing large amounts of electricity and can be used with already existing turbine designs. Open cycle OTEC, which needs modified turbines, may be best suited for places such as island nations that need some fresh drinking water as well as electricity. In addition to the U.S. and Japan, other places studying OTEC include India, the Republic of Palau, and Fiji.

WATER, WATER EVERYWHERE

Ocean electricity-generating systems can turn salty seawater into fresh drinking and irrigation water. For example, an open cycle OTEC power plant in Hawaii at one time produced up to 7,000 gallons (24,498 liters) of fresh drinking water every day while generating electricity. And the McCabe Wave Pump, first designed 20 years ago to produce electricity, has been adapted to provide pumping power to produce 100,000 gallons (378,541 liters) of clean water daily from the seawater of Shannon River Estuary in Ireland.



Open cycle ocean thermal energy conversion

CONSIDERATIONS

- Until recently, the vast energy potential of our oceans had not been widely recognized. Luckily, we are now entering an era in which many different kinds of ocean energy technologies are being perfected and put to work.
- Wave and tidal energy produce no polluting emissions. OTEC produces a small amount of carbon dioxide, but only 4-7 percent of that produced by a traditional power plant.
- The tides, waves, and thermal qualities of oceans are predictable resources. They could produce significant amounts of baseload and peaking power. Tidal power plants work best by coastlines — often highly populated areas with high energy requirements. However it's sometimes harder to get permission to build on-shore facilities because of the recreational and scenic value of beachfront property.
- The effects of tidal power plant operations on the local environment depends on the plant location and the type of technology. Traditional barrage tidal systems have had some unavoidable environmental and visual impacts. The current tidal energy trend is towards systems that do not use a barrage.
- At present, OTEC is much more expensive than many other energy sources, due primarily to the costs of installing and protecting pipes and equipment in the rigorous conditions of the ocean waters. Connecting offshore ocean energy projects to the on-shore electrical grid is a technical challenge and often quite expensive.

FACT OR FICTION

The first documented reference to producing electricity using the temperature differences in the ocean was in Jules Verne's *20,000 Leagues Under the Sea*, published in 1870.

DATA FILE: Ocean

California

- Wave power along the California coastline, if developed, could produce power estimated at 7 to 17 MW per mile (4 to 10 MW per kilometer).
- The mouth of San Francisco Bay is being considered as a site for an underwater tidal power plant.

United States

- The U.S. Department of Energy is considering reopening its ocean energy office, following ocean energy successes in Europe and Japan.
- In the United States parts of the Pacific Northwest and New England have significant tidal resources.

Worldwide

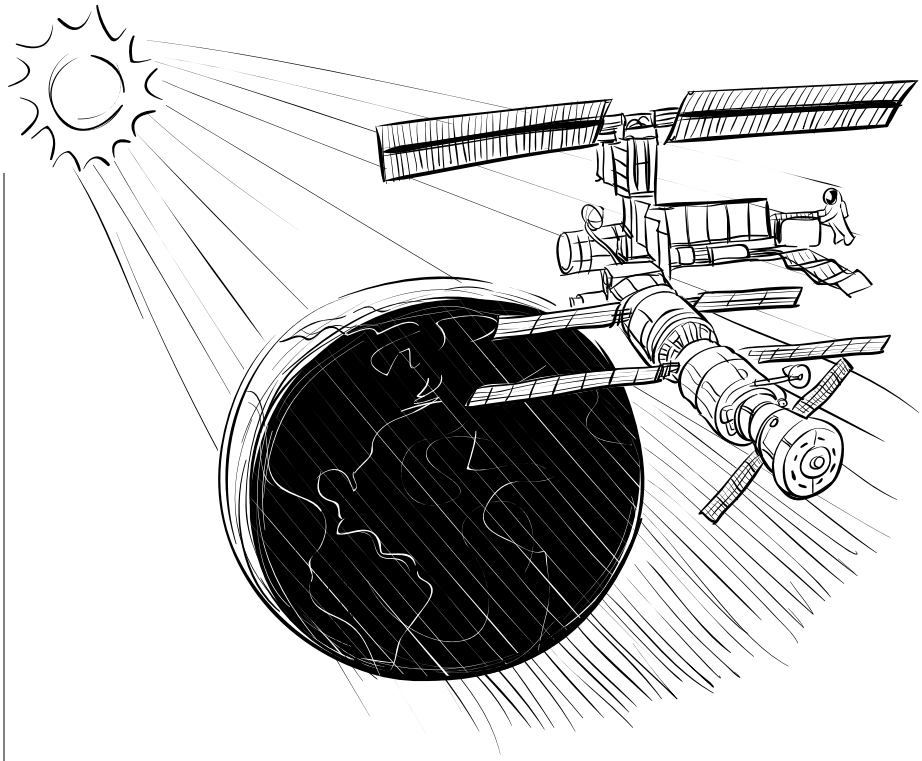
- The heat energy from the sun that is stored each day in the ocean has been compared to the energy stored in 250 billion barrels of oil.
- Approximately 300 megawatts of tidal energy is currently being produced worldwide.

Data available in 2003

Renewable Energy Source: SOLAR

VOCABULARY

array
central receiving tower
Concentrating Solar Power (CSP)
electromagnetic spectrum
heliostat
infrared
module
parabolic trough
photon
photoelectric effect
photovoltaic
radiant energy
silicon
solar cell
solar dish engine
solar panel
spectrum
ultraviolet



WITH SOLAR ENERGY, THE SKY'S THE LIMIT. Our sun is the world's most widely used energy resource. Plants began capturing the sun's energy millions of years ago, and members of the animal kingdom have always basked in its warmth. Human dwellings have long included openings that let in the sun's light and heat. Glass windows were used as early as 79 A.D., as revealed in the archeological ruins of Pompeii and Herculaneum (Roman cities completely preserved under layers of ash from a volcanic eruption). Now, our use of windows to capture the sun's radiation is such a common practice that we don't even think about it. Today we also use the heat of the sun to heat water. And, with technology ranging from tiny solar cells to huge power plants shimmering with rows of curved mirrors, we make electricity.

THE SOLAR RESOURCE

We all know that our sun gives off radiating waves of heat and light energy. Without these, our planet would not have life. The sun also emits many other kinds of radiation (called the electromagnetic spectrum), such as X-rays and ultraviolet waves. All the waves emitted from the sun move rapidly as tiny bundles of energy called photons. These photons travel vast distances from the sun through the vacuum of space and bathe our planet with solar energy every day.

Shedding Light on the Solar Spectrum

The sun emits many kinds of radiation besides X-rays and ultraviolet waves. Altogether, the range of different energy waves from the sun is called the "Solar Spectrum." Forty-five percent of the sun's energy that reaches the surface is what we call light because we can see it. Almost all the rest we do not see (although we can detect and measure it), yet it all delivers energy. For example, ultraviolet radiation, though we can't see it, can tan or burn our skin. A small part of the radiation that reaches the earth as "heat" (infrared radiation) is mostly absorbed in our atmosphere. The heat you feel on your skin is actually generated by your skin as it absorbs the solar light!

Some parts of the earth receive more solar radiation than others. In general, the areas at or near the equator receive the most solar radiation. For example, the tropics get about two and a half times more heat, or infrared, radiation than the poles. Any area that receives a steady supply of solar radiation, whether a little or a lot, can make use of the energy pouring in from our sun.

We use just a fraction of our enormous solar resource.* The total solar radiation received each year is about 3,000 times all the energy used globally.

GENERATING ELECTRICITY FROM SOLAR RESOURCES

In this section we discuss solar energy only as a source of electricity. In Chapter 5 we discuss "direct" (non-electric) uses of solar energy — "active" direct uses such as heating water, and "passive" direct uses such as designing sun-friendly homes.

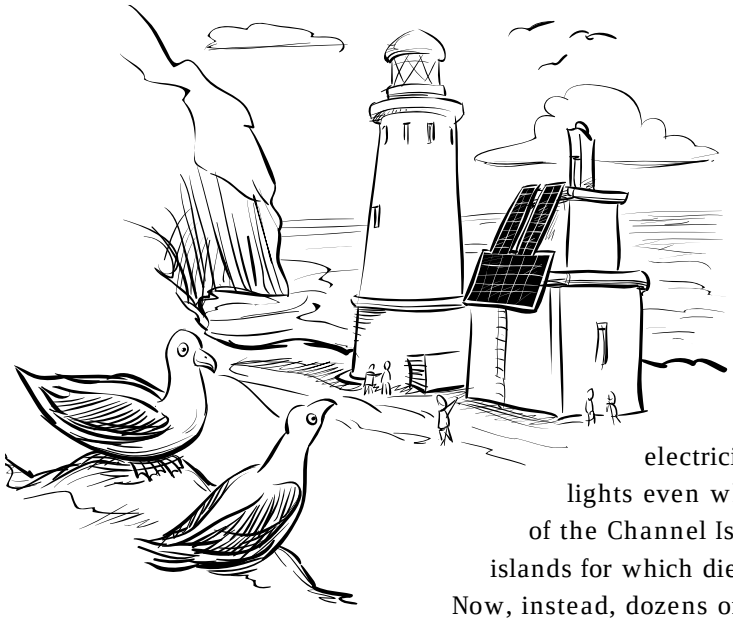
Photovoltaics (PV)

In the 1950s, American engineers sought a method to power U.S. space satellites. They found it in an existing process called photovoltaics (PV). We still use photovoltaics to energize orbiting satellites, space stations, and the Hubble telescope. Back on the earth, PV is widely used for everything from roadside call boxes to large power plants.

UP ON THE ROOFTOP

Today there is a slimmer version of PV technology, something called thin film PV. Thin film PV can be used to replace some of the regular shingles on a building's rooftop. Operating in the same way that flat plate PV does, thin film shingles are as durable and protective as regular asphalt shingles. These solar shingles are textured to fit right in with the architectural design of buildings.

** Statistics buffs, take note: The total amount of solar radiation received by the earth is 1.73 x 10^{17} watts at any one time. This is enough to warm our entire globe, fuel all of the earth's photosynthesizing plants, and create global climatic systems that drive the winds, the waves, and the water cycle.*



POWER SKETCH: Lighting the Way on a Foggy Day

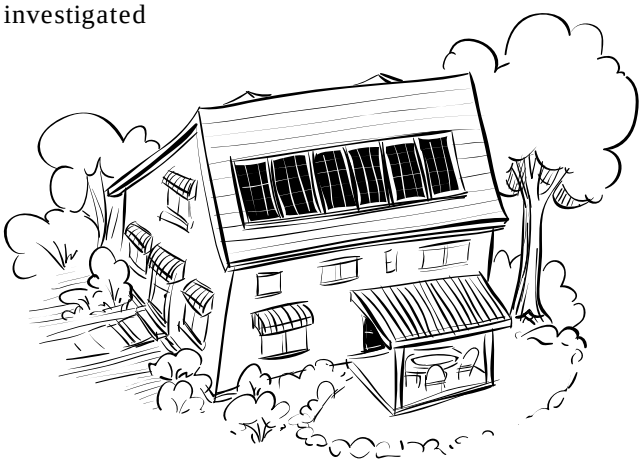
On foggy days along the coast of Ventura, California, a lone lighthouse shines its lights and sounds its foghorn for maritime travelers. Though far from the mainland's electrical connections, the Anacapa Island lighthouse operates entirely on electricity. The source of electricity is a large group of solar panels on the roof that converts sunlight into electricity. This electricity also charges batteries to operate the lights even when the sun doesn't shine. Anacapa is part of the Channel Islands National Park system, a series of islands for which diesel generators once provided the electricity.* Now, instead, dozens of solar panels are powering operations around the islands, including a naval installation on Santa Cruz Island.

** Some of the generators remain, now using cleaner-burning biodiesel, but only as a back-up resource.*

In photovoltaics, photons of sunlight react with specially designed materials in a process that results in electricity. *Photo* means light, and *voltaic* refers to the electrical current. The smallest unit is a photovoltaic cell, made of wafer-thin layers that react to sunlight to create electricity. The most common material in use today is silicon, either in crystalline form or thin films, but other materials are being investigated (see "Inside a Solar Cell," next page).

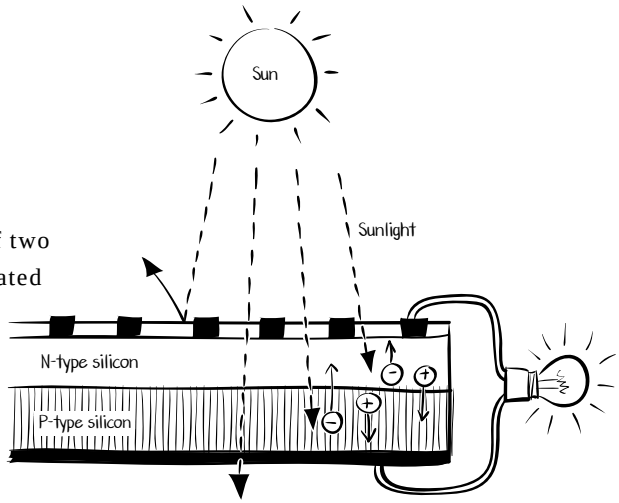
Usually, about 40 solar cells are wired together into a module. About 10 modules are combined together to make up a solar panel. Between 10 to 20 PV panels are collectively known as a PV array and can provide enough electricity for a household. Hundreds of arrays (known as an array field) are grouped together for use by a large commercial or industrial facility or by a utility.

PV systems can be stand-alone (not connected to electric transmission lines) or grid-connected. With grid-connected PV systems some homeowners can sell their extra electricity to their local utility.



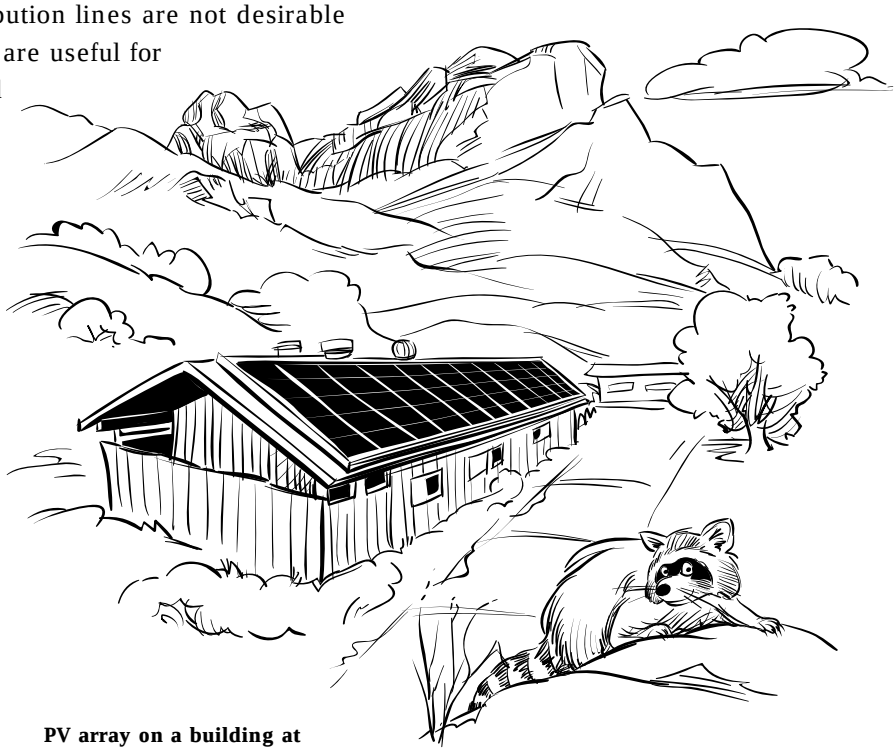
PV panels on the roof of a house

INSIDE A SOLAR CELL



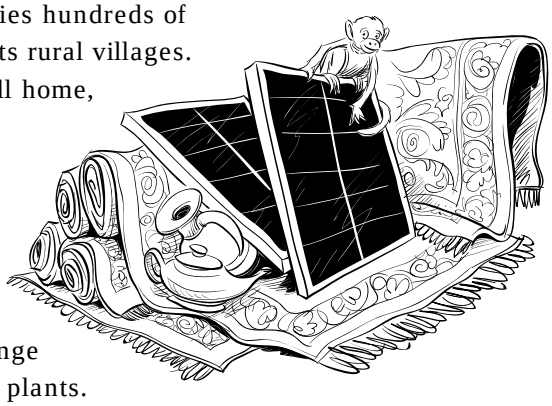
A solar, or photovoltaic, cell is a "sandwich" made of two slightly different, super-thin layers of specially treated crystals. When a photon of light from the sun strikes a solar cell, it frees electrons from some of the atoms of the treated silicon materials. These freed electrons zoom away from their "parent" atoms, leaving behind "holes." Because of the types of materials found in each layer, the electrons, which are negatively charged, tend to collect in what's called the N-layer (N for negative), and the positively charged "holes" collect in the P-layer (P for positive). When wires connect the two layers, electrons flow through the wire circuit in an orderly way. This is because negative and positive charges attract each other. This flow creates a current of electricity. (The freeing of electrons in solar cells by photons of light from the sun is called the "photoelectric effect." Albert Einstein won a Nobel Prize for describing it.)

Stand-alone PV. Photovoltaic systems are very handy for remote locations where transmission and distribution lines are not desirable or practical. These stand-alone systems are useful for lighting highway signs (energy is stored in batteries for use at night), roadside call boxes, and unmanned research installations in remote areas. They are also frequently found in rural areas or in national parks for lighting, battery charging, driving electric motors, water pumping, and more. The airport at Glen Canyon National Recreation Area, Utah, for example, is powered entirely by PV. Pinnacles National Monument in California uses solar cells for all operations including the ranger station, residences, and campground.



PV array on a building at Pinnacles National Monument

Globally, stand-alone PV is providing electricity in many developing areas without widespread transmission lines. Indonesia, a nation of 17,000 islands, is turning to PV electricity rather than trying to connect all the islands with transmission wires. India supplies hundreds of complete PV "kits" (called Solar Home Systems) to its rural villages. These include everything needed to light up a small home, including solar panels, wiring, and even the lights themselves. In Morocco on the edge of the North African desert, solar panels are often found at bazaars, where they are sold right alongside exotic Moroccan rugs and tin ware.



Grid-connected PV. Grid-connected PV systems range from small rooftop home set-ups to large PV power plants. Today, many U.S. government and privately owned buildings are being fitted with PV as part of the government's Million Solar Roofs program. Meanwhile, a number of private businesses, such as warehouse-type stores, are making use of their expansive rooftops to install solar panels. Hundreds of utilities are including PV in their operations. The Sacramento Municipal Utility District in California, for instance, has more than 1,100 PV systems (including 800 to 900 homes with PV roofs) that together can produce about 11 MW. The first neighborhood to put PV on the roofs of all of its homes is in Gardner, Massachusetts. These were installed in the 1980s.

California is the largest user of grid-connected PV. Arizona, Texas, and Colorado are also making wide use of grid-connected PV systems. Globally, millions of small PV systems are in use. Large-scale PV power plants that generate at least 1 MW or more of solar electricity are operating in the United States, Germany, Spain, Italy, India, and Japan.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

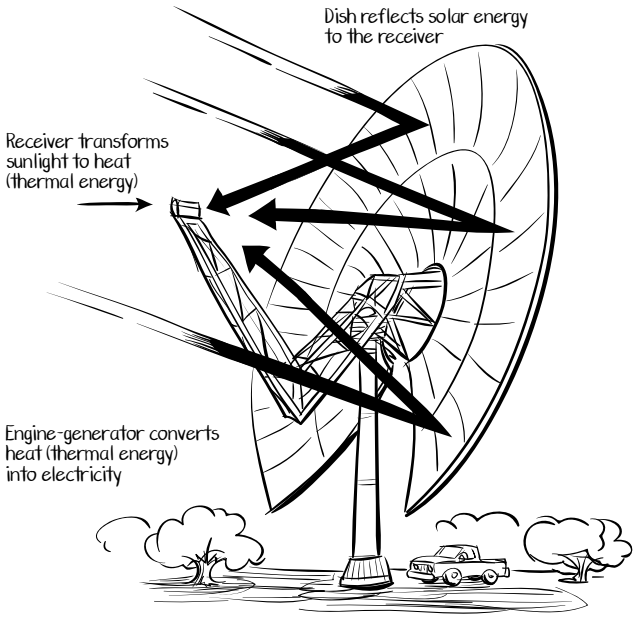
1 megawatt serves about 1,000 homes in the United States.

Solar Thermal: Concentrating Solar Power (CSP)

CSP systems use mirrors to concentrate the energy from the sun to heat liquids held in pipes and containers. Using a heat exchanger (see "Heat Exchangers," page 63) these hot liquids can then produce steam to drive the turbine that makes electricity. CSP works best with a clear, dry sky and a high concentration of the sun's rays. In the United States, the sunny southwestern states have been actively exploring this technology. Sun-drenched areas such as India, Morocco, Egypt, and Mexico are also very interested in CSP. These range from small individual 5 kW units suitable for a remote facility, to huge, utility-scale systems that can produce up to 200 MW.

All CSP systems have two main parts, one that concentrates solar energy's heat, and another that converts this heat energy to electricity. The three main types of CSP systems are solar dish engines, parabolic troughs, and central towers (central receivers).

Solar Dish Engines. Solar dish engines, presently under development, may turn out to be the best option for remote and rural locations. They are composed of two parts: a curved (parabolic) mirror that concentrates the sun's heat, and a "Stirling engine" that uses the heat to generate electricity. Dish engines can be used individually, providing between 5 to 25 kW, which is enough power for a farm or village, or can be combined for large-scale, grid-connected operations.



A large-scale solar dish engine

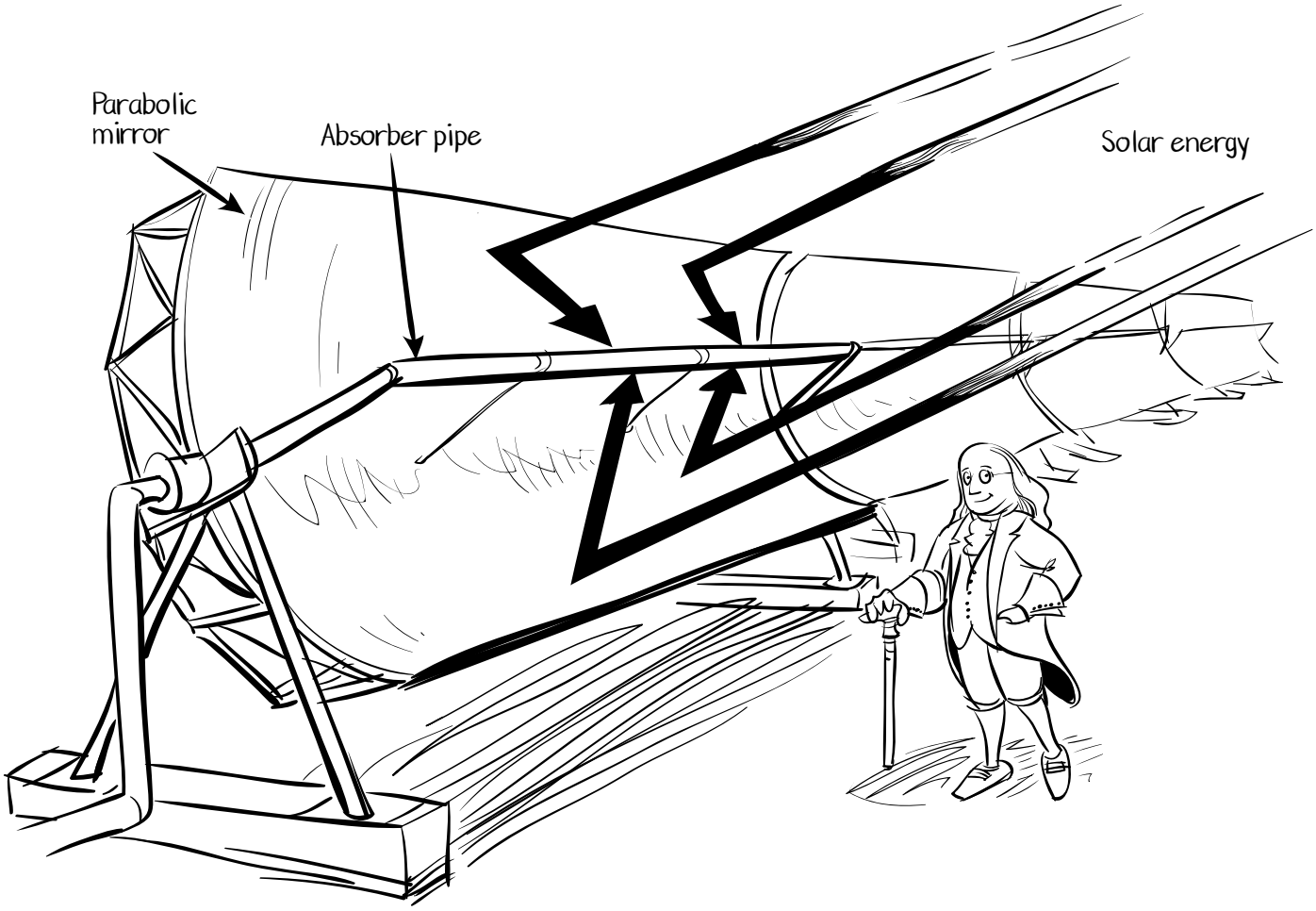
STORING SOLAR ENERGY

Batteries aren't just for *supplying* electrical energy, but also for *storing* electrical energy. This storage capacity is very useful in solar energy systems, since sunlight isn't always available. The same process that provides an electric charge in a battery will also work in reverse. The inflow of electrons from the solar cell causes chemical substances in the battery to recombine and change. This "stores" the energy by charging the battery. When electricity is needed, the battery is activated, causing another chemical reaction that results in a flow of electrons — generating an electrical current.

There are other ways to store the sun's energy. One of these is collecting and holding the sun's heat. Concentrating Solar Power systems use materials that hold a large amount of heat and then release it very slowly. One material is molten salt, which reaches very high temperatures and retains the heat for long periods of time. When the sun stops shining, this "set-aside heat" continues to run the CSP equipment that generates electricity.

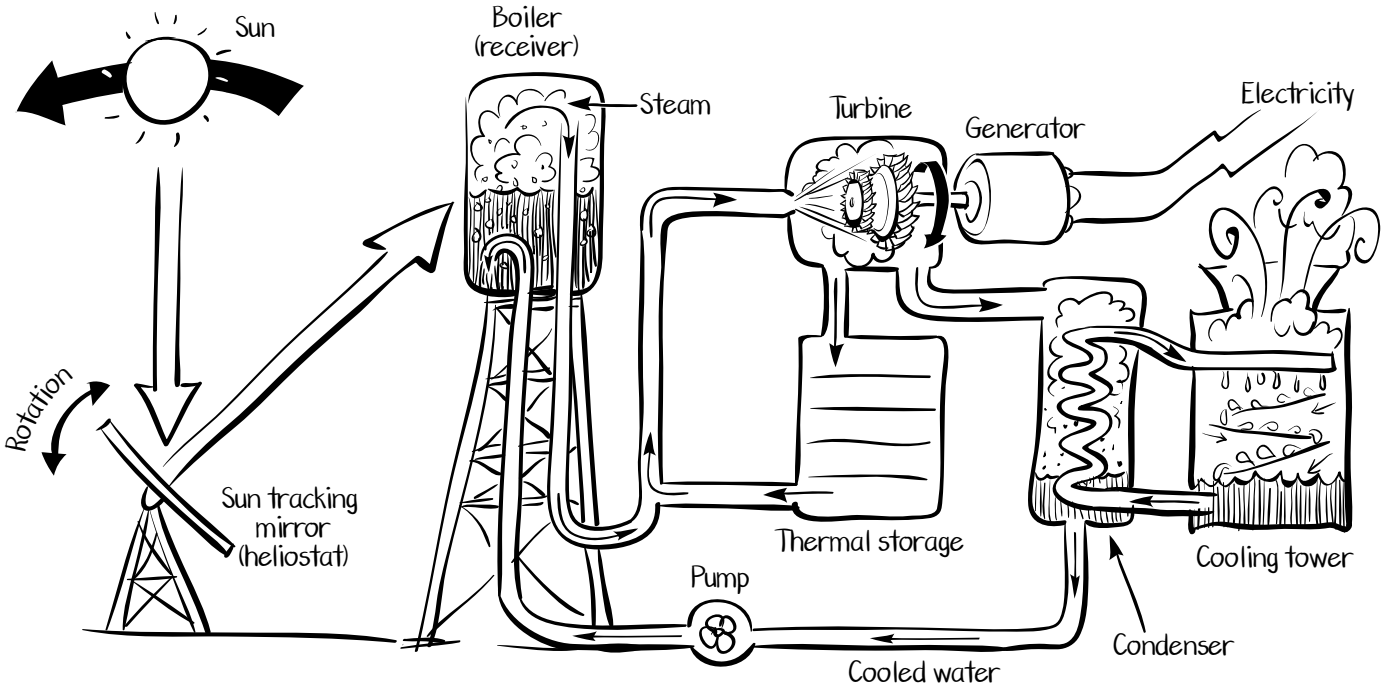
Parabolic Troughs. Parabolic troughs are long, trough-shaped reflectors that focus the sun's energy on a pipe running along the mirror's curve. The concentrated heat warms up an oil flowing through the pipe. Heat energy from the oil is transferred through a heat exchanger (see "Heat Exchangers," page 63) to boil water to create the steam that drives the turbine.

Parabolic troughs rotate from side to side, so they can track the sun as it moves from east to west. They are normally located in many parallel rows. The Mojave Desert is home to the world's largest parabolic trough facility, where nine power plants feed around 350 MW of electricity to southern California homes and businesses.



A parabolic trough uses a type of clear oil in pipes that absorb heat reflected off the trough. The heat from the oil flows through a heat exchanger to heat water to make steam for electrical generation.

Central Receiving Towers. Central receiving towers are tall structures with a boiler on top that houses a liquid suitable for heating, such as water (as shown below), molten salt, or liquid metal. Surrounding the tower are many rows of mirrors, called heliostats, which turn to face the sun and focus its rays onto the boiler throughout the day. The concentrated sunlight from these mirrors heats the liquid to 1,000 - 2,700° F (538 - 1,482°C). This produces boiling water, which makes steam for electricity generation. A thermal storage system ensures that even more power can be generated when the sun goes down (see "Storing Solar Energy," page 92). This technology was first tried in Italy and France, but the United States was the first to apply it with two large multi-megawatt commercial power plants, SOLAR I and SOLAR II, in California's Mojave Desert. Although these projects have ended, they sparked worldwide interest, particularly in Spain, Israel, and Australia.



A Central Receiving Tower Power Plant
Though there is only one mirror shown in this diagram, in reality the tower is surrounded by many sun-tracking mirrors.

CONSIDERATIONS

- Solar energy systems have several attractive features. They are modular (units can be added as needed), make no noise, produce no pollution, and operate during the hours of highest daytime electrical demand.
- There have been two main challenges to the use of solar energy: the amount of sunlight and the cost of the technology. Sunlight supply depends on time of day, the season, the cloud cover, and the location. Today, most of these factors can be controlled with various solar energy storage systems. While cost used to be a major barrier with solar technology, it is becoming less so today. While costs have dropped greatly in the past two decades, solar systems are still expensive when compared with other renewables or with fossil fuel sources such as coal or gas.
- PV panels can be mounted on rooftops or even integrated right into the buildings as glass walls, skylights, sunshades, shingles and more. PV panels can also be constructed over parking lots to provide shade and protection from the rain.
- The rooftops or land area needed to construct a big commercial PV facility is very large. This may present too great a financial challenge. Also, large installations come with some environmental concerns, especially if sensitive desert habitats are threatened.

(continued)

DATA FILE: Solar

California

- Almost 400 MW of electricity is currently produced by solar resources in California.
- Many of California's scenic recreation areas use solar cells for electricity, including national parks such as Death Valley, King's Canyon, Joshua Tree, Mojave, Yosemite, Pinnacles, Lassen Volcanic, and Pt. Reyes.

United States

- Solar energy provides less than 1 percent of the electricity consumed in the United States.
- The top solar electricity producing states are California, Texas, and Arizona.

Worldwide

- Over 1,000 MW of the world's electricity comes from solar. PV production is doubling every three years.
- Some areas making wide use of solar energy are India, Japan, Europe, Indonesia, Australia, Mexico, Northern Africa, and the United States.

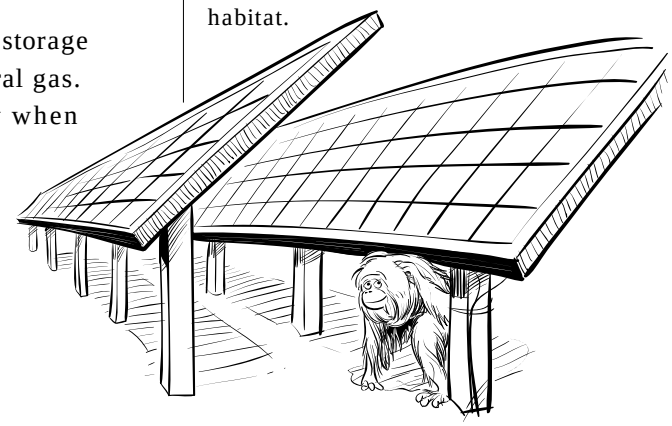
Data available in 2003

CONSIDERATIONS (continued)

- Large-scale solar power plants tend to be located in remote — often desert — locations far from population centers or transmission lines. The challenge is to transport the energy from where it is produced to where it is used. One way would be to use solar electricity to produce hydrogen from water through the process of electrolysis. The hydrogen could be shipped in containers or piped, just as natural gas is piped, to places where it could be used as a clean-burning fuel (see "Hydrogen" section, page 111).
- Small Concentrating Solar Power units do not take up much space and therefore can be placed in populated areas, especially industrial or commercial locations.
- Manufacturing photovoltaic cells takes quite a bit of electricity. It takes two to four years to generate enough electricity from photovoltaic cells to compensate for the original electricity used to make them. The cells generally last 20 years or more.
- Solar thermal plants can run as baseload by use of heat storage systems or by supplementing with other fuels, like natural gas. Solar thermal and photovoltaic plants produce electricity when the sun shines, which generally coincides with times of peak demand.

NO MONKEY BUSINESS

Solar energy is an attractive alternative for island nations, where geography makes the installation of transmission wires difficult and expensive. Stand-alone PV or solar dish engines could provide populations with electricity and reduce the need to cut down trees for firewood and other uses. For example, PV is being installed in many rural villages of the island nation of Indonesia, where it is hoped that orangutans and other threatened animals will benefit from the reduction of logging and its negative effects on their habitat.



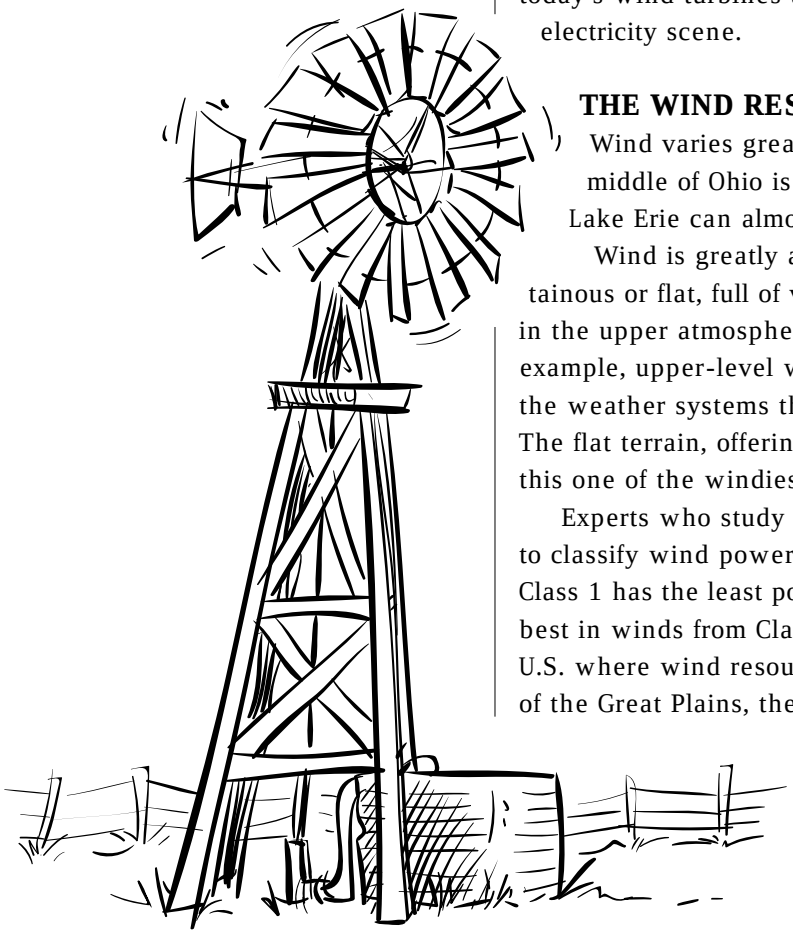
Renewable Energy Source: WIND

VOCABULARY

air current
anemometer
controller
fixed-speed wind turbine
jet stream
multi-megawatt turbine
nacelle
rotor
stand-alone wind turbine
terrain
variable-speed wind turbine
wind farm

THE POWER OF WIND has been helping humans do work for centuries. As early as 5000 B.C., wind propelled sailboats along the Nile River. Windmills may have been used in China in 200 B.C., and by 900 A.D. large windmills were grinding grain on the plains of Persia. The windmill spread to England as early as 1100 A.D. and was a common sight throughout medieval Europe. In the 1800s the American West and many other regions of the world were settled with the help of thousands of water-pumping windmills.

The first wind turbines for generating electricity were designed in Europe around 1910. These soon appeared in the United States, bringing electricity to rural homes and farms. Beginning in the late 1930s, the widespread installation of power lines made these small wind turbines obsolete. However, this was not the wind turbine's last appearance "down on the farm." Today, the wind turbine is once again a familiar sight — on open plains, along mountain passes, even off of windy coastlines. Far advanced from their creaky windmill cousins, today's wind turbines are sleek and powerful contributors to today's electricity scene.



THE WIND RESOURCE

Wind varies greatly from one place to the next. One area in the middle of Ohio is consistently calm, while the winds off nearby Lake Erie can almost knock a person over.

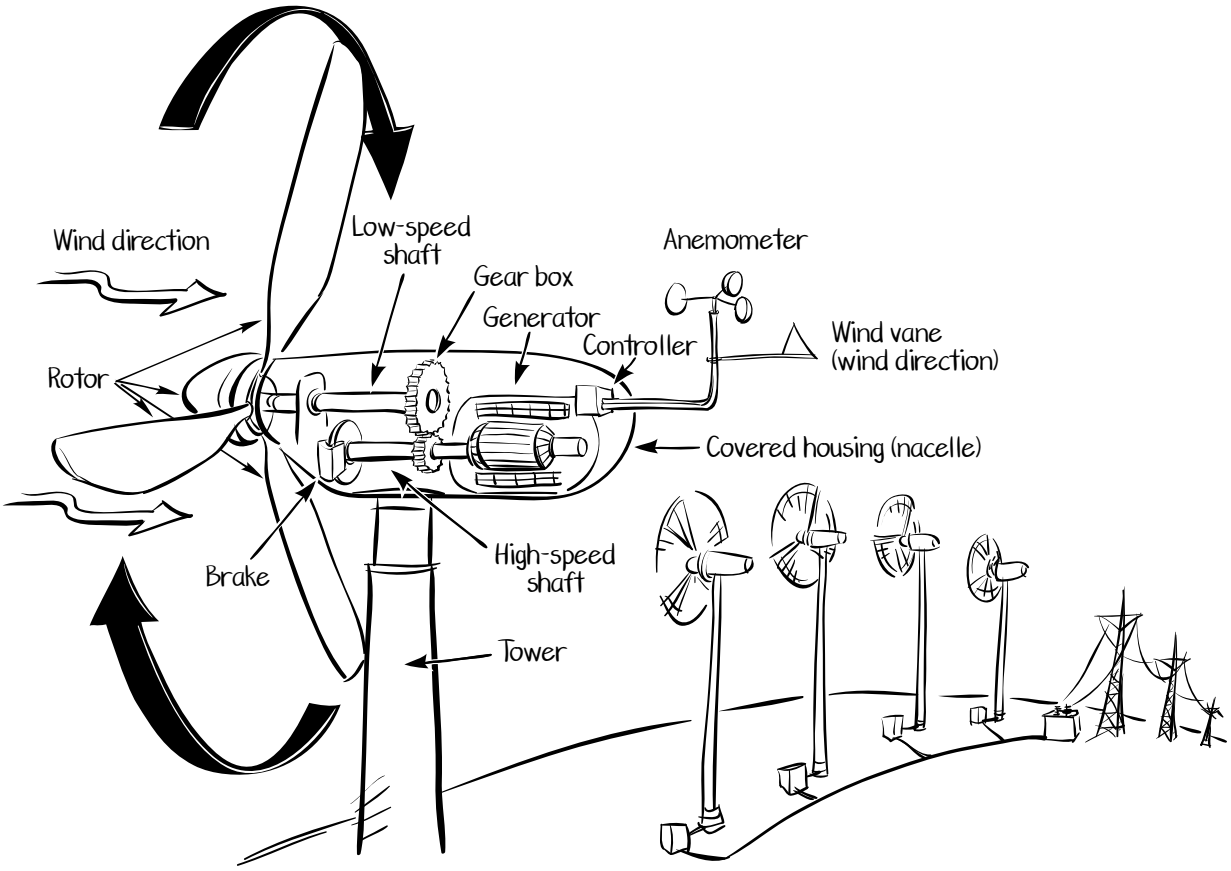
Wind is greatly affected by terrain, whether the land is mountainous or flat, full of valleys or large bodies of water. Air currents in the upper atmosphere also affect a region's wind patterns. For example, upper-level winds (the jet stream) are a primary factor in the weather systems that bluster through the American Great Plains. The flat terrain, offering no obstruction to the wind, also helps make this one of the windiest regions in the United States.

Experts who study wind patterns have developed a scale of 1 to 7 to classify wind power (wind speed, wind height, and other factors). Class 1 has the least power; Class 7, the highest. Wind turbines operate best in winds from Classes 3 through 7. There are many places in the U.S. where wind resources are Class 3 or above, including large parts of the Great Plains, the windy passes of the large mountain ranges, sections of both coasts, and portions of Alaska and Hawaii. Wind experts report that U.S. wind resources are much greater than the total current U.S. electricity generation.

GENERATING ELECTRICITY FROM WIND RESOURCES

The basic machinery that converts wind power to electricity is called a wind turbine, although it has many more parts than other kinds of turbines. The wind spins blades that are attached to a hub that turns as the blades turn. Together, the blades and hub are called the rotor. The turning rotor spins a generator, producing electricity. There is also a controller that starts and stops the turbine blades. The generator, controller, and other equipment are found inside a covered housing (nacelle) directly behind the turbine blades. Outside, an anemometer measures wind speed and feeds this information to the controller.

Wind turbines begin to turn with wind speeds of between 10 and 15 miles per hour (15 and 23 kilometers per hour). They automatically shut off at 55-60 mph (100 km/h), since anything above this speed is too hard on the machinery. Some wind turbine models run at a fixed speed no matter how fast the wind is blowing. Newer models are "variable speed." Their turning speed changes as wind speeds change, making them more efficient and allowing them to withstand gusty gales.



Wind turbines: inside and out

POWER SKETCH: Harvesting the Wind

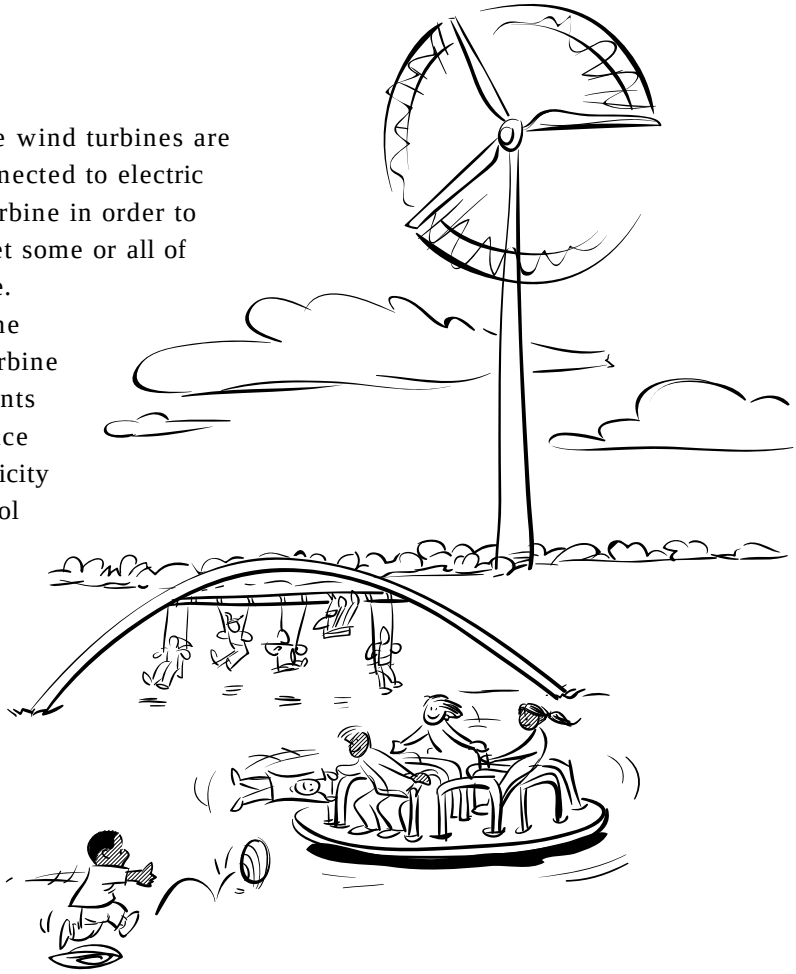
Along Buffalo Ridge, where the Minnesota winds run high, midwestern farmers have found a new cash crop: the wind itself. They have harvested many benefits from leasing their land for the installation of electricity-generating wind turbines. Strong local winds generate electricity for at least 200,000 residents in the area. Some farmers report earning more than 10 times what they would make growing corn on the small area occupied by each wind turbine. Many enjoy the idea of producing non-polluting "green" electricity, and many appreciate the boost to the local economy from increased jobs and even tourism. Most residents of Buffalo Ridge like wind farming so much that several communities hold autumn wind festivals, similar to the harvest festivals of the past.

The most common types of wind turbines have two or three fan-like blades that are usually placed at the top of a high tower. (Note: An earlier "eggbeater" design, which you may occasionally see, was too low to the ground to capture the best wind currents and so is no longer being made.)

Stand-Alone Wind Turbines

In Remote Locations. A wind turbine is a complete "mini-power plant." One alone can be used for electricity with no connection to transmission lines. These stand-alone wind turbines are useful in rural and remote locations. They are ideal for village power in developing countries, though they need the back-up of a diesel or other type of generator for continuous power needs.

A remote scientific research station at Black Island, Antarctica, uses stand-alone wind power for satellite communications and other systems. In spite of winds up to 175 mph (300 km/h) and -60°F (-51°C) winter temperatures, the turbines are remarkably reliable. In the extreme weather conditions of Alaska, several small wind turbines are providing power to remote villages in Kotzebue and Wales. This saves thousands of dollars in diesel fuel and greatly reduces pollution.



In Areas with Transmission Lines. Stand-alone wind turbines are not only for remote areas. They can also be connected to electric distribution lines. Some people install a wind turbine in order to reduce their electricity bill and, frequently, to get some or all of their electricity from a clean renewable resource.

A good example is a large stand-alone turbine installed at a school in Spirit Lake, Iowa. The turbine powers the entire school, while educating students about the values of using renewable energy. Since the school doesn't have to buy very much electricity from its local utility, wind power saves the school around $25,000 a year in utility bills.

Wind Farms

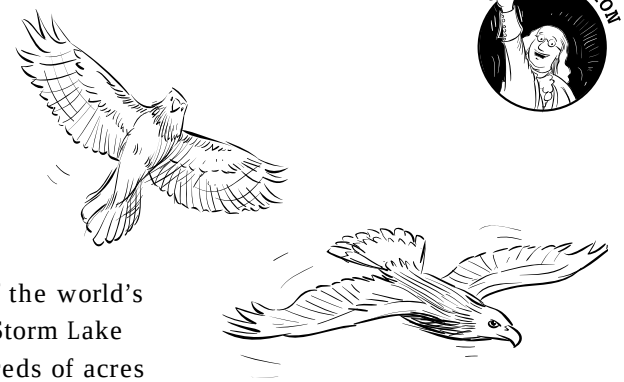
Wind turbines are often grouped together into "wind farms" that send electricity to the local power grid. These energy farms can be installed alongside other land uses, such as agriculture or livestock grazing.

California has three enormous wind farm areas located in some of its windiest mountain passes. One of the world's largest producers of wind-generated electricity is found at Tehachapi Pass, about two hours north of Los Angeles. Here, more than 5,000 turbines can send over 600 MW of power to thousands of customers. The Altamont Pass wind farm, an hour east of San Francisco, has 6,000 wind turbines — the world's largest concentration. Southern California's San Gorgonio Pass, near Palm Springs, has a "forest" of over 3,500 closely grouped turbines. Many older turbines on California's wind farms are now being replaced with more powerful and efficient models.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.



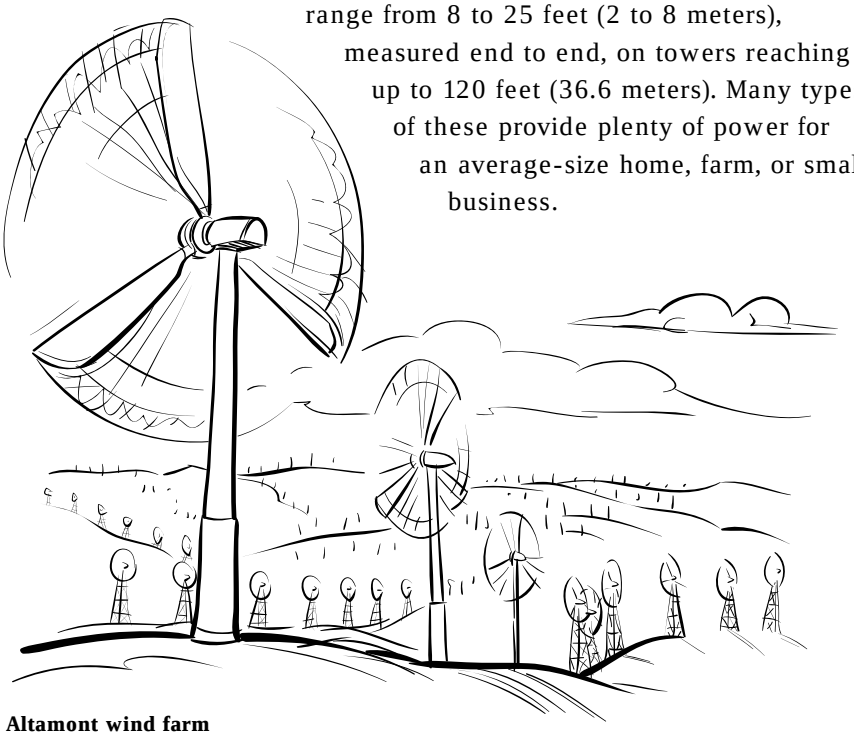
Rural regions are excellent areas for wind farms. One of the world's largest wind farms — in terms of land coverage — is near Storm Lake in Iowa, where over 250 turbines are clustered over hundreds of acres of countryside, much of which is agricultural. The U.S. Department of Energy encourages use of wind through its "Wind Powering America" program.

Wind energy is a big industry in Europe. Germany is the world's largest producer of wind power, followed by Spain. In Denmark and the Netherlands, modern wind turbines are seen alongside the old windmills for which this area is famous. Great Britain is installing many smaller wind farms of between ten and one hundred turbines each, both on agricultural land and other lands. Northern Africa, India, and a number of other areas are also actively investing in wind power.

Wind Turbine Sizes

Wind turbines are usually divided into two categories: small-scale and large-scale.

Small-scale turbines generate less than 100 kW. These can be the principal power source in a remote location with some type of back-up power. Small-scale wind turbines can also be used to supplement existing sources of electrical energy, such as PV panels on buildings or electricity from the local utility. A "home-sized rotor" has blades that range from 8 to 25 feet (2 to 8 meters), measured end to end, on towers reaching up to 120 feet (36.6 meters). Many types of these provide plenty of power for an average-size home, farm, or small business.



Altamont wind farm

FOR THE BIRDS

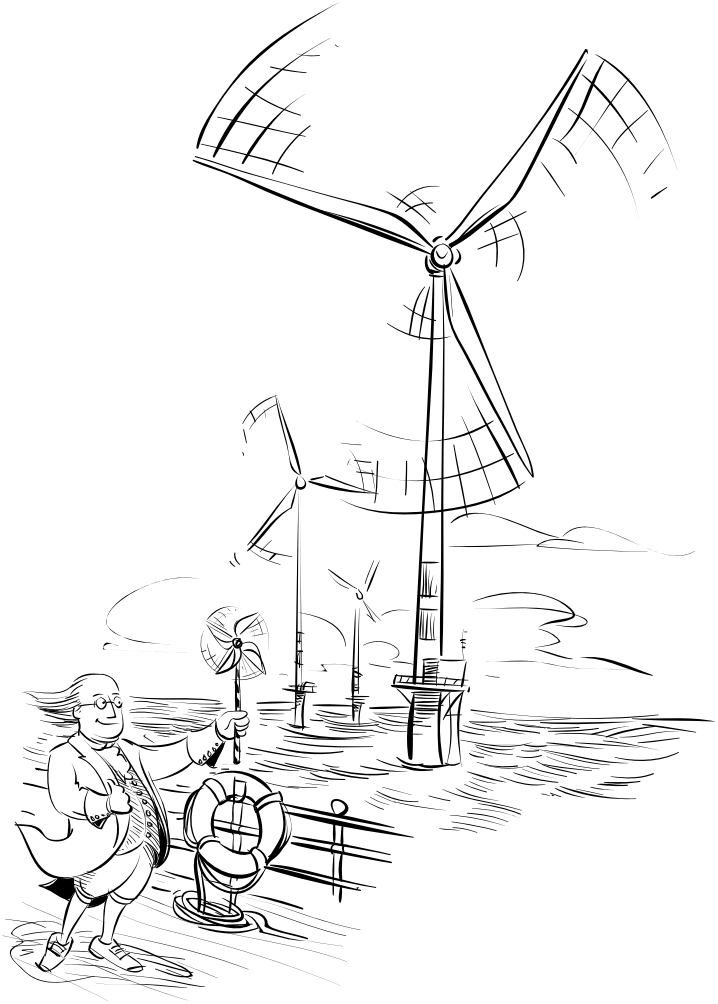
One widely publicized concern is the issue of birds such as hawks and eagles flying into spinning wind turbines. In fact, structures such as buildings, transmission lines, and communications towers pose more threats to birds than wind turbines. Nonetheless, no one wants to see any birds injured. A number of government agencies (including the U.S. Department of Energy) and many private companies are taking steps to reduce the potential impact of wind power on our flying feathered friends. Researchers study sites for bird activity before wind turbines are placed. New smooth tubular towers (with no girders) discourage nest builders. With today's higher kilowatt turbines, the distance between towers has increased, and their blades spin more slowly. We are also trying out ways to make wind turbine blades more visible to birds.

Large-scale turbines range from 100 kW models to the newest, multi-megawatt machines. The most common large-scale turbines are sometimes called "utility scale" turbines, each generating from 750 kW to 2 MW. Large-scale turbines are those that are usually clustered together on wind farms.

Multi-megawatt turbines are enormous, with blades that span a football field and towers twenty or more stories high. New models can generate between 2 MW and 5 MW. These huge turbines can be installed offshore to take advantage of the sea's high winds. The United Kingdom, Germany, Denmark, and the Netherlands are already placing some of these mammoths off Europe's windiest shores. In fact, Britain, with one of the greatest wind resources in Europe, has plans to install at least 18 offshore wind farms.

WIND IN THE CITY

One interesting concept currently being explored in Europe is the placement of wind turbines on buildings in urban settings. These little stand-alone turbines are being positioned to harness the winds that rush through the human-built terrain of "hills and valleys" created by clusters of tall buildings.



CONSIDERATIONS

- Today's sturdy wind turbines stand up to all kinds of weather. They are much more efficient than their earlier counterparts. Wind power is clean, since it burns no fuels that create pollution.
- The cost of producing electricity from wind power has gone down considerably in recent years, so that it is nearly competitive with conventional fossil fuel technologies. Improvements in the equipment have made wind power even more attractive as an energy alternative.
- Wind as an energy resource is usually predictable within 24 hours, and follows daily and seasonal patterns. But, of course, the wind doesn't blow all the time. (On average, wind turbines operate 30 percent of the time.) While some wind energy can be stored in batteries, most systems also need some type of back-up. This is especially true in remote locations where people produce their own electricity. A common solution is a combination solar/wind system (along with batteries and perhaps a fueled generator.
- Some people object to the noise of wind turbines — especially the older models. Newer turbines are usually no more audible than the wind itself. And in rural or remote areas, noise is not a significant issue. Some people find the appearance of a wind farm unattractive, while others really like the way they look. Because today's utility-scale turbines produce more power than earlier models, modern wind farms contain fewer turbines per acre. This reduces noise, visual impacts, and bird collisions.
- In the United States, most electricity suppliers use wind power to supplement another energy source. It reduces the load on other plants operating at the same time, whether baseload or peaking.

DATA FILE: Wind

California

- California's wind farms have the capacity to produce 1,800 MW of power — providing about 1 percent of the state's electricity production.

United States

- There are 4,700 MW of wind turbines installed in the U.S. — enough to power about 1.3 million homes.
- California is currently the top producer of wind power. Texas is the second biggest.

Worldwide

- Total global wind generation capacity is over 31,000 MW.
- Germany, the United States, Denmark, Spain, and India are currently the top consumers of wind energy.
- In Denmark, wind generates 20 percent of the nation's electricity.

Data available in 2003

The Renewable and Nonrenewable Resource

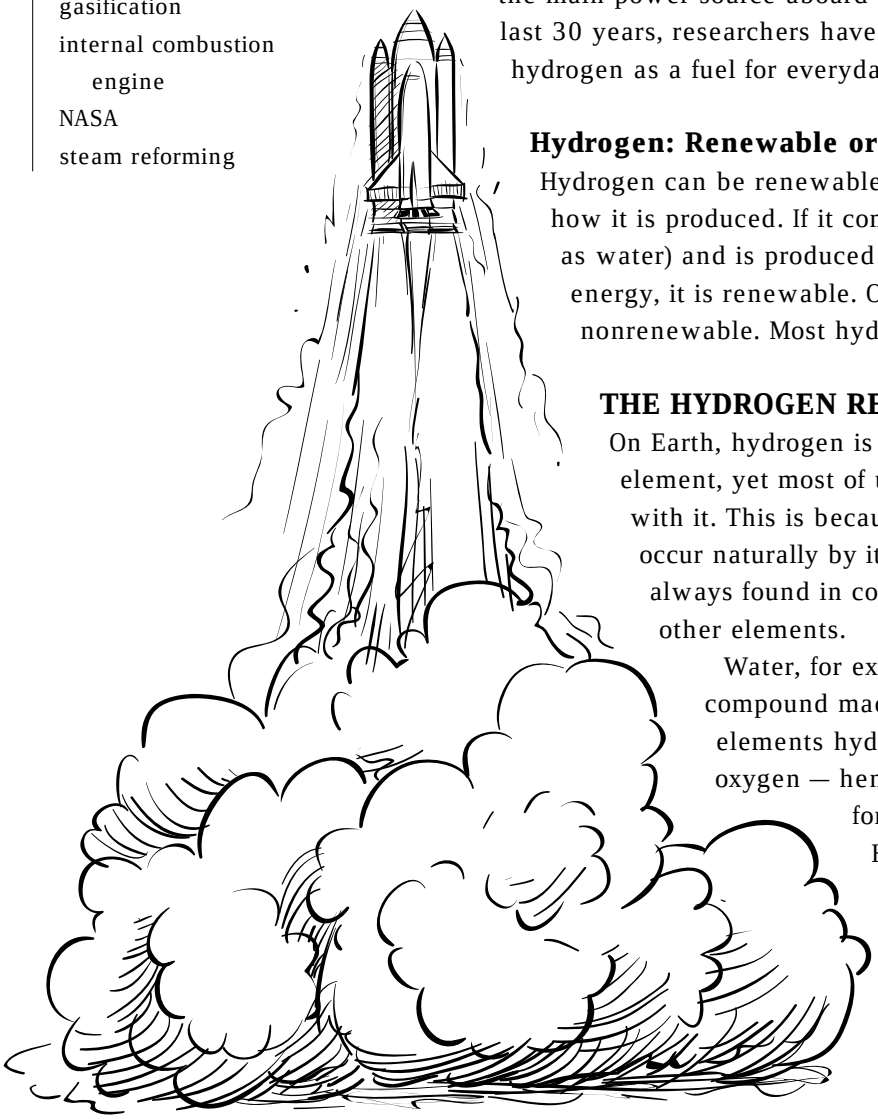
The Renewable and Nonrenewable Resource: HYDROGEN

VOCABULARY

anaerobic digestion
anode
cathode
compound
electrochemical
electrode
electrolysis
electrolyte
element
gasification
internal combustion engine
NASA
steam reforming

HYDROGEN IS ONE OF THE MOST ABUNDANT elements on Earth. Yet it wasn't until the 1700s that scientists first proved its existence, and it was later still that they recognized its value. Finally, by the mid-1800s, people were using hydrogen in "town gas," providing light and heat in cities across the United States and Europe. Later, it became useful in the production of ammonia, fertilizers, glass, refined metals, vitamins, cosmetics, cleaners, and much more.

Hydrogen has launched many U.S. rockets into outer space. Fuel cells using hydrogen, first used successfully in the 1960s, have been the main power source aboard all of NASA's space shuttles. Over the last 30 years, researchers have also been looking at ways to use hydrogen as a fuel for everyday life.

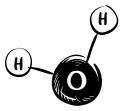


Hydrogen: Renewable or Nonrenewable?

Hydrogen can be renewable or nonrenewable, depending on how it is produced. If it comes from a renewable resource (such as water) and is produced using electricity from renewable energy, it is renewable. Otherwise, the hydrogen is considered nonrenewable. Most hydrogen produced today is nonrenewable.

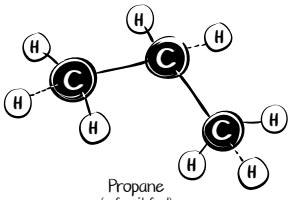
THE HYDROGEN RESOURCE

On Earth, hydrogen is the third most common element, yet most of us aren't very familiar with it. This is because hydrogen doesn't occur naturally by itself. Instead, it is always found in combination with other elements.



Water

Water, for example, is a compound made of the elements hydrogen and oxygen — hence the formula H_2O. Hydrogen joins with carbon to make fossil fuels such as natural gas, coal, and petroleum. It is also found in all growing things.



Propane
(a fossil fuel)

Hydrogen Unbound

In order to use hydrogen we must separate it from the compounds in which it is bound. Once freed, it is a colorless, combustible gas that can release a great deal of energy. Scientists have developed different ways to produce hydrogen. One important method is electrolysis. Other techniques use chemical or biological processes.

Producing Renewable Hydrogen

By Electrolysis. Electrolysis was first closely studied in the 1830s by English scientist Michael Faraday. In this process, electricity is passed through water. The electrical charge causes the hydrogen and oxygen in the water molecule to split apart and turn into gases. A chemical called an electrolyte is often added to the water to help conduct electrons through it.

Water used in electrolysis is, of course, a renewable resource, but for the resulting hydrogen to be considered renewable, the electricity for this process must also have come from a renewable source. Any renewable methods of generating electricity could be used.

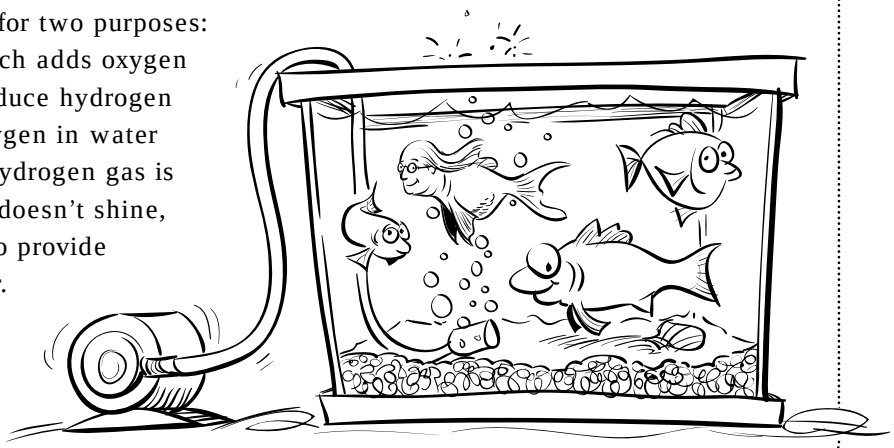
HYDROGEN TO GO

One day some of our cars may operate using hydrogen gas. Already most of the major car manufacturers have designed engines that burn hydrogen instead of gasoline. The engines of these cars are very similar to those in the vehicles we drive today.

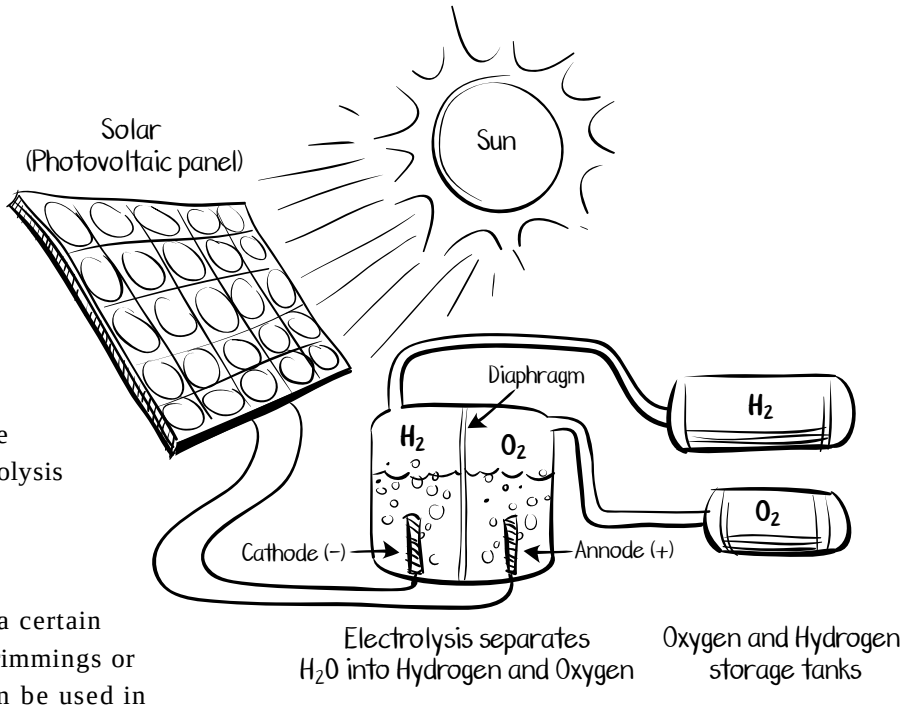
People like the idea of using these engines because burning hydrogen produces few polluting emissions. Researchers are now working on ways to store hydrogen aboard a vehicle, along with ways to make hydrogen "filling stations" widely available.

POWER SKETCH: Hydrogen Fuel Cells Keep Aquarium Bubbling

A unique energy system, the Schatz Solar Hydrogen Project, helps keep fish alive in the marine lab aquarium at Humboldt State University in northern California. Here, solar panels mounted on the roof produce electricity that is used for two purposes: to drive the aquarium's aerator (which adds oxygen to the water for the fish) and to produce hydrogen gas. Hydrogen is separated from oxygen in water by the process of electrolysis. The hydrogen gas is stored and then, whenever the sun doesn't shine, the hydrogen is used in a fuel cell to provide electricity for the aquarium's aerator. This remarkable renewable energy system has been running day and night since 1994.



In the future, electrolysis systems might be installed at renewable energy power plants. Some or all of the electricity could be used for electrolysis, producing hydrogen gas that could be transported and used for other purposes. Electricity could be produced for customer use when needed and shifted to electrolysis at times of lower demand.



Producing renewable hydrogen using electrolysis

Using Biomass. Biomass gives off hydrogen gas when it's heated in a certain way. Plant material (such as tree trimmings or specific crops) or organic waste can be used in this process, called gasification. Gasification is a thermal process that converts organic material into hydrogen, carbon monoxide, carbon dioxide, and small amounts of other gases. This mixture is frequently called synthesis gas, or syngas, because it can also be used to produce other chemicals.

Using Landfill Gas. When organic material begins to break down in our landfills, it can give off gases such as methane. Hydrogen can be produced from this methane gas and then used to generate electricity with a fuel cell. Hydrogen production from methane gas does give off carbon dioxide (as is also true with producing hydrogen from fossil fuels). However, since methane is a more potent greenhouse gas than carbon dioxide, using it to produce hydrogen is still preferable to allowing it into the atmosphere.

Using Biological Organisms. Some microorganisms produce methane and other gases when they are caused to digest under special conditions (called anaerobic digestion). Hydrogen can be extracted from the methane gas. (See "Power Sketch," page 54.)

Producing Nonrenewable Hydrogen

By Electrolysis. If the electricity used for electrolysis (described earlier) comes from a nonrenewable electricity source, such as a fossil fuel or nuclear power plant, then the hydrogen produced is not considered renewable.

By "Steam Reforming." Another method of producing hydrogen involves using a fossil fuel, such as natural gas, and steam to produce hydrogen and byproducts, in a process called steam reforming.

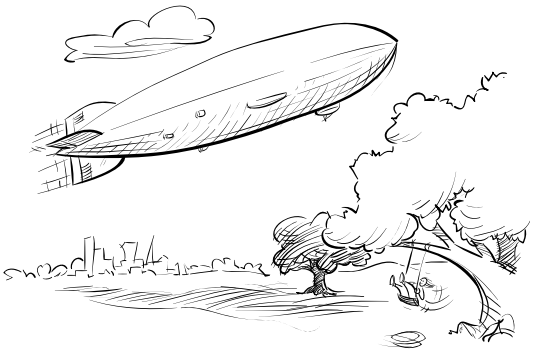
By Gasification. The same process described above for converting biomass can also be used with a fossil fuel to produce hydrogen.

GENERATING ELECTRICITY FROM HYDROGEN RESOURCES

Fuel Cells

Fuel cells were once thought to be a "far out" technology suitable only for use aboard space shuttles. However, fuel cell technology is advancing rapidly. We may soon see fuel cells popping up in many aspects of everyday life, including electrical generation, powering vehicles, and operating small electrical devices.

Most of us associate the word "fuel" with burning something for its heat (thermal energy). However, in spite of the name, nothing is burned in fuel cells. Instead, fuel cells produce electricity using a method that is actually the reverse of electrolysis. Hydrogen (the "fuel") and oxygen are combined (rather than separated) through an electrochemical process that produces electricity, heat, and water.



DISPELLING A MYTH

In 1937, a flash fire engulfed *The Hindenburg*, a luxury zeppelin aircraft filled with hydrogen gas. Dozens of people were killed. As the flaming airship plunged to the ground, newsreel cameras captured the disaster. The film footage caught the world's attention, and for decades hydrogen gas took the rap for causing the fire. Recently, hydrogen expert (and former NASA researcher) Addison Bain proved conclusively that hydrogen was not to blame. Rather, the fire was caused by the design and highly flammable fabric of the craft working in deadly combination with electric sparks from a developing thunderstorm. Bain's findings were confirmed by witnesses who described the fire as a bright, fireworks-like display of color. Hydrogen would have burned with a colorless flame. Experts say that lighter-than-air hydrogen is actually less hazardous than gasoline because it tends to disperse into the air so rapidly.

Fuel cells produce no polluting emissions. And, if the hydrogen used is produced with renewable methods, then the use of the fuel cell is also considered renewable. Fuel cells range from very small units to those that produce 250 kW or more. Because they are modular, extra units can be added when more power is needed.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

Hydrogen as a Combustible Fuel

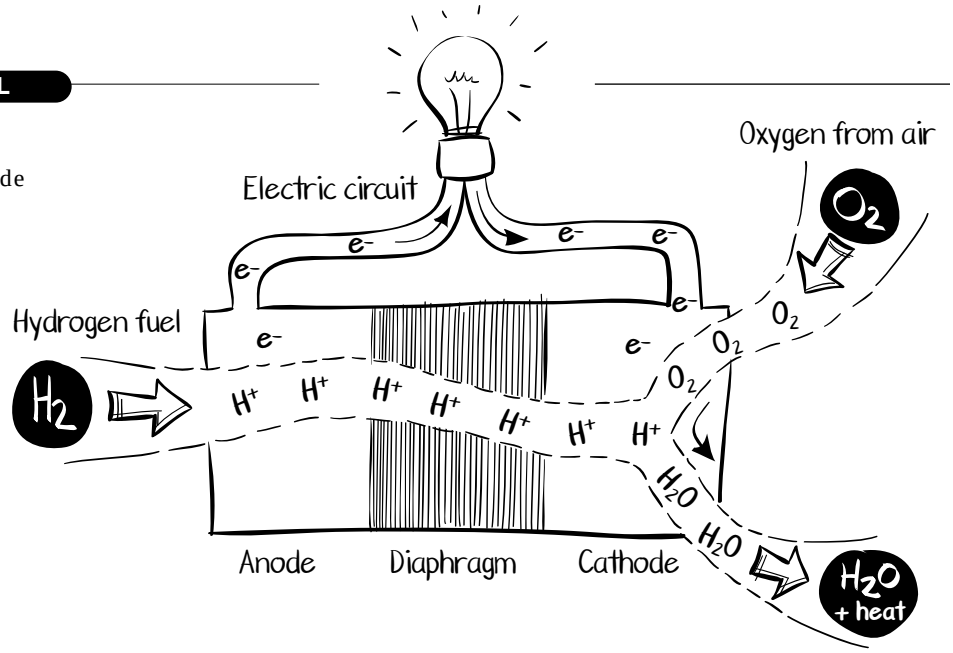
Hydrogen can also be used as a combustible fuel, in either a liquid or gaseous state. Hydrogen burns completely with very few pollutants and has a high energy content.

Sometimes hydrogen is added to natural gas at traditional power plants, making them work more efficiently and helping to reduce pollutants. It is possible that these power plants could be remodeled to run solely on hydrogen gas. If the hydrogen gas came from a renewable source, then these updated power plants would be both renewable power suppliers and easy on the environment.

Presently, most of the attention paid to combustible hydrogen fuel is for use in transportation.

INSIDE A FUEL CELL

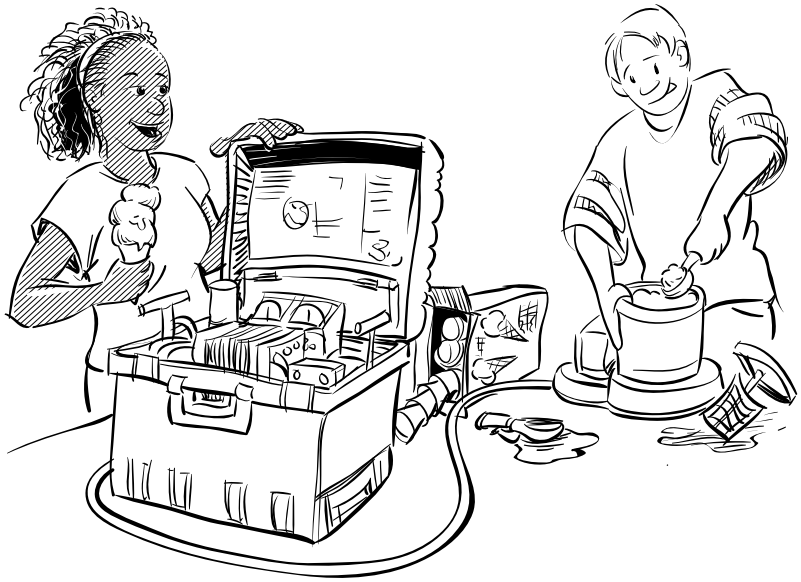
In a fuel cell, hydrogen is introduced into the anode side and oxygen into the cathode side. Electrons are stripped from the hydrogen atoms and flow as an electric current. At the cathode end of the fuel cell the hydrogen joins with the oxygen, resulting in water and heat.



Hydrogen at Work

A microwave relay station mounted atop a fire watchtower in Redwood National Park in northern California is run by solar and fuel cell systems. A school in Santa Cruz, California, has a portable fuel cell unit that fits in a small suitcase. A renewable energy teaching tool for the students, this system can run an ice cream maker, a blender, or even a computer.

The California Fuel Cell Partnership, founded in 1999, links dozens of private and government groups to test and promote hydrogen fuel cells for power generation and transportation. Several California utilities have been exploring the potential for fuel cells in electricity generation.



Portable fuel cell unit providing electricity to an ice cream maker

Image adapted with permission of the Schatz Energy Research Center

The U.S. Department of Defense has already installed several stationary fuel cells at a number of military bases. Fuel cells are also popping up in U.S. civilian life. A large fuel cell installation is providing power for a training school in Connecticut. At a wastewater treatment facility in Portland, Oregon, fuel cells using hydrogen produced from waste gas provide back-up power for plant operations.

Iceland, already a leader in the use of geothermal energy, is actively promoting the use of hydrogen to displace the 30 percent of its energy that comes from imported oil. Doing so would make Iceland completely energy self-sufficient. Germany, Switzerland, India, Japan, and Australia are also pursuing the use of hydrogen and fuel cells.

CONSIDERATIONS

- Hydrogen is a transportable fuel. This is important because many renewable energy resources are not transportable. In remote and unpopulated areas, far from transmission lines, geothermal, ocean, solar, and wind resources can be used to produce electricity. The electricity can be used on-site to make renewable hydrogen that can be stored and/or transported for use as a combustible fuel or in fuel cells.
- If hydrogen escapes from its container, it rapidly disperses into the air rather than puddling on the ground the way heavier-than-air fuels, such as gasoline, tend to do. However, hydrogen does burn easily and invisibly, so care needs to be taken when handling it (especially if it escapes and collects in a contained space). With proper precautions, hydrogen is thought by some to be just as safe as gasoline. Currently, engineers are perfecting systems to contain and transport hydrogen safely and economically because it is considered an important fuel for our future.
- Hydrogen burns cleanly, but does produce some air emissions when burned. When used in a fuel cell, the only byproducts are heat and water.
- Currently, much of our hydrogen gas comes from fossil fuels. If we continue producing hydrogen this way, we will probably have the same concerns about hydrogen production that we now have about fossil fuel use (i.e., energy insecurity, depletion, and pollution). See pages 122-123, "Considerations," and all of Chapter 4, Energy and the Environment.

(continued)

DATA FILE: Hydrogen

California

- The Los Angeles Department of Water & Power installed a 250 kW, state-of-the-art, "molten carbonate" fuel cell plant in 2001.
- The South Coast Air Quality Management District, which demonstrated the first commercial "phosphoric acid" fuel cell in 1992, plans to try six more other types, including one for residential use.

United States

- New York City plans to use gases from some wastewater treatment plants to produce hydrogen for use in up to eight fuel cell power plants.
- Fuel cells already provide electric power at test sites in many states across the U.S.

Worldwide

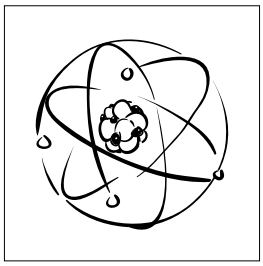
- Japan has had an active fuel cell development program since 1981.
- The European Commission has been supporting fuel cell research and development programs since the mid-1970s.

Data available in 2003

CONSIDERATIONS (continued)

- The production of hydrogen, especially with renewable methods such as electrolysis, is still quite expensive. At present, most hydrogen gas is extracted from nonrenewable fossil fuels such as natural gas. Even so, it remains a superior alternative to ordinary fossil fuels because of the environmental benefits. It is hoped that costs will come down as the technology for producing renewable hydrogen is perfected.

Nonrenewable Energy Sources



Nonrenewable Energy Source: FOSSIL FUELS

VOCABULARY

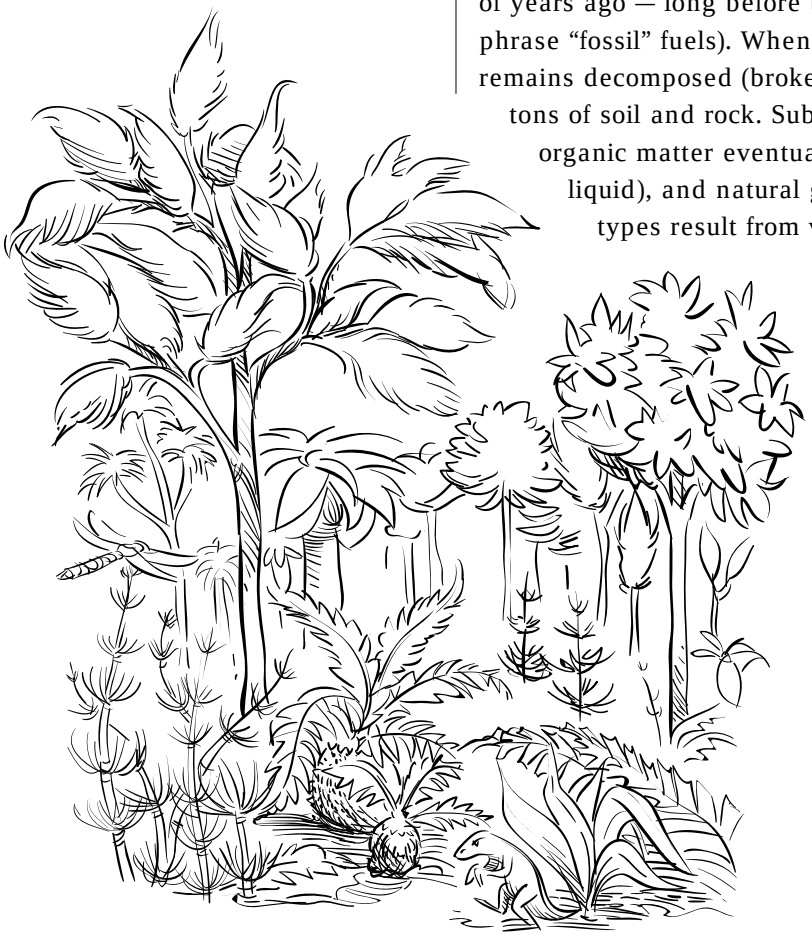
acid rain
carbon-based compound
combined cycle power plant
crude oil
gas turbine
global climate change
greenhouse gas
hydrocarbon
oil rig
oil refinery
scrubber
synthetic

FOSSIL FUELS—COAL, OIL, AND NATURAL GAS—have been highly prized energy sources for centuries. Mining for coal may have first occurred in China as far back as 200 B.C. By 200 A.D. the Romans made wide use of the coal resources they found in Great Britain. In the 1100s, oil wells were being drilled in Europe and along the west coast of the Caspian Sea. It was the Industrial Revolution, however, that launched the widespread use of fossil fuels to power factories and transportation systems. Electricity was first produced using coal in the 1880s. Since that time, fossil fuels have been the dominant source of energy for electrical production, transportation, and industry in the United States and around the world.

THE FOSSIL FUEL RESOURCE

All fossil fuels are formed from plants and animals that lived millions of years ago — long before the days of the dinosaurs (hence, the phrase "fossil" fuels). When these plants and animals died, their remains decomposed (broke down) and were eventually buried under tons of soil and rock. Subjected to heat and pressure over time, this organic matter eventually formed coal (a solid), petroleum (oil, a liquid), and natural gas (a vapor). The three different fossil fuel types result from variations in the underground conditions.

Fossil fuels are nonrenewable resources. That is because today's fossil fuel resources began to form so very long ago, when much of the land was covered with swamps and the climate was very warm. These conditions were perfect for many living things, including huge ferns, trees, and other plants. The swamps and seas were teeming with algae and other small organisms. These lush conditions are not nearly as widespread today. A small amount of fossil fuels may still be forming, but not in significant quantities. And, they will not form in a useful amount of time.



Plants and animals of long ago formed the fossil fuels we use today.

Living things are carbon-based, so all fossil fuels are made of molecules that contain carbon. They also contain hydrogen, giving rise to the name "hydrocarbons." Hydrocarbons burn easily. They are a reliable source of heat energy and are convenient to transport. Carbon combines with oxygen when fossil fuels are burned, resulting in carbon dioxide gas.

Fossil fuels contain other materials in addition to hydrocarbons. These materials, including sulfur, nitrogen, mercury and other impurities, are found in varying amounts in each fossil fuel. When burned, these recombine with other materials and form air pollutants.

Coal

Coal is a solid hydrocarbon that we excavate from underground, just as we mine for minerals. One age-old method is to mine coal from tunnels dug deep into underground rock. The other, and more recent, method is called surface- or strip-mining. Here, deposits within about 200 feet of the surface are exposed by removing the overlaying rock and soil. Once topside, coal is easy to transport, usually in large containers aboard ships or in special cars on trains.

California does not have large coal resources (although it purchases some of its electricity from out-of-state coal plants). There are abundant supplies in other parts of the United States, making the U.S. one of the world's top producers of coal.

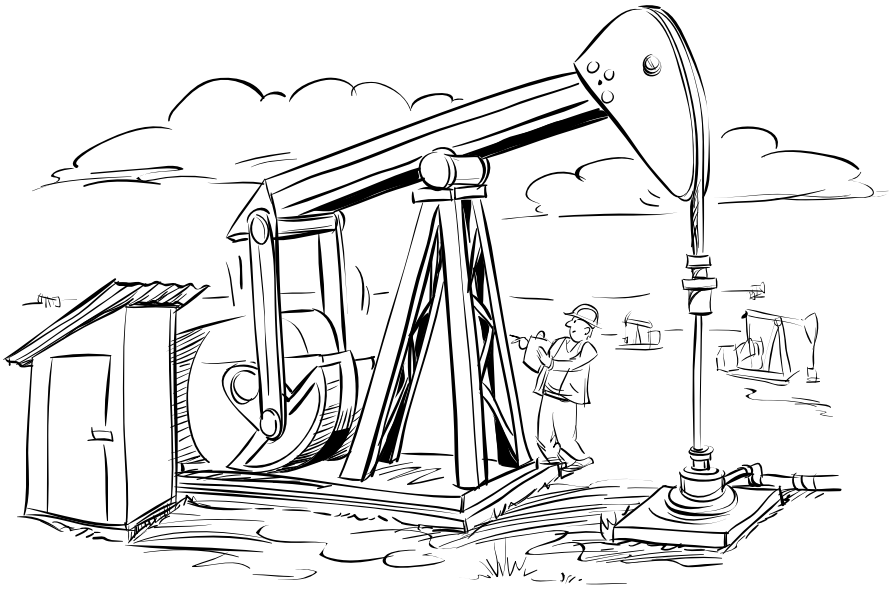
Oil

Oil, also known as petroleum or crude oil, is a thick black liquid hydrocarbon found in reservoirs hundreds to thousands of feet below the surface. We extract it by drilling wells deep into the underground rock and then inserting pipes. Natural pressure can bring the oil shooting to the surface when wells are new; but, in most cases, pumps are needed to bring the oil to the surface. These oil field pumping units are common sights on land and at sea (on offshore platforms) throughout southern California and other oil-rich areas.

Once captured, crude oil is taken to refineries and processed into various products. These include gasoline, diesel, aviation fuel, home heating oil, asphalt, and oil burned for electrical power. Oil products are sent from refineries through pipelines directly to their consumers, or are delivered in large tanks aboard trains, trucks, or tanker ships.

MAKING AMERICA GO

Though less widely used for producing electricity than coal, oil is still America's most widely used fossil fuel. Why? Because for decades it has been refined into gasoline, diesel, and aviation fuel to power our cars, trains, trucks, and planes. It is also used extensively for heating homes and businesses, for industrial process heat, and to make fertilizers, machinery lubricants, medicines, and many types of plastics.



A pumping rig is used to bring up crude oil.

California has sizeable crude oil resources. Of the world's top oil producers, Saudi Arabia is first, the United States is second largest, and Russia is third. Production in California and the United States has already begun its decline. Over half of the oil used in the U.S. today is imported.

Natural Gas

Natural gas (methane) is a vapor that occurs naturally underground. (It is not the same thing as the liquid gasoline that we use in our vehicles, though we do call this "gas" for short.) Natural gas is piped to the surface through wells drilled into the underground rock.

Natural gas can be processed into propane and other types of fuels. All natural gas fuels are highly flammable. Natural gas is odorless, so for safety it is mixed with a chemical to give it a noticeable smell before it is sent to consumers. Huge networks of pipelines deliver most natural gas directly to homes, factories, and power plants. Natural gas can be stored and shipped in pressurized containers. It can also be condensed to a liquid, transported and re-vaporized for later use. Natural gas can also be used as a source of hydrogen gas.

Russia, the United States, and Canada are the world's top producers of natural gas. California has large natural gas deposits, but production has declined. California imports about 80 percent of its natural gas from other states and from Canada.

GENERATING ELECTRICITY WITH FOSSIL FUEL RESOURCES

Most electricity in the United States is produced in "conventional" fossil fuel power plants. A fuel is burned to boil water to make steam. The force of steam is what drives the turbine generator. (See "How a Steam-driven Power Plant Works," page 29.) While some plants burn petroleum or, more frequently, natural gas, the fuel most used for electricity generation in the U.S. has been, and still is, coal.

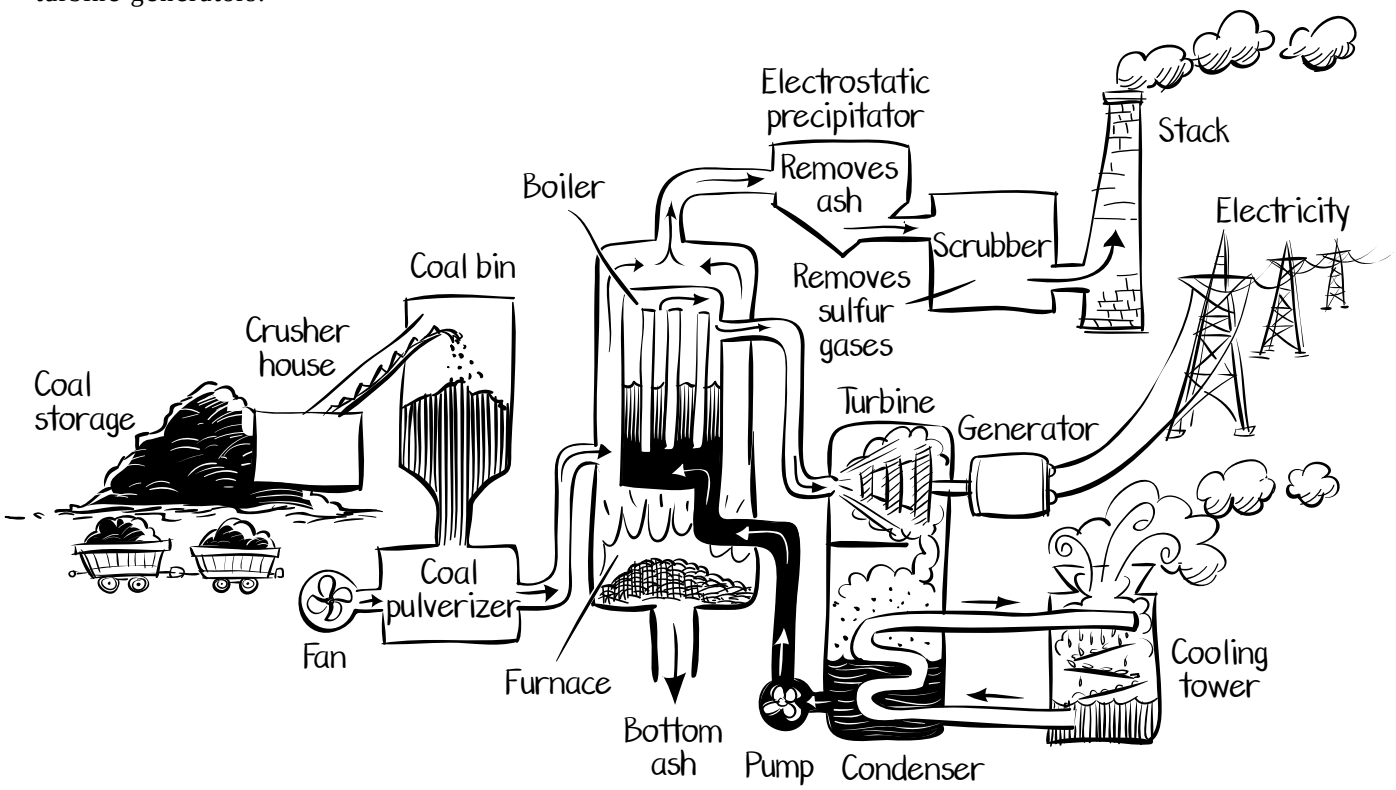
REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

Coal-fired Power Plants

A 1,000 MW coal-fired power plant burns about 10,000 tons of coal a day, providing electricity to about one million people. Sometimes a coal-powered plant is located right at a coal mine. Other times the coal arrives in trains that go back and forth non-stop between the mine and the power plant. The coal is usually processed into pulverized fine particles that are burned to create the steam needed to power the turbine generators.



A conventional coal power plant

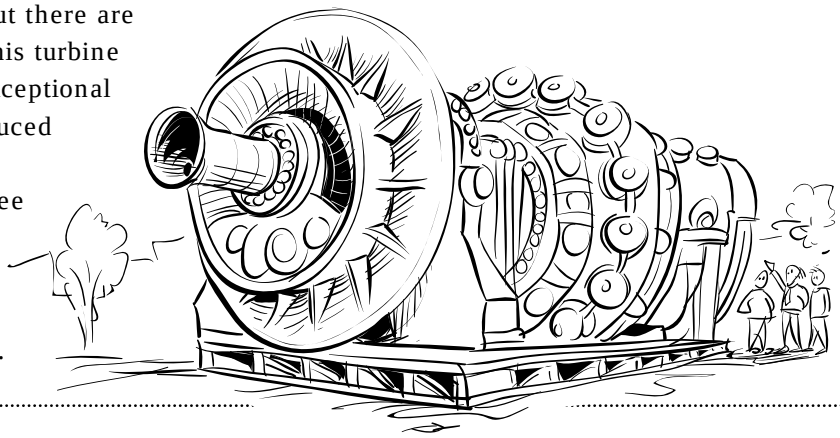
Currently we are developing methods to "clean" coal. These methods reduce the amounts of some impurities, such as sulfur and nitrogen, before the coal is burned. This process lessens the need to remove byproducts after it is burned. We have also developed a technology to "cook" coal using gasification. This produces a cleaner-burning, synthetic (artificially made) gas. Coal gasification can also produce hydrogen.

Conventional Gas Turbines

Natural gas was originally used mostly for heating and in industrial processes. But now it is also used for generating electricity. The first natural gas power plants were conventional steam-driven combustion turbines. Today's gas plants produce electricity using a turbine based on jet aircraft engine design. A mixture of compressed natural gas and high-pressure air is burned in a continuous fiery explosion. The hot exhaust from this combustion reaction is what drives the new turbines. This method is more efficient and cleaner burning than the steam-boiler method.

POWER SKETCH: Clean Spin on an Old Design

A new type of gas (combustion) turbine has recently been perfected with assistance from the U.S. Department of Energy. Larger than the biggest locomotive, this new design uses the same system as older gas turbine models: the exhaust resulting from the explosive combustion of compressed natural gas is used to spin the turbine. But there are other qualities that really make this turbine stand out from the crowd — its exceptional energy efficiency and greatly reduced air emissions. Planned to work in "combined cycle" power plants (see next page), these sophisticated turbines are being applauded as a cleaner way to produce electricity when using fossil fuels.



"Combined-Cycle" Power Plants

Since about 1985, most natural gas power plants have been "combined cycle" plants, in which two turbine types work together to produce electricity. First the gas turbine produces electricity using the hot exhaust from the combustion reaction as described on page 121 (see Conventional Gas Turbines). Then that same exhaust — still extremely hot — is used to boil water to produce steam in a conventional boiler. This steam spins a second turbine that generates even more electricity. Since combined cycle systems produce extra electricity by using what would otherwise be wasted heat, they are exceptionally energy efficient.

Size of Fossil Fuel Power Plants

Coal plants and natural gas power plants are typically large, generating 300 to 1000 MW of electricity or more. But natural gas plants come in all sizes. A university in Florida uses a 42 MW plant to produce electricity, hot water, and heat for the buildings. Often hospitals, or other places that must stay operating at all times, have back-up diesel or natural gas turbines in case the power goes out. Natural gas "microturbines" of 25 to 500 kW can also be used in small businesses and as standby or peaking power.

CONSIDERATIONS

- Coal, oil and natural gas are high-energy fuels that are easily transported. They can also be converted to convenient forms like propane.
- Fossil fuels have the advantage of a long history. Technology using fossil fuels has been refined over time, so their use is convenient and familiar.
- Forecasts differ for how long world oil supplies will last at projected rates of consumption. There seems to be agreement that it will be only decades, not centuries.
- As oil and natural gas production decline worldwide (as they already have in the U.S.), prices will rise due to shortages or fear of shortages.

- Of the fossil fuels, coal creates the most pollution when it is burned, releasing particles, mercury, and gases such as nitrogen oxides and sulfur oxides that cause smog and acid rain. Oil-fired power plants also emit some of these same gases. All three of the fossil fuels produce carbon dioxide, a greenhouse gas thought by most scientists to contribute to global climate change. In the United States, regulations require that most fossil-fuel power plants equip their smokestacks with "scrubbers" that trap some of these pollutants. (See also Chapter 4, "Energy, Health, and the Environment," page 135.)
- Natural gas has fewer impurities than coal or petroleum and burns cleaner than other fossil fuels.
- While every industry has accidents, and, while they are not common, some have greater consequences than others. For example, the 1982 Valdez oil tanker accident in Alaska created an oil spill that covered over 1,000 miles of shoreline. The oil killed many birds, fish and other animals. It greatly disrupted the natural habitat and the local fishing economy.
- Mining coal often causes serious disturbances to the surface habitat of an area. For example, to uncover the coal deposits at some surface coal mines, hilltops are scraped off, and the plants, soil, and rocks are pushed into the valleys and streams below. And with tunnelling, holes usually remain after a mine is abandoned. If soils are set aside and replaced, an agricultural area can usually be "reclaimed" and returned to farmland once the coal has been removed. However, any natural area disrupted by mining activity will in all likelihood never be the same.
- Coal and oil plants are usually baseload plants. Natural gas plants can be operated as baseload or peaking plants, and small gas turbines are often used as emergency backup. Diesel plants are used for peaking or emergency standby power.

DATA FILE: Fossil Fuels

California

- California is one of the top five oil producing states in the United States.
- In the year 2000, fossil fuels produced around 56 percent of all electricity consumed in the state.

United States

- Coal produced half of all electricity used in the United States in 2001.
- The United States gets over 70 percent of its electricity from fossil fuels.

Worldwide

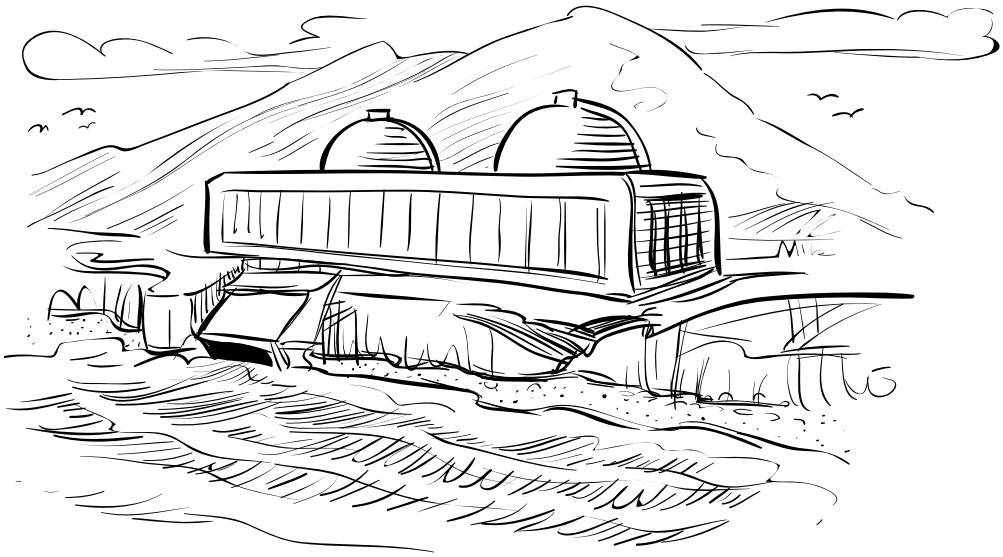
- About 65 percent of the electricity produced globally comes from fossil fuels.
- Russia, the United States, and Canada produce the most natural gas. The countries of the Middle East, the United States, and Russia produce the most oil. China, the United States, Australia, India, and South Africa produce the most coal.

Data available in 2003

Nonrenewable Energy Source: NUCLEAR

VOCABULARY

chain reaction
containment vessel
control rod
fissionable
fuel rod
nuclear fusion
nuclear reactor
radioactive
reactive
reactor core
spent fuel
subatomic particle
uranium



This nuclear power plant uses ocean water for cooling; it does not need traditional cooling towers.

THE ATOMIC AGE WAS BORN in 1939 when physicists burst apart the nucleus of a uranium atom, releasing a tremendous amount of energy as heat and light. They called this reaction nuclear fission.

Nuclear fission's first job was to make atomic bombs during World War II (in the 1940s). However, we soon learned how to control the energy from nuclear fission to produce electricity. Today, nuclear energy is used widely for electricity production. It is also used to power nuclear submarines and aircraft carriers.

THE NUCLEAR RESOURCE

Nuclear energy is the energy trapped inside atoms, those tiny particles from which all matter is made.

The Energy of Atoms and Molecules

In nature atoms are bonded together into molecules, which in turn are bonded into various types of matter. It takes a great deal of energy to hold these molecules together.

Every atom is made up of even tinier "subatomic" particles, including the protons and neutrons in the atom's nucleus (central part). The energy that holds these subatomic nuclear particles together is very great — much greater than the energy that holds molecules together.

POWER SKETCH: A Natural Nuclear Reactor

Nuclear power plants depend on fissionable materials, which include radioactive elements. These can yield (give off) the energy bound in their atoms in a nuclear chain reaction. In most cases, the radioactive element used is uranium. Uranium is so reactive that it will, under very special circumstances, produce its own atomic reaction without any human help. At the Oklo mine in the West African country of Gabon, a deposit of "spent" uranium was found deep underground. This uranium had at one time spontaneously become a natural "nuclear reactor." Millions of years ago, it began its own self-sustaining chain reaction that lasted about 500,000 years!

Making nuclear energy can be roughly compared to burning wood. When we burn wood, we produce energy by breaking the electron bonds between molecules. If we stand beside a blazing bonfire we feel the energy as heat and see the energy as light. Similarly, when we produce a nuclear reaction we break the bonds between protons and neutrons within the nucleus of each atom, releasing enormous amounts of energy — far more than our bonfire.

Uranium Nucleus is "Easy" to Split

Most of the elements found on Earth have stable nuclei (plural of nucleus). Stable means they don't split apart easily. But some elements, such as uranium, have unstable nuclei, which causes uranium to give off small particles (to "radiate"). One type of uranium, Uranium 235 (U-235) is especially unstable.

Uranium: Fuel for Nuclear Power

Uranium is very hard and very dense. That is, it has a lot of mass per given quantity. Whereas one gallon of milk weighs about 8 pounds, one gallon of uranium weighs 150 pounds.

Uranium is found in many parts of the world, including the United States. We dig uranium-bearing rock (ore) from the ground just as we mine other minerals. There is a limited supply — though scarcity is less of an issue than it is for fossil fuels, since uranium is used in much smaller quantities. Uranium is, nevertheless, a nonrenewable resource.*

**Elements other than uranium, notably plutonium, can also be used for nuclear fission. In most parts of the world plutonium is only used in weapons and not for the production of electricity.*

GENERATING ELECTRICITY WITH NUCLEAR ENERGY

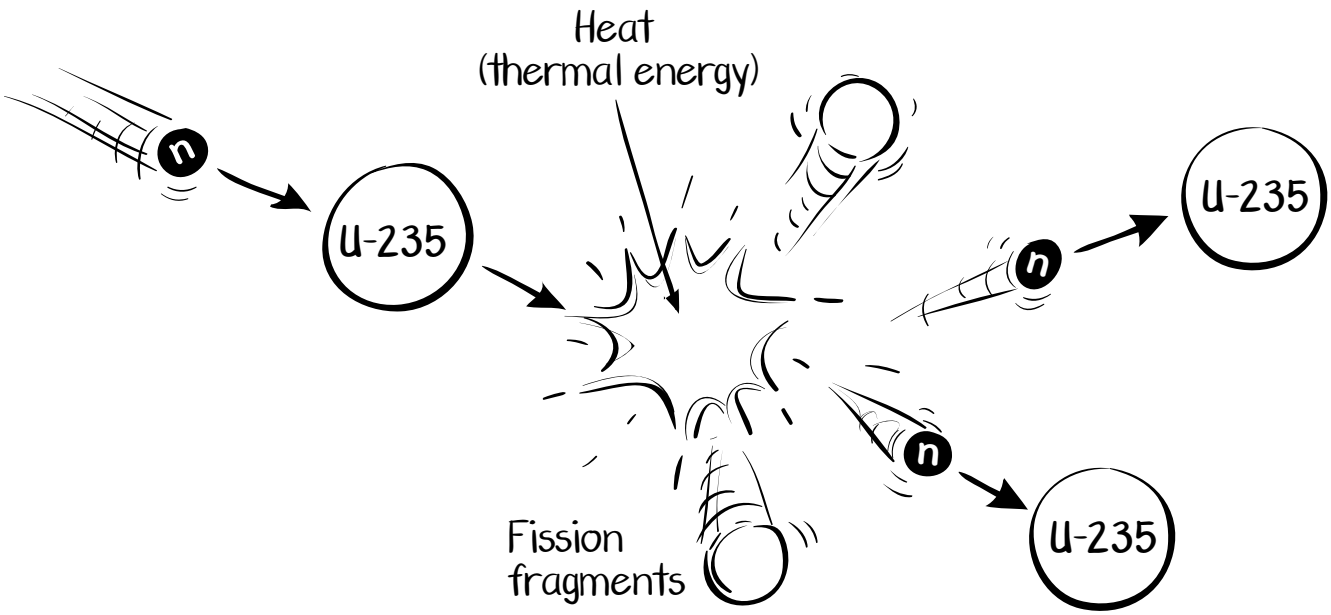
A Nuclear Chain Reaction

In nuclear power production the process of splitting nuclei is accelerated to generate electricity. Splitting the nucleus of an atom is nuclear fission. (Fission means to split.) For nuclear fission to occur, high-energy subatomic particles, called neutrons, are caused to bombard the uranium atom's nucleus, breaking it apart. When this nucleus splits, it releases heat and light as well as other neutrons. These particles strike other uranium atoms, splitting those. These, in turn, strike and split other atoms, and so on, in a nuclear chain reaction.

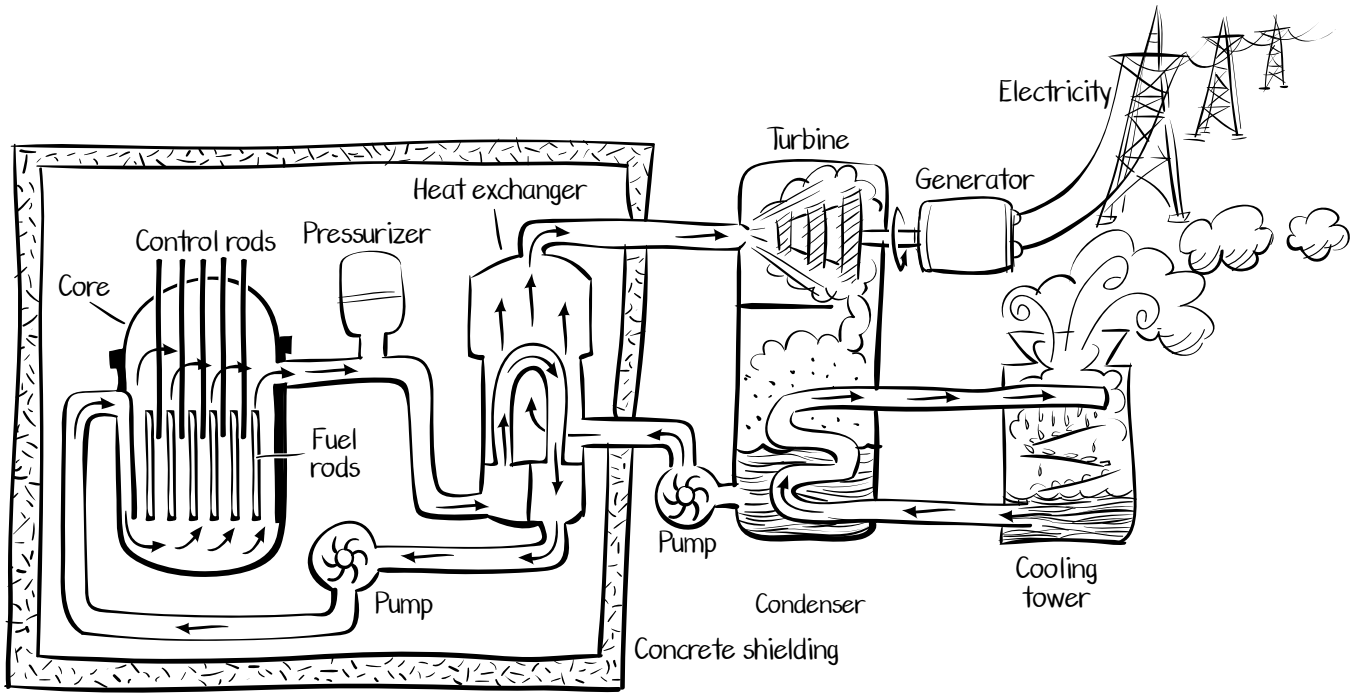
The amount of energy produced by splitting one uranium nucleus isn't much. However, because uranium is so dense, one pound of uranium has billions and billions of nuclei. Once we start a chain reaction, a LOT of energy is released. In a nuclear power plant, this reaction is carefully controlled to allow just the right release of energy needed to produce electricity.

STAR-STRUCK URANIUM

Uranium was produced in the fiery destruction of ancient stars. These stars exploded to provide "dust," which clustered together to make planets, including Earth. Uranium is one of the star-born elements of Earth.



Starting a nuclear chain reaction



A nuclear power plant

Preparing the Nuclear Fuel

At a nuclear fuel manufacturing plant, the natural uranium is "enriched" — a mechanical process that increases the U-235 concentration to make the uranium more useful. The enriched uranium is formed into pellets the size of the tip of your little finger. (Each pellet contains the energy equivalent of a pick-up truck full of coal, 150 gallons of oil, or a house-sized container of natural gas.) The pellets are loaded into long metal fuel rods.

Inside a Nuclear Power Plant

Many fuel rods are placed into a reactor core, interspersed with moveable control rods holding a material that absorbs neutrons. Pushed in or out of the core, the control rods govern the size of the reaction (and, therefore, the amount of energy produced).

The fission reaction is started with high-energy neutrons from a special radioactive source, inserted into the reactor. These neutrons bombard the pellets, splitting some of the uranium nuclei. This releases more neutrons, causing the chain reaction that produces heat and light.

A liquid or gas flows past the fuel rods in the reactor core, carrying away some of the heat to a heat exchanger. (See "Heat Exchangers," page 63.) In the heat exchanger, this heat is transferred to water that boils and makes steam to spin the turbines. The rest of the system works like a traditional steam-driven power plant.

Nuclear Power Plant Safety

Uranium goes through many steps before it is used as fuel. It must be treated very carefully so that no one is exposed to its radioactivity. Exposure while it is mined, milled, enriched (made more reactive), fashioned into pellets, and stored before use is not a risk unless it is inhaled as dust or swallowed. Once used, the "spent" fuel is very radioactive. It must be handled carefully and stored safely in a secure location. This used nuclear fuel will remain a hazard for thousands of years.

Nuclear power plants are designed for maximum safety. The reactor core is surrounded by steel that is between 6 and 9 inches (15 and 23 centimeters) thick. The reactor core and the steam generators are housed in sealed "containment buildings" to prevent the accidental escape of radioactive water or steam. A thick concrete shield that absorbs radioactivity surrounds this steel vessel.

CONSIDERATIONS

- With nuclear energy, we get a generous amount of electricity from very little fuel. One nuclear plant can produce hundreds to thousands of megawatts of baseload power. Also, a properly operating nuclear power facility produces no air pollution.
- In some parts of the world, mainly in industrialized countries such as the United States, nuclear plants have not been built in several years. The U.S. Department of Energy is working to help construct a new reactor in the United States by 2010. In certain developing nations energy from nuclear power plants is expected to increase. One reason is that nuclear plants have proven technology, and can be built in a relatively short time. This allows a developing nation to meet its growing demand for electricity.

NUCLEAR FUSION

Nuclear *fusion* (as opposed to nuclear *fission*) is another form of atomic energy. Nuclear fusion means several smaller nuclei are "fused" to form a larger nucleus. When this happens, a great deal of energy is given off as heat and light. This process is what makes our sun produce the heat and light that it does, making it a natural nuclear reactor. Nuclear fusion is very appealing as an energy source, because it uses less fuel and creates less radioactive material than nuclear fission. However, scientists have not yet learned how to control fusion reactions that produce usable energy. So despite 50 years of effort, engineers haven't yet found a practical way to use the "fusion" nuclear reaction.

CONSIDERATIONS (continued)

- The nuclear power industry has made many improvements in the safety and efficiency of its plants. Whether the improvements make nuclear power safe enough is a matter of great controversy.
- In the U.S., nuclear power plant back-up safety systems helped to avoid several nuclear power plant disasters, such as the 1979 near-accident at Three Mile Island in Pennsylvania. Nuclear power advocates point to this as demonstrating the effectiveness of the industry. Others say that these incidents show the dangers that might not be avoided the "next time around."
- The regulatory system in the U.S. also works to prevent accidents from occurring at nuclear power plants. It includes a program that has on-site inspectors at each power plant. It also encourages the power plant operators to identify and correct safety problems. For example, routine examinations of a nuclear facility in Ohio in 2002 found a potentially dangerous situation that caused the Nuclear Regulatory Commission (a U.S. government agency) to order a check of 68 similar nuclear plants.
- "Spent" rods of used nuclear fuel stay radioactive for 500 to 1,000 years and continue to be a health risk for thousands more. (Future generations will be responsible for monitoring the spent fuels we generate.) Until recently these rods were stored at the power plant that produced them. The U.S. government is designing a disposal facility and containers for spent nuclear fuel, deep under the Nevada desert. Experts disagree over whether this facility, and others like it that may be built, are an adequate solution for the protection of public safety and the environment.

DATA FILE: Nuclear

California

- There are two operating nuclear power facilities in California as of 2003 — Diablo Canyon and San Onofre.
- Each of the two nuclear power plants in the state can produce up to 2,200 MW of electricity.

United States

- Nuclear power provides about 20 percent of all electrical energy in the United States, second only to coal. The U.S. has over 100 nuclear power plants — more than any other country.
- The largest nuclear power plant in the U.S. (as of 2003) is the Palo Verde plant in Arizona. It can generate up to 3,921 MW.

Worldwide

- Almost one fifth of the world's electricity is produced from over 400 nuclear power plants.
- Mines in Canada and Australia have supplied over half of the world's supply of uranium for nuclear power.

Data available in 2003

WATT'S MY LINE?

PLANNING OVERVIEW

SUBJECT AREAS:
Physics, Chemistry, Language Arts

TIMING:
Preparation: 30 minutes
Activity: 4-5 45-minute class periods

Summary

Students demonstrate their understanding of how we use energy resources to produce electricity by giving presentations and participating in a unique game of cooperative charades.

Objectives

Students will:

- Identify major energy resources
- Demonstrate how electricity-generating technologies work
- Compare the advantages and disadvantages of various energy resources

Materials

Nine sets of copies of Chapter 2 and Chapter 3 Discussions (including the introductory pages and all of the resource sections of Chapter 3)

Student Handout: "Electric Power Technologies," one for each student, plus one for teacher to cut up prior to playing the charades game

Hat or other container in which to place the slips of paper naming the power technologies

Presentation materials: These will vary, but may include poster board, markers; video equipment, overhead projector and transparencies; computer presentation software such as PowerPoint® (often bundled with Microsoft Office®), Kid Pix®, Hyper Studio®, or Inspiration®.

Optional: Materials for making props such as paper cups, plates, plastic utensils, string, paper, tape, markers, yard sticks, paper clips, small Slinkies®, springs, used paper towel tubes, and so on.

Optional: Other reference materials on energy resources and their uses; Internet access

Making the Link

Many of us don't think much about where our electricity comes from or how much of it we consume (that is, until there's a power outage!). It would be ideal if teachers could take their classes to visit power plants to see how electrical technologies work and to learn firsthand what resources they use for energy. Because such opportunities aren't typically available, this activity brings electrical technologies to "life" right in the classroom.

Many different energy resources and the electrical generation technologies that use them have been discussed in the previous sections. In studying these in more depth, students may come to recognize the value of using more than one energy resource for electricity, as well as the advantages of using more renewable energy resources.

The Activity

PART ONE

1. Before beginning this activity, divide your students into nine study groups. If you have not yet given students copies of the Chapter 2 and Chapter 3 Discussion sections (including the introductory pages and all the resource sections), do so — one set to each group.

2. Tell students that each group will prepare and give a presentation on one of the energy resources and how it is used to generate electricity. Explain that following the presentations the class will be playing a game of cooperative charades pantomiming a technology that makes use of one of these resources.

3. Review the Sidebar from Chapter 2 Discussion, "What is Energy?" and the section "Understanding Electrical Terms." Emphasize that energy can change, or convert, from one kind to another. In the second part of the activity, students will be showing how energy changes from one type to another (such as from mechanical energy to electrical energy. Discuss that the term "watt," is a measurement of power, specifically the rate of heat flow or of the flow of electricity. It is named after James Watt, an inventor whose experiments resulted in significant improvements to the power of steam engines during the Industrial Revolution.

4. Assign an energy resource to each group. Explain that groups will be studying the information about their resources and then preparing a presentation to give to the rest of the class. Show them the materials that you wish them to use for preparing these presentations. If you have extra references (including Internet access), then point these out as well. Remind students that their presentations need to be very clear, so that the class will be adequately prepared to later play the game of charades.

5. Set a deadline and let groups go to work.

6. When the deadline arrives, have groups give their presentations to the rest of the class. Allow for a question and answer period following each presentation, if time allows.

PART TWO

1. Next, prepare to play the game "Watt's My Line?". Cut up one copy of the handout, "Electric Power Technologies" so that you have one type of system on its own slip of paper. Place all of these slips into a hat or other container.

2. Ask your class if anyone has ever played Charades, Pictionary, or Cranium. Ask for examples of how they had to pantomime something for the other players. Next, explain to your class that they will be playing a pantomime energy game, "Watt's My Line?". Students will be trying to guess what "line" of electrical work is being depicted.

3. Explain that if they get a technology for which there are several different types of systems (such as for Solar Thermal, where there are Solar Dish-Engines, Parabolic Troughs, and Central Towers) they get to decide which one specifically they wish to depict.

4. To show their technology, each group needs to use pantomime. All members of a group must participate in their group's role-play. Group members may speak, make sound effects, and use props, but may not use words that reveal the electrical technology being depicted. Show students the materials you have available for props.

   You may wish to give an illustration before students begin preparing their pantomime. For example, to depict a storage hydropower plant, one student might be the water, another the dam and the penstock (channel through which the water falls), another the turbine, another the generator, and still another the tailrace through which the water spills out to the river below the dam. Sound effects (gurgling, whooshing, humming, etc.) and props will enhance the pantomime and add to the fun.

5. Place your class back into their study groups. Now have each group draw a slip from the hat. Remind groups not to reveal what their technology is. Tell them that they may use the Discussion sections and any other reference materials provided to them, as well as what they learned from the student presentations, to figure out how to portray their energy technology in an interactive group charade.

   Some students may have to take on more than one role in the pantomime if the groups are small. You may also wish to arrange for groups to work outside or far enough away from each other (or as homework) so that their work remains a "secret."

6. Set a time limit and let groups go to work. When the time limit is up, have groups act out their "power pantomime." You may wish to have students put away their reference materials, but allow them to keep a copy of the handout, "Electric Power Technologies," to help guess what is being depicted. Before the class begins, decide how the viewers will guess (raising hands, calling out, etc.). Then proceed to play "Watt's My Line?"

Wrap-up

Lead a class discussion comparing the different energy resources and their technologies. Explore the benefits and disadvantages of each resource, referring to the Consideration sections for each resource, if you'd like.

Assessment

Students will have had the opportunity to:

- Work cooperatively in research groups to produce energy resource presentations.
- Portray and guess the various types of electricity-producing technologies in a game of cooperative charades.
- Compare and contrast the different energy resources and their technologies and discuss their use in a responsible energy plan.

ELECTRIC POWER TECHNOLOGIES

Biomass Power Plant

Geothermal Flash Steam Power Plant

Geothermal Dry Steam Power Plant

Geothermal Binary Power Plant

Hydropower: Run-of-River System

Hydropower: Storage (Impoundment) System

Ocean: Marine Current System

Ocean: Wave Energy System

Ocean Thermal Energy Conversion (OTEC)

Solar: Photovoltaic (PV) System

Solar Thermal: Concentrating Solar Power System (CSP)

Wind: Stand-alone Turbine

Wind Farm

Hydrogen Fuel Cell

Fossil Fuel Power Plant

Nuclear Fission Power Plant

CHAPTER 4

ENERGY, HEALTH, AND THE ENVIRONMENT
How energy choices affect our health and the environment

VOCABULARY

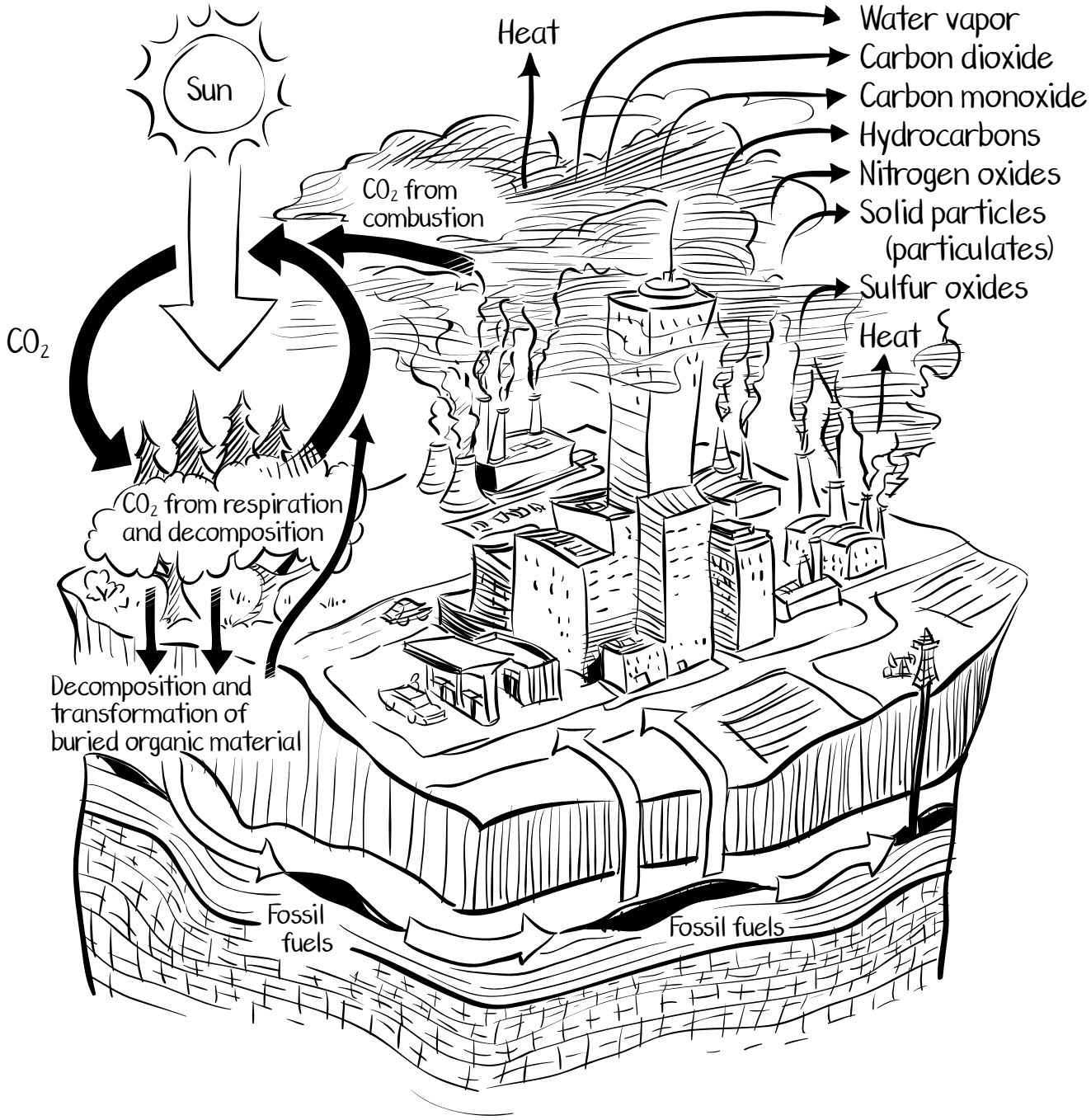
carbon monoxide
carbon sink
conservation
ecosystem
encroach
exempt
greenhouse effect
habitat
nitric acid
nitrogen oxides
old-growth forest
organic decay
ozone
particulates
photochemical smog
sulfur oxides
sulfuric acid
temperate zone
unburned hydrocarbons
wetland

ALL LIVING THINGS NEED CLEAN AIR. They need clean water too, and a temperature range in which they can survive. When the air becomes dirty and polluted, it affects the health of all plants and animals, and it can alter the climate.

Ever since Earth's beginnings, naturally produced pollutants have entered our planet's air from volcanic eruptions, forest fires, dust storms, and pollination. But in the last 200 years, human activities have added greatly to the amount of pollution entering the atmosphere, making it difficult for Earth's natural balancing systems to keep up.

The main cause of excess pollution in our air has been the burning (combustion) of fossil fuels — for industrial processes, transportation, and electricity generation.* Fossil fuel combustion contaminates our air with gases, chemicals, smoke, and ashes, pollutants that are ultimately deposited in our water and soil.

**Generation of electricity and other human activities cause many kinds of pollution, not just air pollution. They also cause land and water pollution. But pollution of our air from traditional power generation is the main concern, and so it is the focus of discussion in this chapter.*



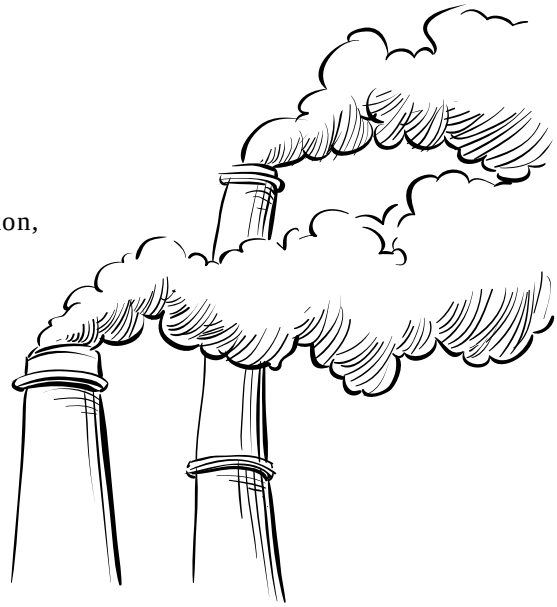
Fossil Fuel Cycle

The fossil-fuel cycle starts with the capture of carbon dioxide by trees, plants, and other vegetation during photosynthesis. Buried organic material goes through chemical changes to form fossil fuels in a process that takes millions of years. The burning of fossil fuels releases heat, water vapor, carbon dioxide, and other air emissions. Some of the carbon dioxide is recaptured by plants, but if there is an excess, much can remain in the atmosphere.

AIR POLLUTION'S HEAVY HITTERS

Pollutant	How Produced	Effects
Carbon dioxide (CO_2)	**In nature:** Forest fires; volcanoes; other natural processes. **By humans:** Burning fossil fuels and biomass.	Excess in the atmosphere is believed to contribute significantly to global climate change, through the greenhouse effect.
Carbon monoxide (CO)	**In nature:** Forest fires; other natural processes. **By humans:** Incomplete burning of carbon in fossil fuels, reduced by pollution controls.	In upper atmosphere, naturally occurring CO is not a health hazard. At ground level, it is highly toxic, even lethal.
Mercury (Hg)	**In nature:** Volcanoes; oceans; soil erosion. **By humans:** Burning of coal and oil; municipal and medical wastes; mining; cement industry.	Toxic in high concentrations; accumulates in soil/water; builds up in fish which, when eaten by humans, causes nerve/liver damage; especially dangerous for fetuses.
Methane (CH_4) (Natural gas is about 94 percent methane)	**In nature:** Wetlands; peat; termites; oceans; wild animal wastes. **By humans:** Cattle/rice farming; natural gas, coal, and biomass production and combustion; landfills; farm animal wastes; human sewage.	Contributes to global climate change. At higher concentrations, displaces air.
Nitrogen oxides (NO_X)	**In nature:** Lightning; organic decay. **By humans:** Burning fossil fuels, especially coal; certain farming practices.	Contribute to formation of photochemical smog, acid precipitation, global climate change.
Ozone (O_3)	**In nature:** In upper atmosphere, occurs naturally; in lower atmosphere, lightning. **By humans:** In lower atmosphere, formed by a reaction involving sunlight and unburned hydrocarbons produced by burning fossil fuels.	In upper atmosphere is necessary to block the sun's harmful ultraviolet rays. In lower atmosphere is a pollutant causing eye, lung, and throat irritation; also degrades rubber and other materials.
Particulates (Very small particles suspended in the air, including smoke, dust, and vapor)	**In nature:** Forest fires; volcanoes; dust. **By humans:** Burning fossil fuels and wastes; construction; mining; certain farming/ranching practices; winter street sanding.	Can directly harm respiratory tracts, cause haze, damage buildings and other materials; may also contribute to global climate change.
Sulfur oxides (SO_X)	**In nature:** Volcanoes, organic decay **By humans:** Burning fossil fuels, especially coal, fuel oil, and diesel	Element of smog that is corrosive and lung-damaging; contributes to "acid precipitation" that damages lakes, forests, and crops.
Unburned hydrocarbons or volatile organic compounds (VOCs) excluding methane	**In nature:** Gas/oil seeps; forest fires; other natural processes. **By humans:** Incomplete burning of fossil fuels; evaporation (fumes) of petroleum fuels, dry cleaning fluids, paints, solvents.	Contribute to formation of photochemical smog.

This chart lists many kinds of air pollution, some caused by nature and some by humans. Much, but not all, of human-caused pollution comes from the burning (or incomplete burning) of fossil fuels.



LOCAL AND REGIONAL AIR POLLUTION

Each of the three main fossil fuels used for electricity generation, coal, natural gas, and oil (petroleum), produces different types of pollutants when burned. Coal puts out the most pollutants: primarily carbon dioxide; particulates such as soot and ash; sulfur and nitrogen gases; unburned hydrocarbons; carbon monoxide; and even a small amount of mercury. Natural gas mainly produces carbon dioxide and nitrogen oxides. Burning oil results in many of the same gases as coal, but not as many of the particulates.

The American Lung Association estimates the cost of air pollution, in terms of medical care and days lost at work, to be billions of dollars annually. Air pollution affects not only our physical health, but also the economic health of business and industry.

Acid Precipitation

Acid precipitation (commonly, but inaccurately, called acid rain) results when sulfur oxides and nitrogen oxides in the air combine with water vapor to form sulfuric and nitric acids. These acids fall back to the earth in many forms, including rain, snow, fog, or even dry particles. Tall smokestacks on fossil-fuel power plants might seem to help local pollution by dispersing it, but they actually end up putting pollutants higher in the atmosphere where winds carry them far from their source. Wherever acid precipitation falls, it damages and destroys crops and plant life on land and in water. It can destroy animal life in these natural habitats.

Photochemical Smog and Regional Haze

There are two main types of smog or haze. Photochemical smog forms when sunlight (the “photo” part) reacts with pollutants such as nitrogen oxides and hydrocarbons in the air. This type of smog (an unsightly brown color) can cause lung damage, aggravate asthma and emphysema symptoms, and harm vegetation.

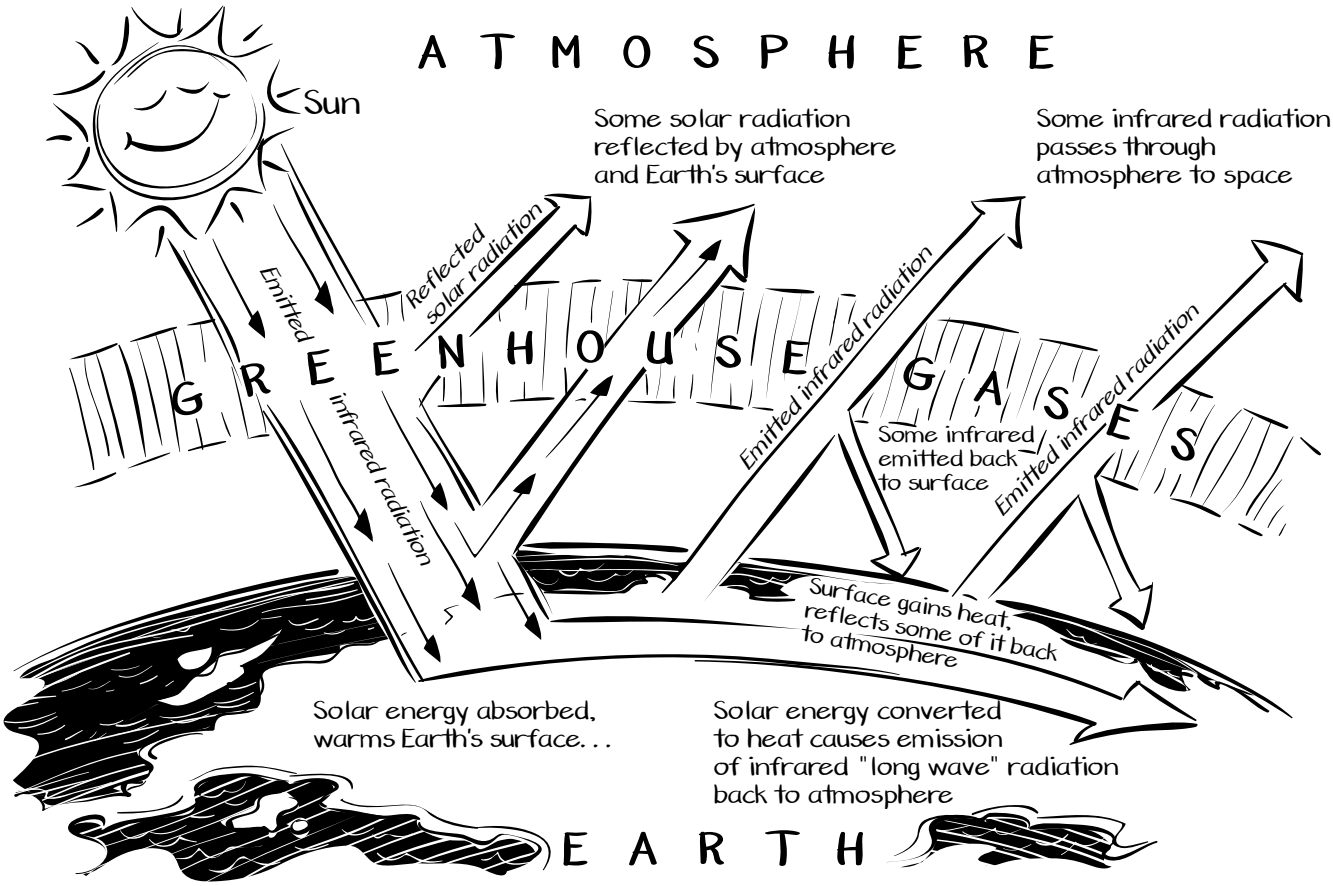
What we call regional haze (from sulfate and nitrate particles) scatters and absorbs sunlight, making a clear day smoggy. Regional haze contributes to lung ailments. It also reduces the number of visitors to some national parks, affecting local economies that rely on tourism.

THE GREENHOUSE EFFECT

Greenhouses are warmed buildings used to grow plants. Solar radiation passes through the glass or plastic roof and walls of a greenhouse to the plant-growing space inside. Some of this solar radiation is reflected back from the surfaces inside the greenhouse in wavelengths that are longer, called infrared (heat) waves. These cannot pass easily through glass, so much of the heat stays inside the building.

The earth's atmosphere acts in a similar fashion. Solar radiation (heat and light) passes through the atmosphere, warming and sustaining life on our globe. Some of the radiation reflects back from the planet's surface. Greenhouse gases (mainly water vapor, carbon dioxide, methane, and ozone) and particulates in the atmosphere absorb some of the reflected heat and emit some of it back to the planet's surface.

Without the greenhouse effect, our planet would be a cold and lifeless place. However, many scientists feel that excess greenhouse gases in the atmosphere are changing Earth's climate, overcoming nature's balancing systems.



The Greenhouse Effect

SOME AIR POLLUTION SOLUTIONS

Improving the Technology of Pollution Control

We can reduce pollution from electric power plants by requiring their operators to install pollution control equipment and to use fuel as efficiently as possible. Such equipment is available, and scientists are always working on ways to improve pollution control equipment and waste disposal methods. It can be expensive to apply new, cleaner technology to existing, sometimes aging, power plants. To ensure that pollution controls are implemented, local and federal regulations set standards for air quality (although some older power plants are exempt from these regulations).

Using Clean Energy Sources

Another solution to the air pollution problem is to create less pollution in the first place by using clean energy sources. Many of the cleanest are renewable energy sources (often referred to as "green" because they are environmentally friendly). Renewable energy sources do not produce many of the air pollutants associated with traditional fossil fuel-burning power plants.* For example, most renewable energy sources produce very little or no carbon dioxide as they generate electricity.

Conserving Energy

A very important way to help avoid air pollution is by conserving (using less) energy. There are lots of ways we can do this. (See Chapter 5, pages 155-157.)

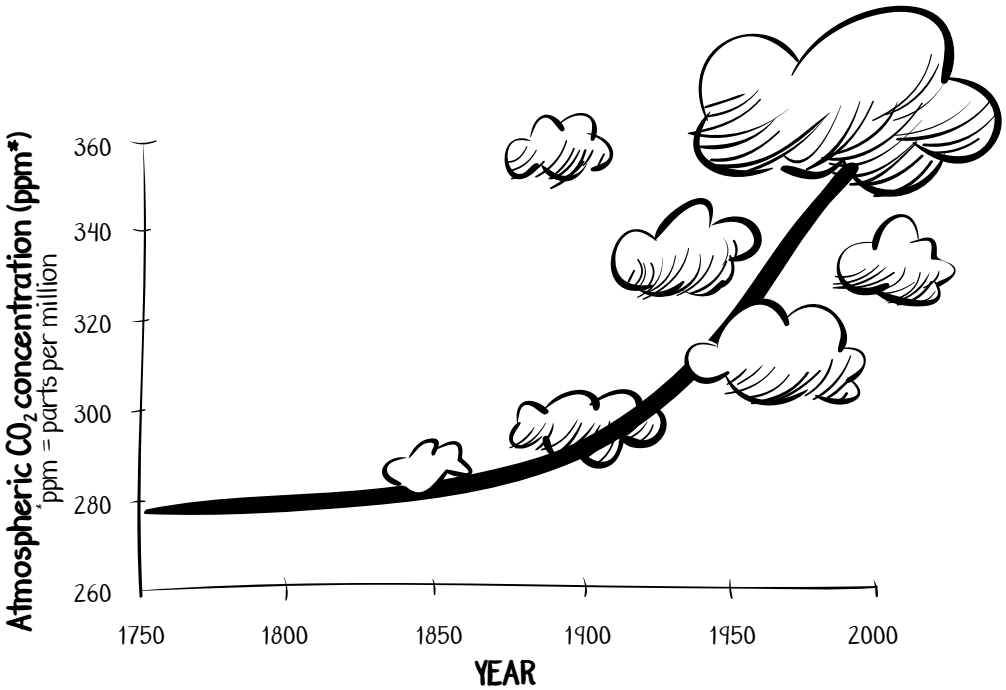
GLOBAL CLIMATE CHANGE

Our planet's climate has changed many times. Since the last ice age (about 18,000 years ago) it has been gradually warming. In the last 200 years the earth's climate has warmed up at a much faster rate than in earlier years. Some say that this change is part of a natural series of warming and cooling cycles. Many others think that humans are responsible for the most recent climate changes, and that the long-range effects could be very harmful.

**In California alone, the use of renewable energy has kept three million tons of carbon dioxide (that would have come from fossil fuel plants) from being emitted every year. Renewable energy power plants also have prevented the emission of other hazardous air pollutants, including about 17,000 tons of nitrogen oxides and 14,000 tons of sulfur dioxides each year.*

One thing most people agree upon is that the earth's atmosphere has been warming up, especially since the late 1800s. The earth's average surface temperature set new record highs in recent years. In fact, according to the U.S. National Oceanic and Atmospheric Administration (NOAA), the 1990s were the warmest years on record. Temperatures of the uppermost level of the sea have also been rising in many parts of the globe. The Intergovernmental Panel on Climate Change (an international group that assesses scientific climate data) says that this century will experience even greater warming if certain human activities are not changed.

The main cause of the current warming trend is thought to be an increase of carbon dioxide and other greenhouse gases (such as methane) in the atmosphere. Experts agree that the burning of fossil fuels for transportation and electricity production is the primary cause. The amount of carbon dioxide in the atmosphere has risen dramatically since the 1850s, when we began to burn fossil fuels in larger and larger quantities. The United States contributes the greatest share of carbon dioxide to the atmosphere each year — one fourth of all the CO_2 produced in the world — though it has only 4 percent of the world's population.



The rise of carbon dioxide levels in the atmosphere

The Potential Effects of Climate Change

In recent years, some natural worldwide patterns and systems have been changing in a dramatic way, enough to attract the attention of researchers. This notable shift is thought by many to be the result of global warming.

For example, along the Antarctic Peninsula, five major ice shelves are starting to break up, yielding some of the largest icebergs in recorded history. In the Arctic, sea ice covers 15 percent less of the ocean than it did 20 years ago, and the ice has thinned from an average of ten feet to less than six. Greenland's ice cap, the second largest ice sheet in the world, is melting at a rate of 12 cubic miles each year. In Alaska, glaciers are retreating.

As ice sheets and glaciers melt, they add water to the oceans and as ocean waters warm, they also expand. Already, encroaching seas are eroding our coastlines. In some areas, delicate marsh systems are being destroyed by excess salt from rising seawater. In fact, global sea levels rose an average of 10 times faster in the twentieth century than any time known previously. Even a very small rise can affect millions of miles of shoreline and flood coastal cities. Many people will be affected by this, since much of the world's population lives along the shorelines.

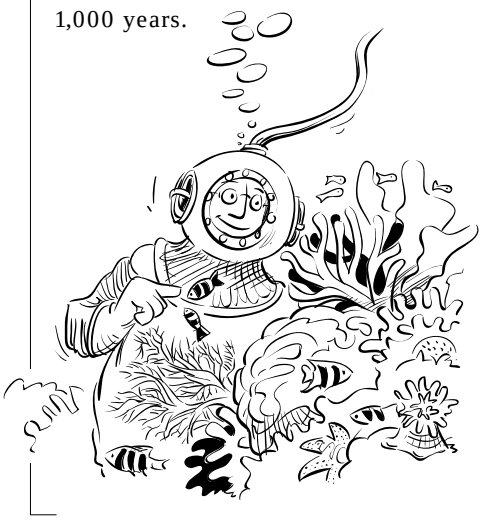
Normal weather patterns will probably be altered by global climate change. Rainfall patterns could change, drought and flooding could be more common, tropical storms could become more severe, and ocean currents and wind patterns could alter. Places that once were warm may begin cooling, and cooler places may warm up. This is why experts prefer the term global climate change to global warming.

Already, habitats worldwide are reacting to changes in climate and weather patterns. Plant and animal ranges are shifting toward cooler latitudes and higher altitudes. Fragile ecosystems, such as those of coral reefs, are also seriously affected. The human habitat may also be affected. Potential impacts are expected to include heatstroke and other health problems, along with economic concerns. These could range from agricultural losses and property damage to decreased tourism. A major economic effect of changing climate conditions is the increased need for energy to respond to hotter- or colder-than-normal temperatures.

RAINFORESTS OF THE SEA

Around the globe, higher sea surface temperatures have been affecting almost all species of corals — sea animals whose hard skeletons eventually form a reef. Coral reefs provide an extensive habitat for varied ocean life, earning them their nickname, "rainforests of the sea." They provide resources for fisheries, medicines, and other products. Many economies rely on them as a draw for tourism. Coral reefs also protect entire island nations from wave and tidal erosion.

Corals need warm waters, but they already live at the upper edge of their temperature tolerance. Therefore, higher-than-normal sea temperatures damage corals, causing bleaching and death. Already, 27 percent of the world's once-thriving coral reefs are now skeletal grave sites. At current rates, more than two-thirds of the world's coral reefs could be destroyed within the next 30 years, including ancient reefs that have existed for over 1,000 years.



Storing Carbon

Our planet has a natural carbon cycle through which carbon is both produced and stored. Carbon is stored during this cycle in carbon "sinks." Two of the primary sinks are plants and the oceans.

Plants use carbon during photosynthesis, removing it from the atmosphere. The best sinks are old-growth forests, which have many mature trees and other vegetation, as well as a rich and varied forest floor litter (duff). This litter also holds carbon, especially in temperate regions. All over the globe, old-growth forests are disappearing at an alarming rate. In the United States, most of the old-growth forests are already logged. Tropical rainforests, with their rapid and prolific plant growth, also play a critical role in the carbon cycle, which is being further disrupted by the burning of these forests worldwide. In Africa, the Sahara Desert is already expanding onto once-forested areas.

The oceans are the world's largest carbon sinks. Carbon dioxide dissolves in the water. Tiny ocean-dwelling organisms use carbon dioxide to build their shells or skeletons, and so take the carbon with them when they die and fall to the ocean floor. Limestone, a sedimentary rock (primarily calcium carbonate), is formed on ocean floors from the shells and skeletons of these organisms. Some people feel that our vast oceans provide an adequate sink for the excess carbon humans produce. However, there is only so much surface water in direct contact with air, and deep ocean circulation is a slow process. We are increasing the carbon dioxide, but not the oceans' ability to absorb it.

GLOBAL CLIMATE CHANGE SOLUTIONS

Many solutions have been proposed to avoid long-term global climate change (see Chapter 5, "Energy Policy and Management"), including the following:

- Use clean energy from renewable energy sources, since they do not produce carbon dioxide. (This includes biomass, because carbon is absorbed while the biomass is growing, which offsets the release of carbon when the biomass is burned.)
- Make the most of the fossil fuels we do use by practicing conservation and energy efficiency. The less we use, the less carbon dioxide and other greenhouse gases are produced.

- Increase the protection of all remaining old-growth forests and tropical rainforests.
- Practice "restoration ecology," which includes revegetating areas with the plants and trees that originally grew in a certain locale before it was disturbed by human activity.
- Research other ways (besides natural processes) to capture more carbon dioxide in the future. Some experimental ideas include injecting it into oil or coal fields and using chemical methods to bind it with other substances.
- Enforce air pollution standards. Policies that support these and other approaches to reducing carbon dioxide emissions are beginning to become more widespread. For instance, in 2002 California enacted a law requiring that 20 percent of its electricity must come from renewable energy (not counting large hydro) by the year 2017. Even some private industries, including several fossil fuel industries, have begun to reduce their carbon dioxide emissions and invest in renewable energy sources. Insurance companies, fearing the huge claims that might arise from climate change, are also speaking up.
- Over 100 countries have signed greenhouse gas reduction agreements, even though there still exists an ongoing debate about the causes of global climate change and its effects. Recent revisions in government policy and in corporate attitudes may indicate that environmental issues such as these will be given more attention, both now and in the future.
- Several county and state governments as well as private conservation organizations are purchasing large and small tracts of forest, woodlands, and grasslands so they will be left in their natural state.

GRIME SCENE INVESTIGATION

PLANNING OVERVIEW

SUBJECT AREAS:
Language Arts, Ecology, Environmental Science, Government, Math

TIMING:
Preparation: 30 minutes
Activity: 3-5 45-minute class periods; some students will spend extra time outside of class

Summary

Students form detective agencies to gather evidence regarding air pollution in their own community.

Objectives

Students will:

- Identify particulate matter as an air pollutant.
- Identify energy sources that don't contribute to particulate (and other) air pollution.
- Design and build particulate matter collection devices.
- Develop hypotheses predicting the amount of particulate deposition found at each experiment site.
- Measure the rate at which different sources deposit particulate matter in a given locale.
- Identify possible sources of deposited particulate matter in a specific area.
- Prepare a class master list of experiment procedures and results.
- Prepare experiment write-ups, using the scientific method.
- Draw conclusions regarding particulate pollution in a certain area.
- Prepare summary reports based on the entire class's findings.
- Optional: Conduct extension activities regarding other types of air pollution.

Materials

For warm-up demonstration:

Small mirror

Paraffin wax candle and candleholder

Matches

Tongs and oven mitt

For activity, per group:

Copy of "Air Pollution's Heavy Hitters," page 137

Optional: Copy of Scientific Method Form, page 185

Particulate Chart, page 152

Wax pencil or other means to mark glass slides

Glass microscope slides (minimum of two per group)

Petroleum jelly or double-sided tape

Clean jar lids and plastic wrap or petri dishes in which to place slides

Maps of your city or area

Information on industries in your area from the chamber of commerce (optional)

Entire class:

Microscopes, handheld microscopes, or hand lenses. (Each detective group should examine the particle samples under the same magnification, or use the same type of magnifying lenses.)

Other materials for devices to protect particulate matter collection slides, including sturdy dowels or other posts, empty coffee cans, cardboard boxes, aluminum pie plates, foil, Superglue, nails/hammer, and so forth

Optional: Other materials for extension activities (see Extensions, page 151)

Making the Link

Sometimes it's hard for students (and even adults!) to picture that the air around them, while invisible, is actually full of many different substances, an excess of which may be bad for their health and for the environment.

This may be especially true for students who don't live in an obviously hazy or smoggy urban area. These students may be surprised to find that their air contains contaminants (such as those from farming, logging, or a factory miles away, whose pollutants are carried by wind). Those who live in congested, urban areas will more easily recognize the effects of smog, smoke, or other pollutants.

While it is difficult to measure the gases in the air with ordinary classroom or science lab equipment, we can measure some of the materials released into the air from human activities. These released materials are tiny solid and liquid particles called particulate matter that become suspended in the air.

It is normal to have some particulates in the air (as from volcanic eruptions, forest fires, dust, and pollens). In fact, without some airborne particles, we wouldn't have rain. However, humans have been producing an excessive amount of particulates from combustion of fuels, contributing to poor air quality. As discussed in "Energy and the Environment," the reaction that occurs when we burn fuels for energy is one that releases different types of gases and small solid particles. Certain other industries also put extra substances into the air.

After conducting this activity students may have a heightened sense of what is in the air they breathe every day. The study may also provide motivation for action regarding what they learn. (An action plan activity is included in Chapter 5, "Energy Policy and Management.")

Teaching Notes

Acting as detective teams, students will attempt to identify possible sources of airborne particulate matter by collecting samples. An increased rate of deposit in the vicinity of, for example, a local factory or fossil-fuel power plant may point to it as a possible source of particulate pollution. Students can then conduct further research, such as contacting the Environmental Protection Agency, your local air quality board, or other organizations that may have information to substantiate their hypotheses.

If time and resources are limited, consider conducting the Adaptation or one of the Extension investigations as an alternative to this activity. You may also choose to do a data exchange with other classes to share and compare your findings.

Warm-up

Use this quick demonstration to show how byproducts are often created when we burn something. Light the candle. Wearing an oven mitt, grasp the mirror at one corner with the tongs. Hold it over (not in) the candle flame for about five seconds. Take the mirror away and show it to your students. They should see a dark sooty residue on the mirror.

Ask what the sooty residue might be. Guide the discussion to the idea that whenever something is burned, a chemical reaction called combustion occurs. Combustion refers to the chemical combination of certain materials with oxygen and the release of energy.

When we burn a paraffin candle, heat, light, and some byproducts are given off. (The byproducts occur because the combustion reaction is incomplete. With complete combustion the only products, besides energy, are water and carbon dioxide. Complete combustion is rare and occurs only under specially controlled circumstances.) These byproducts show up as the residue on the mirror. In large quantities they are considered pollutants.

If any students have been camping, they can also relate this demonstration to the soot they see inside the lantern of a used kerosene lamp. Kerosene is a form of fossil fuel, as is the paraffin commonly used to make candles.

Explain to students that they will be investigating industries that may add to particulate pollution in their area. They will also identify industries that may not contribute to this type of pollution.

The Activity

STAGE ONE

1. Go over the background information in the "Energy and the Environment" Discussion section with your students. Review the chart on page 137, (Air Pollution's Heavy Hitters). Ensure that students have a clear understanding of "particulate matter."

2. Post a map of your community and, if possible, display literature from your chamber of commerce on local industries. (For this activity, the term "industries" includes any place of work, including retail businesses, service industries, manufacturing firms, repair firms, high-tech companies, home offices, and academic institutions.)

   Use the map and the business literature, along with your class's general knowledge of the community, to brainstorm a list of the possible industry sources of particulates in your locale. Make another list of industries that students think might generate little or no particulate pollution. One of these sites could certainly be your school.

3. Next, ask students to identify the industries to which they personally have safe and easy access. This could include places where their parents, other relatives, or friends work or attend classes. Narrow these down to those industries that seem the most likely to grant permission to set up experiment stations.

   As a class, compare each of these places to the lists made in Step 2. From this comparison, make a list of six to eight places (depending on how many groups you have) to contact. Remember that some of these should be suspected generators of particulate matter and others should not.

4. As a class, compose and send a letter (or e-mail) to the general manager of each of these industries or businesses, explaining the purpose of the project and asking permission for specific students (or their adult contact) to set up an experiment station on the firm's premises. Be sure to mention the connection — parent, neighbor, etc. — that the student has at that industry. A copy of this letter should be sent to each student who has a connection, as well as to the connections themselves.

   Keep your lists from Step 2 handy, so that your class can select another potential site if any of your inquiries results in a negative answer.

5. While waiting for answers to the inquiries, divide your class into teams.

   It is optimal to have at least six teams, even if there are only two or three students on a team. The more research sites, the better. Explain that each team is to form a "detective agency." Their assignment: to identify some industries in your area that may be particulate matter polluters, as well as some that may not be.

   You might allow time for each team to develop a name for its agency, as well as a pseudonym for each detective participant.

The student who has the connection at a potential experiment station site could be the team leader.

If some of the teams do not have a specific connection, or if one of the selected industries denies the request, assist these groups in selecting and contacting another potential experiment station from the lists developed in Step 2. As an alternate, use public property, skipping the permission process.

6. Make a master list to organize and collect experiment designs and results. When your initial inquiries are answered in the affirmative, place in the far-left column the names of the industries that have agreed to participate. Write the student team names and team members in the next column. Highlight the team member with the industry connection. Allow for other columns to show information such as the number of slides placed and the particulate count for each. (See example below.)

Assist students in following up with industries that don't respond to your first inquiry.

7. As a class, decide how many slides will be left at each location. The more slides, the more accurate the data. Make sure that each team plans to leave the same number of slides.

8. Show the class the materials you have available for each group to make protective set-ups to safeguard their collection slides for one week. Have each group draw up a plan that will use these materials, plus any others they think of that are reasonable to acquire (e.g., Sam's mom is the manager of a shipping company and always brings home discarded, but usable, packing materials).

You may wish to give students an example of a protective device: An uncovered empty coffee can could be attached, using hammer and nails, to the top of a pole inserted into the ground. The collection slides could be placed inside the can to prevent their being disturbed.

Once completed, have each group present their plans to the rest of the class. After discussing the merits of each, have the class vote on the best (and most feasible) plan. Then all the groups will construct the same protective devices. Groups might wish to make a separate protective set-up for each different slide. If so, all groups should do so.

Make arrangements to acquire any additional materials and make a copy of the chosen plan for each group. Allow time for groups to construct their devices.

10. Assist students in making arrangements to take these devices to the selected experiment sites. Remind students that once the collection devices are set up, the covers are removed.

Experiment Site	Adult Contact	Team	Number of Slides Placed	Particulate Count

11. Pass out a copy of the Particulate Chart, page 152, to each group and explain that when they retrieve their devices they will be comparing the amount of particulates left on their collectors to the amounts on the chart. Explain that the chart shows an approximate amount of particles per square inch (which can be recalculated in centimeters).

    For the write-up of this experiment, you can have students use the Scientific Method Form on page 185 of the Appendix or have them use one of your own. Pass out copies to your students. Review your expectations for each category.

    Explain that, though they will be working in groups, each student will fill out his or her own write-up.

    Have each student develop a hypothesis predicting how much particulate matter he or she thinks will be deposited at the team's site, based on an average taken from all of their group's collection devices.

STAGE TWO

1. After seven days, the collection devices are retrieved and brought to class. Ask students to cover them, taking care that nothing touches the slides' surfaces.

2. Each team then carefully examines its slides with a microscope or hand lens. Ask students to make a list of what they think the particles may be and to draw what they see. Have them compare their drawings to the Particulate Chart on page 152 and estimate the amount of particulate matter collected on each slide. Have them calculate the average number of particles deposited at their site. Explain that the rate of deposit is this amount per the time period (in this case, seven days).

3. Have student groups finish the write-up of their findings using their scientific method form. For the Research portion, students can cite the Chapter 4 and your classroom discussion (You may wish to have students do other research as well.) For the Procedure section, you can ask them to briefly summarize the steps they took. For the Data section, students should identify their test site and list the count of particulates for each slide. You may also wish to have them draw a picture of what they see on each slide. Then the average of all slides should be listed. For the Conclusion, each student will be revisiting his or her Hypothesis, saying whether it was correct or not, and explaining why.

Wrap-up

Have each team report its findings to the class, using their write-ups. Record the results on the master list. As a class, identify the experiment site that produced the most particulates and the possible types of particulates found. Discuss how this compared to their original suspicions. What results did they find for the suspected nonpolluters? Were there any surprises? Where could particulate matter be coming from at what was thought to be a clean site?

Ask each group to write a brief summary of the entire class's findings, drawing conclusions based on all the evidence gathered.

Each group should also write a thank-you letter to the establishment that allowed an experiment to be set up on its premises.

As a class, talk about how more extensive tests could be conducted to determine if the suspect is the actual source of the pollution. Additionally, your class may wish to contact your local air quality board or the U.S. Environmental Protection Agency (EPA) to see if they have data that might corroborate student findings.

Assessment

Students will have had the opportunity to:

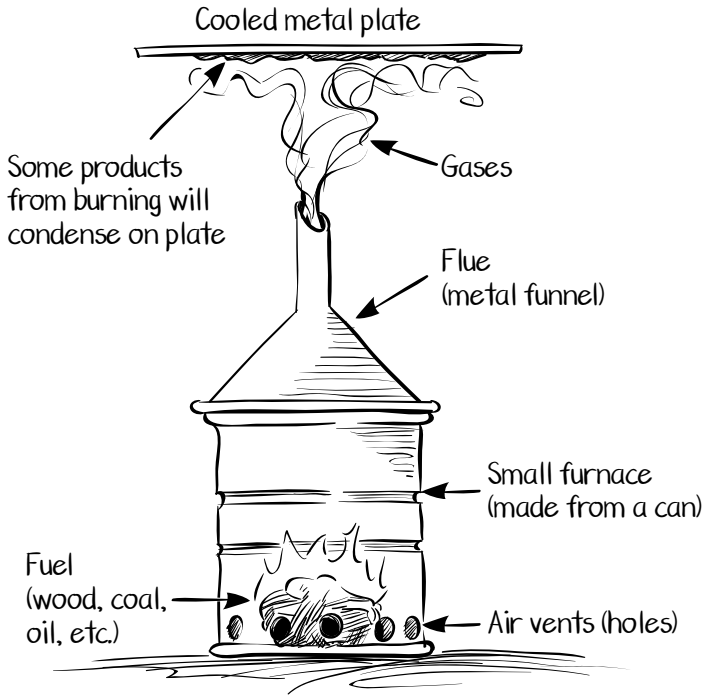
- Select experiment sites and ask permission to test for particulate matter pollution.
- Develop hypotheses predicting the amount of particulates deposited at various test sites.
- Design and build particulate matter collection devices.
- Measure the rate at which particulate matter is deposited in a specific locale.
- Develop a class master list of experiment procedures and results.
- Compose experiment write-ups using the standard scientific method.
- Prepare summary reports.

Adaptation

If your students aren't able to go into the field to collect samples, you may wish to simulate the conditions that produce particulates. Under controlled circumstances, burn wood, other dried biomass, paraffin candles, charcoal, or use a kerosene lantern and compare the particles gathered to those collected in a cleaner location in your room or lab.

In this case, you may wish to make a simple furnace using an inverted metal funnel on top of an empty can. Use a cooled metal plate or mirror as your collection device. Set the furnace on a noncombustible surface and provide adequate ventilation. Follow all safety rules for working around heat and flames. Wear goggles and have a bucket of sand, a fire extinguisher, or a fire blanket handy. Place the charcoal, wood, candle, or dried biomass directly in the can, ignite it, and use tongs and an oven mitt to hold the cooled metal plate or mirror over a funnel to collect particles. The kerosene lantern can be lighted and the collection device held directly over its chimney.

You may be able to examine the particulates using a hand lens or handheld microscope and compare them to the Particulate Chart on page 152. Relate your findings to possible sources of particulates in your community.



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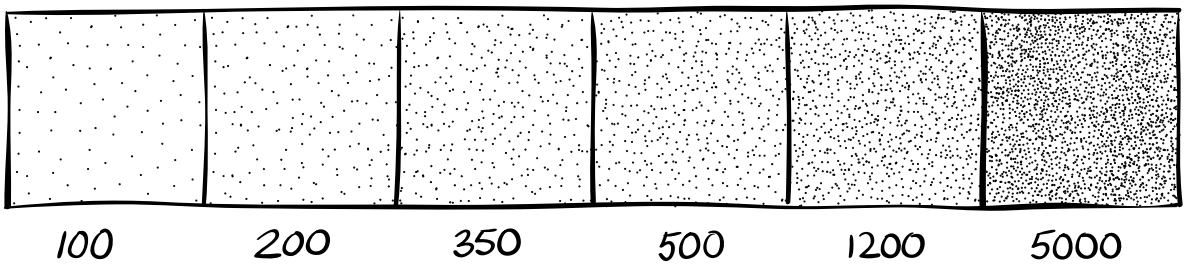
Extensions

- Research the feasibility of an electric utility company that uses fossil fuels (or other heavy polluter such as a charcoal production plant) switching to cleaner energy sources that don't contribute to particulate matter pollution. If one of your test sites was a heavy particulate polluter, discuss diplomatic ways to share your findings with the owners, along with suggestions for alternatives.
- Discuss the idea that some of the evidence may have blown in from another source. Consider ways to verify that the particles collected actually came from the source identified.
- Contact the EPA or local air quality board for information about how scientists determine and quantify levels of various air pollutants.
- Learn more about how industries try to control air pollution.
- If your specific situation allows, plan a day when everyone in your class, or even in the entire school, gets to school without burning fossil fuels. Suggest that students (as well as teachers and staff!) walk or ride a non-fossil fuel-powered vehicle (bike, electric scooter, skateboard, or an electric train or bus). For safety, and depending on the age of your students, encourage students to travel with a buddy, in small groups, or with an adult.
- Devise demonstrations to show relationships between the greenhouse effect and global warming, using simple materials such as a small clear box, two thermometers, and an incandescent lamp or sunlamp. Bring the two thermometers to the same temperature by placing them under the lamp for a few minutes. Place one thermometer under the clear covered container and the other in the open, both under the lamp. List the beginning temperature, then the temperature of each thermometer for every minute thereafter.

  Make a chart or graph of the results. Relate findings to information in the previous section on global warming. Note: Explain to students that other factors also affect the temperature readings inside and outside a greenhouse. The warming inside a greenhouse also results from the isolation of the inside air from the outside world, so the heat cannot escape. Additionally, the outside thermometer is being air cooled, while the inside one is not.) Even so, this demonstration is a fun and simple way to bring a big concept down to classroom size.
- Explore the effects of a household acid on ordinary materials, and compare them to the effects of acid precipitation. Obtain things to test (such as hard-boiled eggs, leaves, chicken bones), two clean glass jars, water, and vinegar. Place the same amount of a test item in each jar. Cover one with water and the other with the same amount of vinegar. Label the jars; cover and leave for several hours or days. Check at regular intervals and make notes of your observations. Try testing other items. Relate your findings to what you have learned about acid precipitation.

GRIME SCENE INVESTIGATION

PARTICULATE CHART



Number of particles per square inch

CHAPTER 5

ENERGY POLICY AND MANAGEMENT
How energy policies affect our lives

VOCABULARY

active solar
blackout (brownout)
Clean Air Act
direct use geothermal
disclosure
distributed generation
ecological
energy efficiency
"green" pricing
incandescent light bulb
indirect (hidden) costs
net metering
passive solar
peak load
policy
rebate
Renewable Portfolio Standards
system efficiency
U.S. Environmental Protection Agency (EPA)
true-cost pricing

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

WHEN IT COMES TO ENERGY ISSUES, you can make your mark — whether you are a sixth grade student or the president of a country. We can all start making a difference right now at home, at school, and at work. If five million of us turned off just one unneeded light all at the same time, we would reduce the demand for electricity by about 500 MW. This is the size of an average power plant. And during the summer, if only one family or small business adjusted its air conditioning thermostat up by 3°F or about 1°C, they would keep about 470 pounds (213 kilograms) of carbon dioxide from being emitted into the air every year. Each individual counts when it comes to energy use.

In many ways, we are all connected to each other and to the environment in which we live. Our actions affect our own quality of life and the lives of others. This means that we can and should think about what is important to us and to others. This thinking will help guide the decisions we make and the actions we take.

ENERGY POLICIES: THINKING ABOUT WHAT'S IMPORTANT TO US

A policy reflects values, or what people think is most important to them. Policies provide guidelines that shape decisions and actions. All governments, federal, state and local, have policies that show what they think is important. Many businesses and other organizations also have policies to govern their operations. Families have policies as well.

Many individuals, businesses, and governments have policies specifically about energy. Energy policies have a direct impact on our daily lives. They affect how energy is produced and used, which in turn affects public health, the environment, the economy of a region, the security of a nation, and the energy choices of future generations.

PUTTING POLICIES INTO ACTION

Once we establish an energy policy, we can create a list of specific things we will do to put these ideas into action. This course of action is an energy management plan — the specific ways we will use our energy.

Your school, for example, can develop its own energy policy. As a group, you and your schoolmates might decide that you will conserve (use less) energy because you feel that it's important not to waste resources. You might also wish to have some of your electricity come from renewable resources because you've learned they are better for the environment, or you might want to save money on energy bills so you can spend it for classroom computer equipment.

ECOLOGICAL FOOTPRINTS

When we walk on a beach or in the snow we leave footprints. Less visible, but much more important, are the ecological footprints we leave when our activities alter the environment or result in the overuse of our natural resources. An ecological footprint is a measure of how much of nature's resources we use to sustain ourselves. We all have footprints; however, some are much bigger than others.

Our footprints grow as the economy, the world's population, and our use of natural resources grow. They also expand based on our need for places to absorb waste and pollution. Sometimes the resources we use are renewable — like the trees that supply the wood for building houses or for biomass energy. In other cases — for instance, the consumption of oil — the resources decline with use. Either way, our footprints may become permanent if we exceed nature's ability to regenerate itself.

Once your class or your school has decided on its energy policy, you need to decide how to go about putting it into action. This is your management plan, or set of strategies. In the following sections you will find examples of energy management strategies, some of which your school or local civic government could pursue.

CONSERVING ENERGY AND INCREASING EFFICIENCY: EVERYONE CAN MAKE A DIFFERENCE

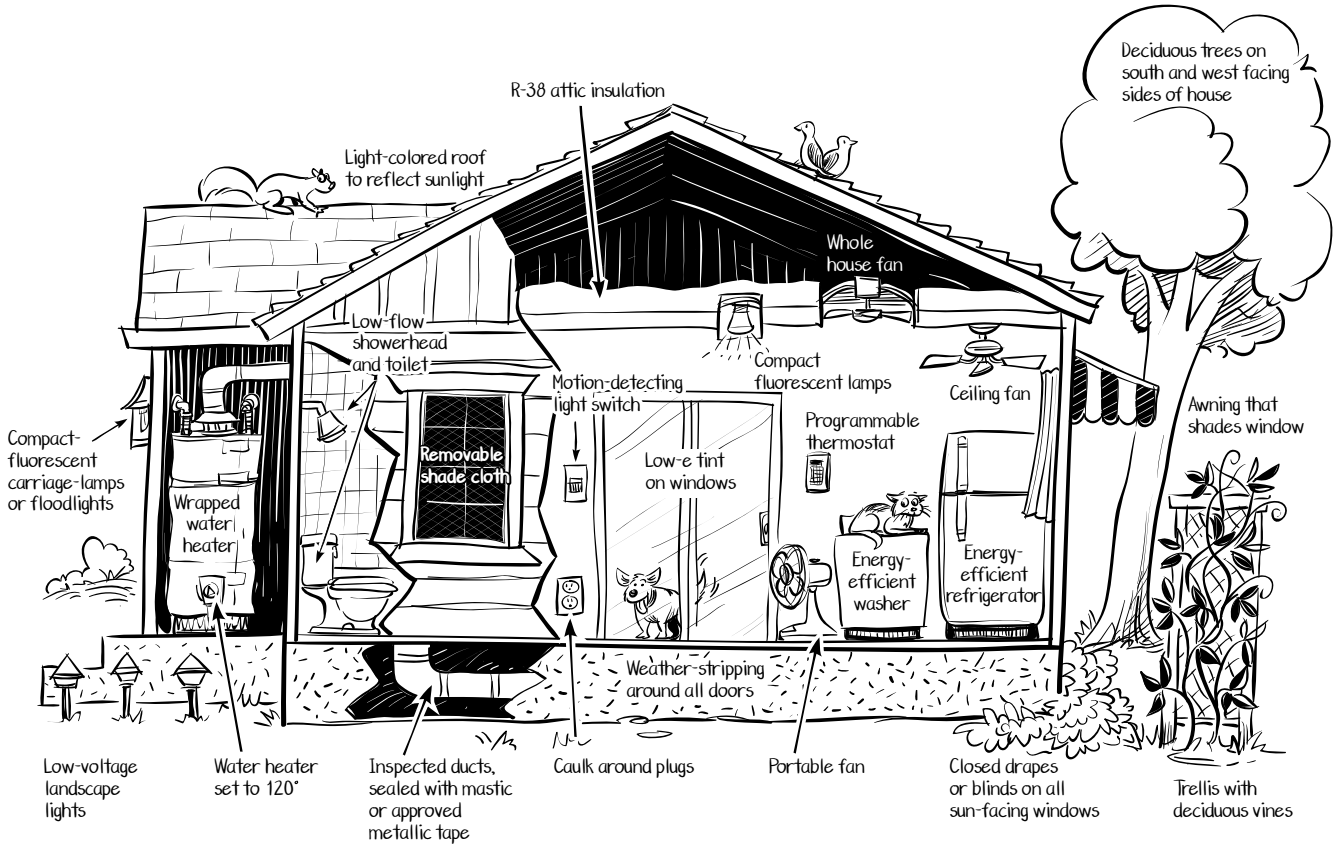
We often hear about saving, or conserving, energy. This doesn't mean not to use energy. It means not to waste energy. There are several important reasons not to waste energy. One is that, since much of our electricity is produced using nonrenewable fossil fuel resources, we want to make the best use of the fossil fuels we have left. Another just as important reason is that the less fossil fuel we use, the less pollution we produce.

The biggest uses of energy in an average American home are for heating and cooling. These represent about 44 percent of energy used. Refrigerators alone consume almost 10 percent, and lighting, cooking, and other appliances operate on approximately 33 percent. Water heaters use up most of the rest. This makes the home a good place to start conserving energy. Buying appliances that are energy efficient is one way to reduce energy waste. (Perhaps it is time to replace that old energy-guzzling refrigerator.) However, there are many other low- or no-cost energy savers. These include turning up your thermostat several degrees in summer and down a few notches in winter; changing furnace air filters frequently; using shades or curtains to block the sun in summer; using compact fluorescent light bulbs; turning off lights, TVs, stereos, and computers when you aren't using them; and installing insulation in your attic and walls.

One neat energy-saving solution is to plant deciduous trees — trees that lose their leaves in winter. If you plant them along the south- and west-facing sides of your house (or ask your building manager or owner to consider doing so), you will have shade on those hot sides of your house in summer. In the winter, with the leaves gone, sun can reach through the bare branches to warm your house.

PEOPLE POWER

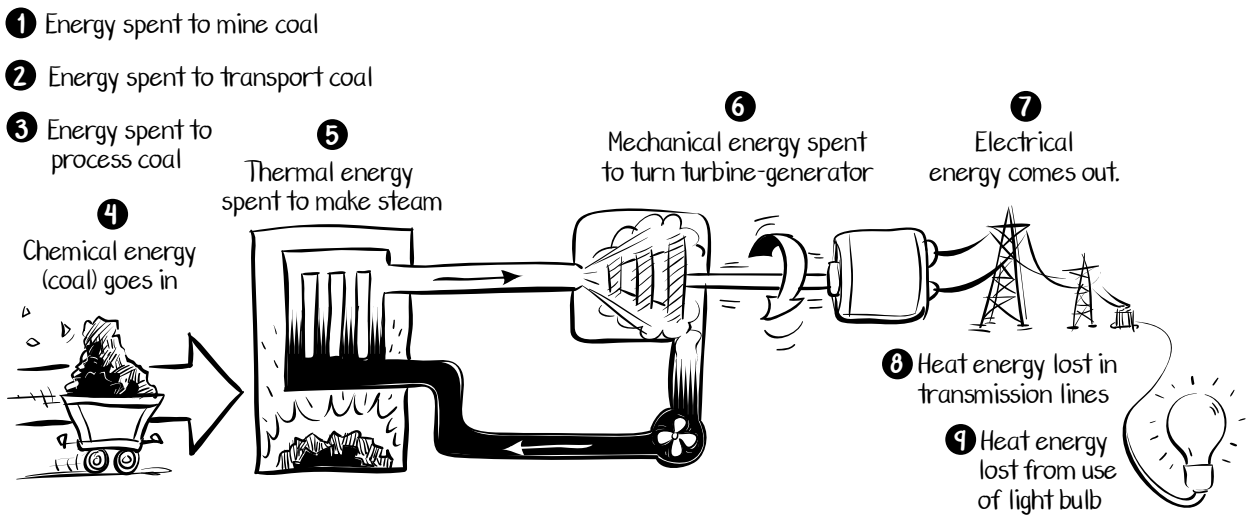
The people of Princeton, Massachusetts, have demonstrated more than once that ordinary citizens can make a difference in the quality of life of their community. In the mid-1980s, in order to meet an increasing demand for electricity, their local utility proposed buying electricity from a nearby nuclear power plant. Princeton residents voted instead to build their own wind farm, which they supported with a bond measure. The farm's eight wind turbines were installed on a windy ridge of Mount Wachusett in 1984. Then, in 2003, Princeton residents once again spoke in favor of renewable energy. In another election they approved replacing the eight older, less-efficient wind farm turbines with two tall, sleek, 1.5-megawatt turbines. In spite of some concerns about the "look" of the taller turbines, the majority of Princeton voters were proud to produce their own clean electricity from a local renewable resource.



Home Energy Conservation
Everyone's home can save energy.

Permission given from Sunset Publishing Corporation to adapt graphic from *Smart Water and Energy Use in the West*

WHAT'S THE BIG DEAL WITH ENERGY EFFICIENCY?

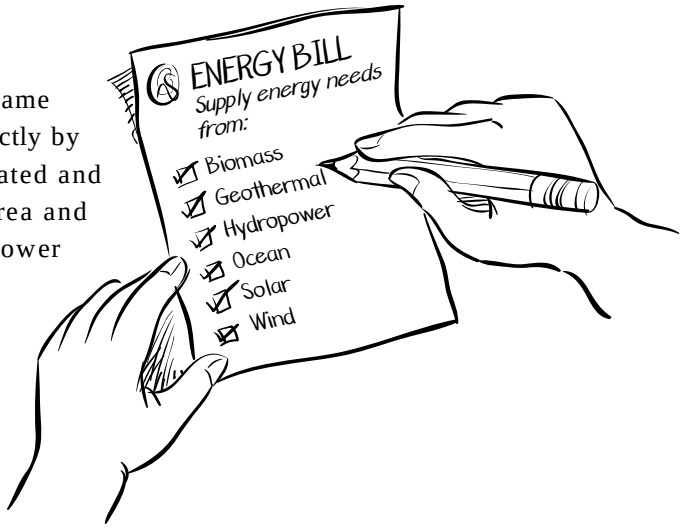


Energy efficiency is never 100 percent.

Energy efficiency means making the most out of the energy we use. When a device performs work for us, some of the energy is lost (wasted) as heat. Some things waste more energy than others. In a standard, incandescent electric light bulb (the kind many of us have used at home for years) only 5 percent of the energy entering the bulb is converted to light! Most of the energy is lost as waste heat from the filament that glows to produce the light. Older models of refrigerators, gasoline engines, and steam power turbines also waste a great deal of energy. Newer models are designed to waste less, so they are considered more energy efficient.

An energy system — such as a power plant — can also be thought of in terms of efficiency. At each step in such a system — from creation to use — some energy is lost, mostly as heat. Say, for example, we light that incandescent light bulb with electricity from a traditional coal-fired power plant. During the many steps required to make electricity at such a plant (mining, transporting, processing, burning, spinning the turbine and waste disposal), about 65 percent of the coal's energy is lost. Next, about 10 percent more of the remaining 35 percent is lost as heat when the electricity moves along transmission lines. Then the electricity is used to light our inefficient light bulb. That's a lot of wasted energy! Luckily, many of our renewable energy technologies use more energy efficient systems.

POLICY FOR POWER PRODUCERS



Before the mid-1970s, most of our energy came from huge utilities that were regulated directly by government agencies. These utilities generated and provided all electrical services to a given area and they were the only ones allowed to build power plants. There was no competition. When our imported oil supplies were threatened in the 1970s, Congress wanted to encourage the development of new energy sources and greater energy efficiency, and businesses that consumed a lot of energy also began demanding more choice in power providers.

Therefore Federal laws were passed in 1978 requiring certain utilities to use electricity from independent producers. The energy market was opened up for these independent power companies, many of which began producing electricity from renewable energy resources. Today, though these regulations have changed, independent power producers remain and have become a permanent part of our energy scene.

Around half of the new electric generation in the United States now comes from these independent power companies. This allows many utilities to offer their customers choices that include electricity from renewable energy sources. Sometimes the utilities buy this electricity from independent power producers, and sometimes they generate their own.

DEREGULATION

Deregulation literally means elimination of regulation from a previously regulated industry. Many states have started to deregulate the electricity and natural gas industries to make electricity sales less a utility monopoly and more an open market. But it doesn't mean there are no rules. It just means the rules are changing. One common way to deregulate is to make it possible for large businesses, or a group of small customers joined together, to buy their electricity directly from a supplier rather than from a regional utility. The electricity industry in the United States will continue to change while new ways are tried and are either found to work well or are rejected.

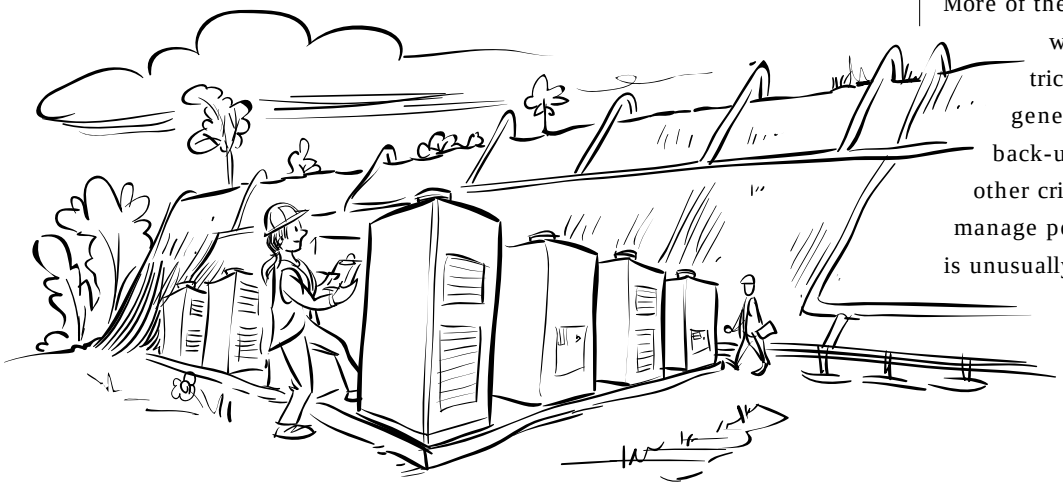
HANDLING THE LOAD

There are times when everyone in a region uses a lot of electricity, all at once. This is called a peak load. In general, people use more electricity (especially in the summer) between 12 noon and 6 P.M.— the "peak" hours. Sometimes there just isn't enough electricity for everyone, all at the same time. This can happen during a heat wave when everyone wants to run air conditioners. Certain areas may end up going without electricity for a specific period (usually several hours), which is commonly called a blackout. Brownouts (meaning reduced power) or even blackouts can also occur when something damages the production equipment or wires.

We can all pitch in to help prevent blackouts by using our big, energy-gobbling appliances at "off-peak" times. We can also pay closer attention to how much we use our air conditioning and heaters.

DISTRIBUTED GENERATION

Distributed generation means supplying power with small generating units. These are usually located at or near the place where the energy is needed. It is used to add more baseload power to the general supply (avoiding the need to build more large-scale power plants) or to supply peak power needs. This can be done with energy-efficient microturbines (running on natural gas or biomass gases), fuel cells, small wind turbines, small-scale hydro-power, modular binary geothermal units, and photovoltaics. Because each of these technologies is a "mini-power plant" on its own, each is ready to provide electricity whenever or wherever it is needed. More of these units can be added when the demand for electricity increases. Distributed generation is also useful for back-up power in a hospital or other critical facility, or to help manage peak loads when demand is unusually high.

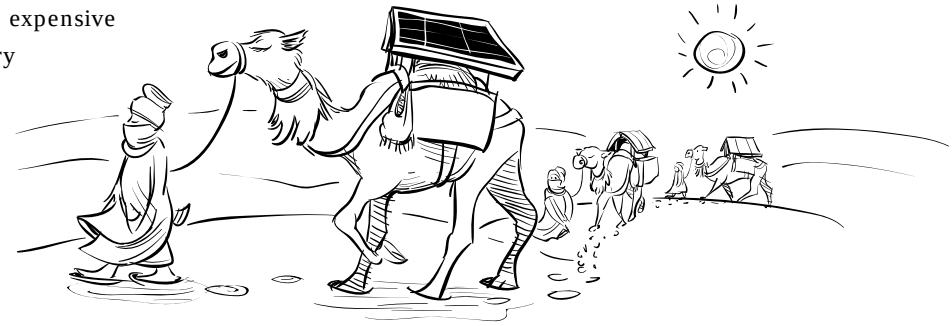


Microturbines running on biomass gas; the landfill is behind the wall on the right.

DISCUSSION

MANAGING ENERGY IN THE MIDDLE OF THE DESERT

In Africa's Sahara Desert, health care workers needed a way to carry perishable vaccines across the hot, sandy desert to remote health clinics. Rather than take an expensive refrigerated van out in the desert with very few gas stations, the workers decided to make use of the best options available to them: camel caravans and the sun. The vaccines traveled in style, safely carried in small refrigerators powered by solar charged batteries — all sitting atop the camels!



THE RIGHT SOURCE FOR THE RIGHT USE

One way to get the most out of the energy we use is to match the right source with the right use. For example, if we need heat, then we can use a source that is already hot, such as solar or geothermal energy. Or, we can use the waste heat from power plants. That way we don't need to use electricity or burn a fuel to produce heat. These approaches save resources, are energy efficient, and are easier on the environment. Here are some of the ways we do this.

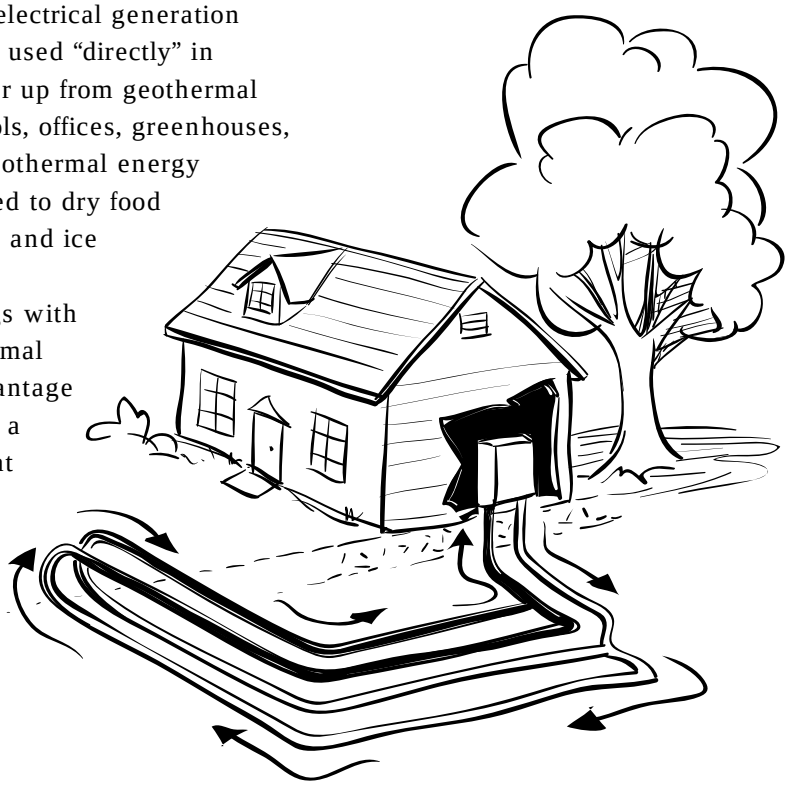
Active and Passive Solar Heating

Active solar heating systems absorb heat using solar collectors (often found on rooftops) that are filled with a liquid such as water. Pumps can move the heated water through equipment that warms a building, takes the chill out of a swimming pool, or preheats water for a water heater. Buildings with *passive* solar systems naturally collect the sun's heat during the day, using thick walls or large tile or brick floors in the sunny areas, and expansive south-facing windows. Rooms with these features are sometimes called sunspaces. These "solar collectors" then slowly release the heat at night, when the heat is usually needed. In summer, deciduous trees or awnings can shade the windows or walls from the sun.

Direct Use Geothermal

Geothermal water that is not hot enough for electrical generation can still be very handy. Around the world it's used "directly" in many different ways. After pumping the water up from geothermal reservoirs, people use it to heat homes, schools, offices, greenhouses, swimming pools, and water for fish farms. Geothermal energy also provides heat for industry, where it's used to dry food and lumber, as well as heat for melting snow and ice from sidewalks.

We can also heat (and even cool) buildings with a geothermal heat pump — without a geothermal reservoir. A geothermal heat pump takes advantage of the constant temperatures of the earth just a few feet underground. With a geothermal heat pump, water or another liquid circulates through loops of pipe buried next to a building. During cold weather, the circulating liquid transfers heat from the ground to help warm the building. During hot weather, the liquid carries the heat from the building into the ground.



A geothermal heat pump system

Cogeneration

Cogeneration, also referred to as combined heat and power (CHP), is a way of using energy more efficiently — reducing costs, saving energy, and cutting back on pollution. It means producing electricity and heat at the same time, from the same fuel or energy source.

Facilities using cogeneration produce their own electricity and then use the resulting excess, or "waste," heat for another use. For example, a pulp and paper mill might produce its own electricity using a steam-driven turbine-generator, then use the waste heat to help produce paper products.

If it's a power plant that uses cogeneration, the waste heat that is captured after producing electricity can be used to produce even more electricity, to heat power plant offices, or to be sent right next door for use at a fruit-drying plant, for example.

A wide variety of power plant types can make use of cogeneration, including geothermal, solar thermal, landfill gas, hydrogen combustion, fossil fuel, nuclear, or even fuel cell power plants. A "combined cycle power plant" (see page 122) is actually a cogeneration power plant.

WEIGHING IN ON FEDERAL ENVIRONMENTAL POLICY

A balancing act of decision-making goes on every working day for our elected officials in Congress. Health and the environment must be weighed against the economy and other interests of those who elected the officials. You can influence these decisions by contacting your representatives in Congress to let them know what's important to you.

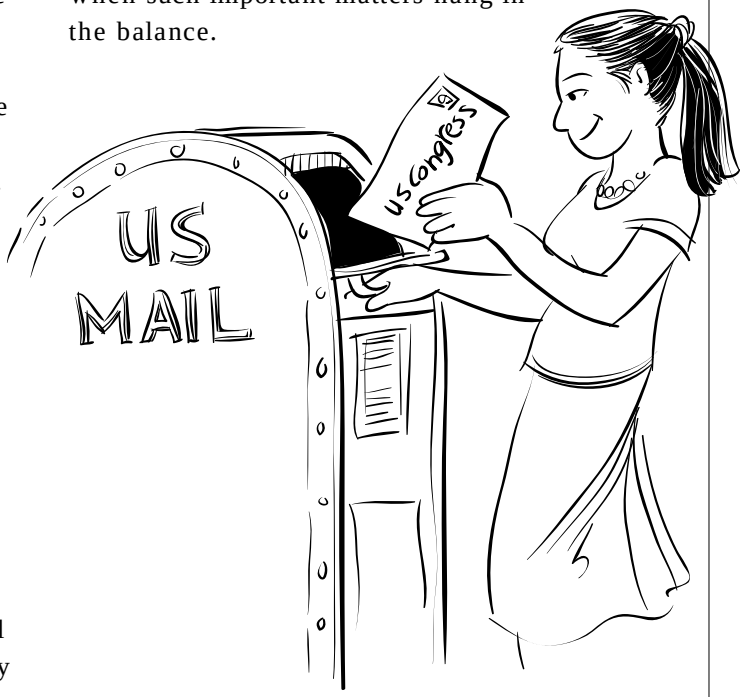
One important example to consider is the Clean Air Act (CAA). Originally passed in 1970, the CAA is a Federal law designed to protect public health. It requires the U.S. Environmental Protection Agency to set standards and enforce regulations for industry and power plants regarding the air pollution they produce.

Some industries and energy producers have not liked this regulation. They say it costs too much to use all the pollution controls required. However, other businesses have found that, by using energy efficient measures and cleaner energy sources, they have not only met pollution standards, but they actually have increased their profits.

Some people have pressed to repeal (do away with) the CAA. Others wish to keep it in place, but would like to change the specific ways the regulations are put into action. Over the years, however, the basic intentions of the law have stayed in place.

Policies such as these have been successful in controlling pollution. For example, air quality in the Los Angeles area of southern California has improved due to the efforts of local agencies, such as the Air Quality Management District, which makes sure that both the CAA and state pollution regulations are being followed.

With a complex issue such as the CAA, members of Congress should understand and consider all sides. The opinions of their citizenry — young and old — add weight to one side or the other of an argument. Therefore it is in everyone's own best interest to be informed and vocal about what happens at our nation's capital, especially when such important matters hang in the balance.



RENEWABLE ENERGY AND CONSERVATION STRATEGIES

Time of Use Pricing

Some power providers install "time of use" meters that record both the kilowatt-hours used and the time of use. Customers are then charged more for electricity used during peak hours (when the cost of electricity is higher to the power provider and the most-polluting plants are turned on). Customers can reduce their bills by doing laundry, for instance, during off-peak hours.

Communicating with Electricity Customers

When businesses and the public are notified that the electricity load needs to be reduced, they lower their electricity use as much as they can.

Disclosure

Disclosure in this instance means that electric utilities are required to tell their customers which energy resources they use to make electricity and the amount of air emissions they produce each year.

Green Pricing, Green Tags and Green-E

In some states utilities offer electricity from renewable resources. Customers who choose renewables generally pay a few dollars more a month for up to 100 percent renewable electricity. (Note: Only a portion of our electric bills is for the electricity. The rest is for transmission, distribution, and taxes.) Another way to support renewable energy is to buy Renewable Energy Certificates, also known as Green Tags, or Tradeable Renewable Energy Credits. When a utility or a customer buys Green Tags, the money goes to the construction of new renewable plants somewhere, even if in a different region. Renewable electricity and Green Tags can be certified as truly renewable by such programs as the Center for Resource Solution's "Green-E."

Renewable Portfolio Standards

Many states are adopting standards that say a minimum amount of renewable energy has to be included in the "portfolio," or assortment, of electricity resources produced by that state's power providers. For example, California recently passed a bill that requires 20 percent of the state's electricity to come from renewable energy sources by the year 2017. Some groups are also working to have a set of national renewable portfolio standards established in the near future.

TRUE-COST PRICING

Traditionally, the price of a product reflected only the cost of making and delivering it. If a company's factory polluted the air and people got sick, those costs and losses were borne by the community, not the company that did the damage. These are called hidden, or "external" costs.

Electricity also has hidden costs. Health and environmental costs, for example, result from using fossil fuels. Air pollution causes ailments, especially of the lungs, which require costly treatment and interfere with work. In addition there are disturbances of soot, reduced visibility, and water pollution. And there are risks in importing fuels, the costs of which are covered in military defense budgets (our tax dollars), not in our electric bills.

With renewable energy, we get added value without paying for it — like reducing the cost of waste disposal to landfills by using biomass for electricity, improving our "balance of trade" by importing less fuel, and increasing our energy security by using more numerous, small distributed power plants.

When the true costs are considered, renewable energy is often less expensive than electricity from fossil fuels. Understanding this, consumers are often willing to pay a bit more for renewable energy, knowing they are getting a bargain.

Government Research and Tax Policies

State and federal governments can help improve renewable electricity generation technologies by sharing research costs. And governments can reduce the cost of renewable electricity by reducing the taxes on it. One important law, the Production Tax Credit, already is reducing the cost of some renewables. Another method is to add a "public benefits charge" to everyone's electricity bills. The money collected is then used to promote energy conservation and renewable energy.

Net Metering

This is a program that encourages residences and business to generate some of their own electricity from specific clean renewable sources. If consumers need more electricity than they generate, they can draw on energy from the grid to which they're connected. If they generate an excess of electricity, they "sell" it back to their electricity provider!

Rebates for Renewables

A number of state energy agencies as well as utilities provide cash rebates (partial refunds) for the purchase and installation of certain renewable energy systems, such as photovoltaics on rooftops.

Energy Efficient Buildings

The government provides assistance to people who want to make older buildings more energy efficient. This program also encourages the use of energy efficiency and conservation in the building of new homes and businesses. The federal government is even using this policy on some of its own buildings.

ENERGY STAR Program

The U.S. Environmental Protection Agency established ENERGY STAR in 1992 to identify and promote energy-efficient products. You will recall that reducing energy use helps to reduce air pollution and greenhouse gas emissions. ENERGY STAR-rated products have superior energy efficiency and now include office equipment, home appliances, heating and cooling equipment, lighting, home electronics, and even new homes and businesses.

Renewable Energy Action Project: WHAT'S IN *YOUR* ENERGY PORTFOLIO?

PLANNING OVERVIEW

PLANNING OVERVIEW
Environmental Science, Ecology, Government, Math, Fine Arts, Language Arts

TIMING
Preparation: 1 hour
Activity: Will vary depending on several factors, including size of survey group and scope of research. Estimated minimum: 5 45-minute class periods

Summary

Students will survey adult attitudes in their own community in order to raise student and public awareness about the use of renewable energy for the generation of electricity.

Permission given by the Population Coalition to adapt the survey in this Activity from *Life In My Community*

Objectives

Students will:

- Develop hypotheses regarding the possible outcomes of the class investigation.
- Determine the potential for renewable resources in their region.
- Ascertain which energy resources their local power provider(s) are currently using to produce electricity.
- Develop and conduct a renewable energy survey to assess the knowledge and attitudes of a selected target audience of adults.
- Collate survey information and interpret results.
- Prepare a summary paper of their findings, including suggestions for further action.
- Compare the actual investigation results to their earlier predictions (hypotheses).
- Formulate a conclusion and reflect on the changes in their reasoning based on the investigation findings.
- Present their findings to various audiences.
- (Extension) Report findings to a wider audience and/or conduct a vigorous public information campaign.

Materials

Per student:

Information logs. Report folders with 5-10 sheets of lined binder paper. You may also wish to copy Chapters 3, 4, and 5 Discussion sections and relevant information from the Appendix for each log.

Student handouts. Investigation Task List, Report Task List, Survey, and Cover Letter

Per survey participant:

Cover letter

Survey

Final report

Thank-you letter

General materials:

Information from electricity bills, city hall, and chamber of commerce regarding all electricity providers in your area; other resource materials such as phone books

Letter-writing materials

9" x 12" mailing envelopes: enough for entire survey group

Other envelopes to enclose with survey: enough for entire survey group

Paper or tag board for classroom charts

Optional: Computer with printer and Internet access

Optional: Report materials: poster board, markers; overhead projector and transparencies; presentation software such as PowerPoint®, Kid Pix®, Hyper Studio®, or Inspiration®

Making the Link

Students may ask: "If renewable energy is so great, why isn't it already more widely used?" Now that they've gotten this far in this unit, your students will easily recognize renewable energy resources all around them. Perhaps they live in an area that is very windy or sunny. Their town may be located by a seashore with strong wave action, a roaring river, or an active geothermal area. It certainly can be puzzling why we aren't making greater use of this abundant energy.

Many reasons may be cited regarding the challenges renewable energy has faced over the years, some of which will be addressed in this activity. However, perhaps one of the most important challenges today has been a lack of public awareness regarding how our electricity is produced. Many people are still not aware of the variety of resources available for the production of the electricity we use everyday.

In this activity, students have an opportunity to survey key adults in their own lives, to present a report to them and to others, and to inform them of the renewable energy options available to them right in their own communities.

Teaching Notes

Though rigorous, activities of this type are well worth tackling with your students.

There are a number of educationally sound justifications for doing so. This activity cultivates essential critical thinking strategies. Also, class work that moves into a "real-world" context is an effective and engaging type of learning. Working cooperatively with a variety of people is a skill that not only enhances learning, but will also serve students well as future citizens. Further, students will feel empowered, not just by their own involvement, but also by the involvement of the adults who show interest in this project.

A number of skills practiced in this activity are hallmarked in the National Science Education Standards & Benchmarks for Scientific Literacy. These standards support the importance of students being able to look at and analyze evidence, deduce a conclusion, and develop an interpretation or opinion based on evidence.

When working with the results from the survey, prepare students for the fact that the survey findings may not come out the way they'd anticipated. Emphasize the importance of reporting their findings honestly and accurately.

Remind students that, when giving presentations (see Wrap-Up, page 171), it is imperative that they act maturely and keep their cool in order to be convincing. Some people may simply have no interest in the subject. Others may consider energy use and the environment to be controversial "hot button" topics. Prepare your students for the fact that a few people may ask pointed questions or behave in a confrontational manner. Remind students that they must always be professional and polite. If they don't know an answer to a question, suggest that they get back to that person with sources of information or an answer to his or her question. Make sure that students get, with permission, contact information (phone number, e-mail, address).

Warm-up

Your students may be surprised to learn just how much of a difference they can make in the way things are run in the adult world. Share the following narrative, "Students Making a Difference," which shows how one teacher and a group of students made such a difference.

Students Making a Difference When an environmental science teacher joined the staff of a Massachusetts high school in 1990, she found a neglected solar array right behind the school. She learned that the dozens of solar panels had been installed there as part of a U.S. government study on solar energy in 1981. At the time solar PV was very expensive, but the federal government policy regarding renewables was very supportive. Then, because of changes in policy in the late 1980s, support for the project was withdrawn.

The teacher decided that this "backyard" opportunity for educating students about renewable energy was just too good to miss. So, along with the original project developer, she launched a student-based lobbying campaign. They worked hard to convince the federal government to resume funding the project.

The teacher and students were very successful. Public funding was renewed in1994 to restore the array and keep it running. To top it off, this project also supported what was to become a nationally recognized renewable energy education program.

Interestingly, when repairs were finally made on the array, engineers discovered that only 7 out of 3,200 solar modules had failed. They found that the array had been quietly generating electricity in spite of the lack of maintenance and the harsh New England weather. Now kept in tip-top shape, it will continue to supply both energy and education for many more years to come.

This story is just one of many examples of teachers and students affecting energy policy and management.

In the following venture, students will conduct a public information survey of adults in the community about electricity sources and report the findings. This research might raise awareness that could eventually result in some real changes in the way electricity is produced and used in their own area.

The Activity

STAGE ONE: **Setting the Scene**

1. Distribute an Information Log to each student (*See Materials*). Explain to students that they will be using these logs to record plans and information. Remind them to always date each entry. You may wish to have students place a title on the front cover, such as "Renewable Energy Action Project."

2. Divide your class into groups of 3-5 students. These will be their action groups for the duration of this activity.

3. Ask each group to consider the reasons why renewable energy has not been more actively used in our country (at least not until very recently). Ask them to brainstorm and list on scratch paper what they perceive these challenges to be.

   Have each group share its ideas with the rest of the class. As they do, make a master list on large chart paper. Label the list with a title such as "Barriers to Use of Renewable Energy."

   Students might list the following barriers:

   - Many people may not understand about the "hidden costs" of producing energy with resources such as fossil fuels, so they may perceive that renewable energy technologies are expensive.
   - People may hear that it takes a long time to make up for an investment in renewables with the savings they realize on their energy bills.
   - Some renewable resources are "intermittent;" they can only be used at certain times (e.g. solar, wind).
   - There are some concerns about wildlife safety with certain renewable energy technologies (e.g. wind turbines, hydropower dams).

- Some people object to power plants in their cities, rural areas, or favorite forests.
- Some government policies — whether local, state, or federal — haven't always supported renewables, or have only supported a select few.

4. Explain to students that you would like to add other challenges to the list: first, public awareness; and second, lack of "choice." Write these on the Barriers master list. Discuss the first challenge, noting that electricity customers may not be aware of the renewable energy technologies now available to us.

   For the second challenge, discuss that the electricity providers may not offer a "green energy" or renewable "customer choice" program. Once aware, adults may begin to question why their power suppliers aren't offering renewable choices. Some may even start urging their power providers to add more renewable options. Additionally, these adults may have already considered adding renewable energy technologies to their own places of work or at their homes.

5. Ask students to copy the Barriers list into their logs.

6. Tell students that they will be doing an action project to determine attitudes and raise awareness about renewables in your community. This project will be done in stages. Students will determine the policies of your power provider(s) regarding renewable energy. They will learn what the potential is in your region for various resources. They will conduct a survey on renewable energy, with the target group being their parents, teachers at the school, and other adults in their lives. They will collate, assess, and present their findings. If their findings reveal a strong interest in renewable energy, a ripple effect of interest and demand could result in eventual changes in the use of renewable resources in your area.

7. Have students get back into their groups and give their group a name. You might suggest that they choose energy-related names, such as Kilowatt Kids or The Transmitters, etc.

STAGE TWO: **Investigation**

1. Use a large piece of chart paper on which to place an "Investigation Action Plan." On the page opposite is an example matrix that can be placed on the chart. Adapt this to suit your individual situation.

2. Distribute the student handout "Investigation Task List" to each student and review its contents with your class. Have students place this handout in their "Information Logs."

3. As a class, read over and discuss the various tasks, then decide which groups will be in charge of which tasks. If there is more than one power provider in your area, then assign a different group to each one. Note the name of each provider on the master chart alongside the assigned group's name. You will most likely assign each group to more than one task. Establish target dates for the completion of each task. Place all this information on the chart. Remind groups to use their "Information Logs" as the organizer for all their work on this project.

4. Pass out the sample survey and cover letter. As a class, read through each of these

Investigation Action Plan				
Task	Who's in Charge	Action	Target Date	Results
Determine power providers' portfolio				
Assess local energy resource potential				
Investigate future plans for renewables				
Determine survey participants				
Analyze and adapt survey				
Analyze and adapt cover letter				
Prepare and deliver surveys				
Collect and record completed surveys				

and discuss any suggested changes. The group(s) assigned to make these changes should take notes during these discussions.

5. Have groups meet to discuss their assigned tasks, using the handout, "Investigation Task List" (page 174). Assist groups in determining how they will go about gathering and writing up their information or making changes to existing documents (e.g., survey or cover letter).

6. Ask student groups to discuss what they think their investigation will reveal, based on what they presently know about their community. Do they predict that their power provider is or isn't already using renewable energy? What types of energy resources might be available in their region? What attitudes and knowledge about energy use will their survey uncover?

   After some discussion as a group, have each student write his or her predictions in his or her log. Ask each student to form a hypothesis regarding the possible outcomes of the class investigation.

   Call the class together and ask students to share their hypotheses and to explain the reasoning behind their choices.

7. Allow time in future class periods for student groups to work together on their appointed tasks. If needed, allow time, too, for students to do any required research, or perhaps assign as part of their homework.

8. Make enough copies of the final Cover Letter and Survey for your survey participant group, plus extras for use in collating responses. Have students (or classroom volunteer) prepare self-addressed envelopes by placing the school address in the "To" position of the envelope. Place these along with the cover letters and surveys into the clasp envelopes. Have students deliver packets to their own survey participants. To avoid duplication, decide who will deliver surveys to adults at your school and to other parties such as district personnel.

9. As surveys are returned, have the group assigned to collecting and checking them off do this on the "Survey Participant Chart." You will want to keep the surveys in a safe place until students are ready to process the information.

STAGE THREE:
Collation and Interpretation

1. When the surveys are returned, it is time to collate the information.

   Divide the survey responses among the groups. Have students tally up each question's results, using the extra blank copies of the survey. Decide who will prepare a final master copy with a total of all responses.

   Using a blank master copy of the survey, "tic marks" are placed by each response. Then these tic marks are totaled. Any written comments are copied down beside their respective questions or on the blank sheets to be attached to the tally sheet.

2. Make a copy of the final collated results for each student. Have them place these in their logs. Have students examine and discuss these results in their groups.

3. Then call the class together. Ask each group what their general impressions of the results are and what they think the results may mean. Explain that when they are doing this, they are "interpreting" the results.

   These interpretations reflect the overall trends that you and your class see based on the responses to the survey questions. For example, in one case, your class might learn that your local power provider does not have a diverse energy portfolio that includes renewable energy resources, though your research shows that there are several such resource choices available in your area. Your survey findings might show that the majority of the participants are quite interested in having the option to get electricity from renewable energy resources and may be willing to pay a bit more for such choices. In this case, students may reasonably interpret the results to indicate that there is an indicator of community interest in further use of renewable energy sources.

   In another instance, what may seem like a lack of community interest may actually be lack of knowledge. Certain questions are indicators of this lack. Perhaps the survey participants (and most likely other community members) need more information regarding the benefits of using renewable energy and the great strides renewable energy technologies have taken in recent years. Or perhaps you may learn that your region has few renewable resources.

4. On large chart paper, make a master list of your class's general interpretations of the survey results. Have students copy these into their logs.

STAGE FOUR: **The Report**

1. On a large piece of chart paper, create another action plan matrix, this time for developing your final report. As before, place the task list vertically on the left side and place the following on the top horizontal: Group Name(s), Action, and Target Date.

2. Distribute the student handout, "Report Task List." Explain that they will be developing a report of their findings. It will have four sections (see "Task List"). A group will be assigned to each section. Another group will need to develop a thank-you letter to participants. The report and the thank-you letter will also need to be typed, copy-edited, and revised.

3. Encourage students to make charts and graphs displaying their numerical information (by hand or using presentation software). Once written, have different groups proof and edit each other's sections of the report, as well as the thank-you letter.

4. Decide how the report and thank-you letter will be typed up. Make enough copies for each survey participant who requested one, plus one for each student. Have students place their copies in their logs.

5. Have students individually review their original hypotheses and compare them to the actual findings of the class report. Ask them to reflect, in writing, on the reasons for their previous understandings and how they have now changed. Then, ask them to write up their own conclusion based on the investigation findings.

   Have groups get together to discuss their conclusions and how they may or may not differ from their original hypotheses. Have them share things that were surprises. For example, was it a surprise that their power provider is (or isn't) already using renewable energy. Maybe they didn't realize that a certain type of energy resource is so widely available in their region. Or, perhaps they thought that the adults surveyed would know more than they do about energy use.

   Bring the entire class together and ask a spokesperson from each group to give a general summary of their group's exchange. Invite further class discussion about any interesting points that may arise and make notes of any items for future class or individual investigations.

6. Send a copy of the report (with contact information for inquiries) to your local newspaper, your community government, and chamber of commerce. Make sure that your local power provider(s) receives a copy. Discuss with your students how inquiries arising from this distribution will be handled.

7. Educators for the Environment would be very pleased to receive a copy of your students' report along with any information you'd like to share about the outcome of this activity. Please send to: Educators for the Environment, 664 Hilary Drive, Tiburon, CA 94920, or, if electronically produced, to energyforkeeps@aol.com.

Wrap-up

Prepare a presentation in which your class will tell an audience about its findings and its recommendations. As a class, choose selected portions of the report to give orally or use in a visual format. You might consider presentation software, overheads, or other visuals such as charts and posters. Discuss the students' purpose in giving the report. For example, do they wish to persuade consumers, such as their parents, to ask their utility to use more renewable resources? Would they like your school board to consider installing solar panels on school buildings or to provide information to the school's power provider about diversifying its energy resource portfolio? Whatever the purpose or audience, steer students away from making strident demands.

If charts and other visuals are to be made or presentation software (see Materials) will be used, assign various sections to different groups.

Determine who will deliver the presentation. It might be a representative from each student action group.

First practice the presentation by giving it to another class at your school, or to an audience of the parents of your class. Invite your district's school board members to attend. Afterwards entertain questions. Based on the audience response, revise your presentation.

If the students' presentation is impressive, consider inviting a local power provider to send a representative to visit. In preparation, have students meet in their groups to discuss their opinions about the provider's policies. Then have the class meet to share and discuss each group's opinions. Make a class decision about the purpose of giving their presentation to the power provider. Will it be to applaud their efforts, to raise their awareness, or possibly to encourage a policy change?

Discuss the nature of persuasion and the different ways to promote one's point of view without being demanding. Once the presentation has been given, allow the representative time to digest and pass the information on to his colleagues. Then encourage follow-up contacts. Ideally, class members might continue an ongoing dialogue with the company. The results in the long run could be quite positive.

Assessment

Students will have had the opportunity to:

- Organize and maintain an information log.
- Do research concerning the potential for and attitudes about use of renewable resources for electricity in their community.
- Collate and interpret survey results.
- Develop a summary report of research findings and recommendations.
- Formulate hypotheses and conclusions regarding anticipated and actual investigation results.
- Prepare and deliver a presentation of findings.

Extensions

- Publish results to a wider audience. Contact regional TV and radio stations. Ask for display space in your community's library. Send a copy of your report to your federal and state officials.
- Contact established organizations that may share a common purpose. Share your report findings with them. Discuss the possibility of a working together to develop a more extensive public information campaign on renewable energy.

Additional Culminating Activity Suggestions

Civics Simulations. Have your class simulate a civics decision-making process. Here are two ideas, which you can adapt to meet your specific educational goals:

1. Your class might establish a "town council," made up of five or six students with various assumed identities. The rest of the class can 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. Be sure to include all the resources that would apply to your area (including fossil fuels and nuclear). Groups can meet to prepare for the town council, and appoint a representative to speak for their group at the meeting. Consider having "representatives" of renewable

energy power providers, an oil company, a nuclear power facility, environmentalist groups, home owners, business owners, college professors and students, people who will be living right near the plant, and so on.

While these groups are meeting, the town council can meet to establish whether future power needs can be generated in the region or must be purchased from elsewhere, what they perceive the needs of the community might be, and some guidelines for the council meeting discussion.

Students can make up their own names and identities, or you can develop some and pass them out randomly. Invite a member of your local town/city council to come and advise students about the town/city council decision-making process, or, if possible, have your class (or representatives from your class) attend a town/city council meeting.

2. If you have been studying state or national government, you can adapt the above activity by changing it to a state or federal legislative "hearing" on energy. Each student (or small group with a spokesperson) would be a member of Congress testifying before the rest of his or her peers, advocating a particular type of resource to be supported by Congress to meet future energy needs.

Once all have testified, then the entire "Congress" would vote on a 10 to 20-year energy plan (or whatever). One or two students may wish to assume the Congressional leadership role to moderate the discussion.

Not only will students need to study their energy resource in preparing for the hearing, they will also need to learn how the governing body they are simulating conducts its meetings. You may wish to watch a broadcast of a Congressional hearing or invite your local representative to advise the class.

Forecast the Future. Assign a different energy resource to each student group. Ask them to brainstorm what they think the future would be like if that resource replaced fossil fuels as the most widely used energy resource. Select a time period such as 50 or 100 years in the future.

Have them consider all aspects of an industrial society: agriculture, transportation, factories, high tech businesses, service industries, schools and universities, recreation, national parks and wilderness areas, and so forth. What would cities and towns be like? How about air and water quality? What about the value of open space and having an enjoyable view? What role do they picture the government having?

Have groups develop a method to present their forecasts to the rest of the class. You might consider offering these choices: poster with report; play, puppet show, or "news hour broadcast;" computer presentation; travel log or travel brochure.

Ecological Footprints. Explore the idea of Ecological footprints more extensively. One way to do this is by going online. Students can compute their own "eco footprint" and learn how to shrink it by visiting the "Redefining Progress: Sustainability Program" website (see page 213).

What's in Your Energy Portfolio?
INVESTIGATION TASK LIST

Assess Local Energy Resource Potential

Find out what energy resources are abundant in your local area. For many resources there is information available online. Several good places to start are the U.S. Department of Energy, your state's energy department, and possibly your local power provider.

Review Local Power Providers' Energy Portfolios

First, learn who your local power providers are (there may be only one in some cases). Then investigate their energy portfolios. Find out what percentage of the total electricity produced is coming from each renewable source (if any). Disclosure regulations in many areas should make this information readily available. With some power providers, this information will be online. Otherwise, call or write to ask their community relations department.

Investigate Future Plans for Renewables

Contact each power provider's community relations department. If they aren't currently using any renewables, ask what their plans are for adding renewables in the future. If they are already using renewables, ask them what their plans are for adding more, if possible. Get specific information regarding which types and what percentage of the total electricity produced they estimate each will be.

Ask their community relations department what they consider the barriers to more extensive use of renewables to be. Urge them to be specific. Use your list of "Barriers" to assist in the conversation. Remember to be courteous!

Determine Survey Group

Each student should list people he or she knows and trusts in the community who may be willing to participate in the survey. The group assigned this task should then gather all these names from each student and create a master list of participants. Additionally, the class should add other key adults to this list, including your school's administrator(s), office manager, teachers, librarian, custodian, as well as school district personnel. This list of survey participants should be posted. The group assigned this task is responsible for making sure that enough cover letters and surveys are copied. They are also responsible for following up to see that most (or all, if possible) of the surveys are returned (see below) and are checked off on the list.

Develop or Adapt Survey

A sample survey is provided. You may want to use it as it stands or adapt it. Or, your class may wish to create one entirely on your own, based on your individual circumstances. Your teacher should conduct a class discussion to brainstorm any changes to the sample survey. Your group should take notes of these suggestions and then make the changes to the survey.

Analyze and Adapt Cover Letter

Your teacher will conduct a class discussion regarding ideas for revising the sample cover letter. Your group should take notes during this discussion, then make the needed changes to the letter.

Collect and Check Off Surveys

See "Determine Survey Group" above. Once the surveys are checked off, give them to your teacher.

REPORT TASK LIST

SECTION ONE: **Our Area's Energy Resource Potential.** This section reports on findings regarding your region's potential for various energy resources.

SECTION TWO: **What's in Our Power Provider's (Providers') Energy Portfolio(s)?** This section reports your findings regarding what energy resources your local power providers are currently using to produce electricity, along with whether they offer a "green energy" or other customer choice program.

SECTION THREE: **Survey Findings.** This section reports the findings and interpretations of your survey.

SECTION FOUR: **Summary and Recommendations.** This section includes a summary, as well as recommendations for further action. The recommendations should be based on the opinions of all the groups.

Edit Report. Several or all groups should help proof and edit the report, with the teacher and/or volunteer's guidance.

Thank-you Letter. This letter should contain a thank-you to the participant, a recap of the investigation's purpose, a very brief overall summary of what is found in the report, and possibly a paragraph stating future hopes and expectations of the class.

Type Report. You may want to have an adult or high school/ college student volunteer to type the report in order to save time.

Prepare and Deliver Report and Letter. Stuff clasp envelopes with the thank-you letter and report; each student delivers to his or her own key adults; mail, or otherwise arrange to deliver, the remainder to those who requested the report.

COVER LETTER

(Date)

(School address)

Dear Survey Participant,

_____ grade students from _____ class at _____ School, _____ District, have been studying the use of renewable energy. We have explored the many interesting choices available in different locations for the production of electricity.

We are now conducting a study on electricity production and energy use in our local community. We are investigating the potential for using renewable energy resources in this region. We are also learning what energy resources our local power providers are using to produce electricity. We have explored what the possible barriers, or challenges, have been to a more extensive use of renewable energy sources in our area.

We would like to learn community attitudes about renewable energy and are asking you to take a few minutes to fill out this survey. The questions are about:

- Your general feelings about the quality of life in our community.
- What you think is important regarding electricity production and energy use in our community.
- What you already know about the renewable energy choices we do have available.
- Whether you think it is important to be using more renewable energy for the production of electricity and what you would be willing to change in order for this to happen.

We are gathering and collating this information in order to gain an overall impression of adult awareness of and interest in these issues. Your individual responses will be completely anonymous.

The information from this survey will be collated with other respondents' answers and used as part of a report on energy production and use in our community. You will be sent a copy of our final report if you wish.

We plan to present our findings to various audiences, including fellow students and teachers, as well as school board members. We also might deliver a presentation to one of our local power providers.

Please return this survey to _____ class, _____ School, by _____.
(date)
A self-addressed return envelope is enclosed for your convenience.

Thanks so much for helping us with this project,

Sincerely,

(Name of class)
(Name of school)

Your ZIP code: _____

SURVEY:
Renewable Resources for Electricity in our Region

A ABOUT QUALITY OF LIFE IN OUR COMMUNITY

Using the scale shown below, please indicate your answer to questions 1 - 4 by circling one of the letter abbreviations.

VS = Very satisfied
S = Satisfied
N = Not sure
D = Dissatisfied
ED = Extremely dissatisfied

1. How satisfied are you with the overall quality of life in our community?	VS	S	N	D	ED
2. How satisfied are you with each of the following conditions of our community?					
a. Physical environment (Consider, for example, parks/wilderness/ open space vs. areas of buildings and pavement.)	VS	S	N	D	ED
b. Air quality	VS	S	N	D	ED
c. Water quality	VS	S	N	D	ED
d. Economic conditions	VS	S	N	D	ED
e. Cleanliness	VS	S	N	D	ED
3. Our government representatives are responsive and proactive about reducing air pollution.	VS	S	N	D	ED
4. I am happy with our community's waste management program.	VS	S	N	D	ED

Check the statements that apply to the following question.

5. Our community's waste management program includes these features:

- ☐ Green waste (yard waste) is collected in a separate container and placed at our curbside.
- ☐ Recyclables (paper, newspaper, glass and plastic containers, plastic bags, aluminum foil, Styrofoam, etc.) are collected altogether in one container and placed at our curbside.
- ☐ We separate our recyclables by type and place them at our curbside.
- ☐ We separate our recyclables by type and take them to a recycling center.
- ☐ We collect and place our garbage in a separate container at the curbside
- ☐ None of the above. Describe _____

B ABOUT RENEWABLE ENERGY IN GENERAL

Place a check mark by as many answers as you feel apply to the following question.

6. The following energy resources are considered to be renewable resources:

- ☐ Coal
- ☐ Oil
- ☐ Natural Gas
- ☐ Nuclear energy
- ☐ Biomass
- ☐ Solar energy
- ☐ Wind energy
- ☐ Geothermal energy
- ☐ Storage-type (dam) hydropower
- ☐ Run-of-river hydropower
- ☐ Hydrogen
- ☐ Wave energy
- ☐ Tidal energy
- ☐ Not sure

Using the scale shown below, please indicate your answers to statements 7-9 by circling one of the following letter abbreviations.

SA = Strongly agree
A = Agree
N = Not sure
D = Disagree
SD = Strongly disagree

7. Renewable resources are generally environmentally friendly.	SA	A	N	D	SD
8. It is important to produce electricity with locally available, renewable resources so that we can be more energy independent.	SA	A	N	D	SD
9. It is important to protect the environment and our health by reducing the amount of polluting resources we use for energy.	SA	A	N	D	SD

C ABOUT ELECTRICITY PRODUCTION IN MY REGION

Check the box beside each answer you feel applies to the following three questions.

10. The electricity we are using in our region is currently being produced with the following resources:

- ☐ Coal
- ☐ Oil
- ☐ Natural gas
- ☐ Nuclear energy
- ☐ Biomass
- ☐ Solar energy
- ☐ Wind energy
- ☐ Geothermal energy
- ☐ Storage-type (dam) hydropower
- ☐ Run-of-river hydropower
- ☐ Hydrogen fuel (for example, hydrogen fuel cells)
- ☐ Wave energy
- ☐ Tidal energy
- ☐ Not sure

11. In our region, we have the potential for, but aren't necessarily using, the following energy resources to produce electricity:

- ☐ Coal
- ☐ Oil
- ☐ Natural gas
- ☐ Nuclear energy
- ☐ Biomass
- ☐ Solar energy
- ☐ Wind energy
- ☐ Geothermal energy
- ☐ Storage-type (dam) hydropower
- ☐ Run-of-river hydropower
- ☐ Hydrogen (for example, hydrogen fuel cells)
- ☐ Wave energy
- ☐ Tidal energy
- ☐ Not sure

12. Renewable resources provide about what percentage of electricity in the United States? (*Check one.*)

- ☐ 2 percent
- ☐ 5 percent
- ☐ 10 percent
- ☐ 15 percent
- ☐ 25 percent
- ☐ 50 percent or more
- ☐ Not sure

Using the scale below, indicate your answer to statements 13 - 17 by circling one of the following letter abbreviations:

SA = Strongly agree
A = Agree
N = Not sure
D = Disagree
SD = Strongly disagree

13. Our region has an adequate supply of electricity.	SA	A	N	D	SD
14. Our electricity is reasonably priced.	SA	A	N	D	SD
15. My local power provider(s) offers me a "green energy" option. In other words, I can choose to get some of my electricity from clean and/or renewable energy sources.	SA	A	N	D	SD
16. Although my local power provider(s) does not offer a green energy program, I would like to be offered more choices of how my electricity is produced.	SA	A	N	D	SD
17. I would be willing to pay a bit more on my energy bill for an option to get some or all of my electricity from renewable energy.	SA	A	N	D	SD

D ABOUT SAVING AND PRODUCING RENEWABLE ELECTRICITY AT MY HOME AND WORKPLACE

My Home

18. According to my electricity bill, last month, which is the month of _____ , our household used _____ kilowatt-hours (kWhr) of electricity.

Using the scale below, indicate your answer to each statement by circling one of the following letter abbreviations:

SA = Strongly agree
A = Agree
N = Not sure
D = Disagree
SD = Strongly disagree

Please answer the questions in this section whether you are a homeowner or not. If you aren't, answer them as you would if you did own your home or as they may apply to the place you occupy (apartment, student housing, shared rental home, etc.).

19. We are willing to pay more for energy efficient lightbulbs and appliances such as Energy Star appliances.	SA	A	N	D	SD
20. My household would be interested in producing some of our own electricity with a renewable energy system (such as solar panels).	SA	A	N	D	SD

21. If you agreed to Item 20, then list the renewable energy systems you would be most likely to use:

_____

_____

22. We already have a renewable energy electrical generation system installed at our home.	SA	A	N	D	SD

If you agreed to Item 22 above, then please answer the following three items. If not, then skip to Item 27.

23. List the type of renewable energy system(s) you have installed at your home:

_____

_____

24. We are participating in a "net metering" plan, in which we have remained connected to the electrical grid and can sell any excess electricity that we generate back to our utility.	SA	A	N	D	SD
25. We are satisfied with our renewable energy electrical generation system.	SA	A	N	D	SD

26. Why or why not? _____

_____

My Workplace

27. My work associates and I may be interested in producing some of our own electricity with a renewable energy system installed at our workplace. SA A N D SD

28. If you agreed to Item 27, then list the one(s) you would be most likely to use:

_____

_____

29. A renewable energy electrical generation system is already installed at my workplace. SA A N D SD

If you agreed with Item 29, then please answer the following three items.

30. List the type of renewable energy system(s) you have installed at your workplace:

_____

_____

31. My workplace is participating in a "net metering" plan, in which we have remained connected to the electrical grid and can sell any excess electricity that we generate back to our utility. SA A N D SD

32. People at my workplace are satisfied with its renewable energy electrical generation system(s). SA A N D SD

33. Why or why not? _____

_____

E ABOUT OUR HOUSEHOLD (OPTIONAL)

34. Including yourself, how many of your household members are in the following age categories. (*Write the number of people for each category.*)

____ Birth to 5 years old

____ 6-17

____ 18-64

____ 65 or older

35. How long have you lived in our community? ____ years

36. Why did you come to our community? (*Check as many as apply.*)

☐ Born here ☐ Reputation

☐ Employment ☐ Geographic location

☐ Health reasons ☐ To live in a bigger city

☐ Friends/Relatives here ☐ To live in a smaller city

☐ Physical environment ☐ Other _____

37. Is your workplace or school in another community? ☐ Yes ☐ No

For the following question, check as many as apply.

38. To get to work or school, do you:

☐ Drive ☐ Take public transportation

☐ Walk ☐ Bicycle

39. What is your main occupation? _____

_____

40. Do you own or manage a business in our local area? ☐ Yes ☐ No

41. Are you involved in the civic government of our community? ☐ Yes ☐ No

42. If you answered yes to the above question, please describe your involvement:

_____

_____

43. Please remember to enter your ZIP code on the first page of this survey. Thank you.

44. If you would like to receive a summary report of our findings, please complete the following:

Name: _____

Address: _____

_____

E-mail (optional): _____

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SCIENTIFIC METHOD FORM

Attach extra pages as needed for any of the steps listed below.

Name:

Group:

Activity:

Date:

1. Research

2. Hypothesis

3. Procedure

4. Data

5. Conclusions

ENERGY TIMELINE

4 million B.C.
First known use of tools in East Africa (muscle power)

460,000 B.C.
World's earliest known use of fire in area now known as China

10,000 B.C.
Asphaltum from natural oil seeps used for variety of purposes on America's Pacific coast

9000 B.C.
Farming begins in the Middle East and elsewhere; people begin permanent villages

6500 B.C.
Metalworking with copper begins in Middle East

3500 B.C.
Sails on boats used on the Nile in Egypt (wind power)

3200 B.C.
Wheels used in Urak, Iraq

3000 B.C.
First recorded use of crude oil, in Mesopotamia

2000 B.C.
Chinese use crude oil for home heating

1500 B.C.
Hittites (Asia Minor) first produce wrought iron

1500 B.C.
Fire-starting kits carried in Europe

1500 B.C.
People around the world use hot springs for bathing, healing, recreation, cooking, heating

1000 B.C.
Iron becomes commonly used metal throughout Mediterranean

750 B.C.
Ironworking reaches Europe

500 B.C.
Magnetic properties of lodestone (type of iron) described by Thales of Miletus in Greece

500 B.C.
Iron plow share first used in Europe, making plowing much faster (muscle power)

500 B.C.
Passive solar energy used in Greek homes

200 B.C.
Coal mining in China

50 A.D.
Hero of Alexandria invents first steam engine (not put to productive use)

50
Romans perfect glass windows (solar)

100
Greeks invent waterwheel

300
Natural gas drilling in China

644
First windmill with a vertical axis, recorded in Iran

700
Iron smelting introduced in Spain

1060
Possibly world's first city-wide space-heating project using geothermal built at Paquimé, Mexico

1088
Water-powered mechanical clock made by Han Kung-Lien of China

1100
Oil wells drilled in Europe and the Mediterranean

1100
Windmills introduced in Europe

1200
Coal mining begins in England

1320
Germans improve blast furnace, advancing the process of iron smelting and casting

1322
French village pipes water from hot springs for home heating

1400
Blast furnace introduced in Holland, enabling the first production of cast iron in Europe

1510
Leonardo da Vinci designs the precursor of the water-driven turbine

1582
First waterworks using water-wheels founded in London

1615
Use of coal for heating in England increases, owing to rising timber costs

1680
Mills driven by waterpower in common use throughout Europe

1688
Large sheets of glass used for windows in France (solar)

1690
Widespread use of coal begins in Europe due to wood depletion

1695
Frenchman G. Buffon uses mirrors to concentrate sunlight to burn wood and melt lead

1698
Englishman T. Savery develops steam engine to pump water out of flooded coal mines

1700
Textile mills and other factories driven by waterpower throughout Europe

1700
Greenhouses using glass windows become popular (solar)

1705
T. Newcomen, England, invents first practical steam engine

ENERGY TIMELINE (continued)

1709
Iron smelting process using coke developed by A. Darby, England; coal demand increases

1712
Piston-operated steam engine built by T. Newcomen

1746
B. Franklin conducts research that will later result in clearer understanding of electricity

1748
First American commercial coal production in Virginia

1752
B. Franklin's kite experiment verifies nature of static electricity; leads to invention of lightning rod

1757
First public gas streetlights in the American colonies light Philadelphia

1769
Improved steam engine patented by J. Watt, England

1770
Spinning jenny patented by J. Hargreaves helps automate manufacturing

1782
J. Watt invents rotary steam engine; soon to have widespread use in factories

1785
Textile plant in England is the first to be powered by steam

1790
First working United States cotton mill

1792
British engineer W. Murdock invents "town gas"

1800
A. Volta produces the first electricity from a wet-cell battery

1800
Several French towns use geothermal energy for space heating

1800
Hot springs resorts flourish throughout United States, Europe, and Asia

1803
Robert Fulton builds first steam-powered boat

1804
R. Trevithick invents and operates first steam locomotive on a track

1807
Commercial paddle-wheel steamship cargo service begins in New York

1807
First public street lighting using town gas occurs in London

1814
First practical steam locomotive invented by G. Stephenson

1818
First steamship (*Savannah*) crosses the Atlantic

1820
Ampere, Faraday, and Sturgeon experiment with electromagnetism

1821
M. Faraday, England, demonstrates that electricity can produce motion

1821
First U.S. natural gas well drilled in Fredonia, New York

1825
First steam train passenger service offered in England

1830
Steam-driven cars common in London

1831
Joseph Henry perfects electric motor

1831
M. Faraday invents dynamo, one of the first electric generators

1839
Englishman W. Grove builds first fuel cell

1859
First petroleum oil well in America drilled in Pennsylvania

1860
First internal combustion engine built by E. Lenoir, Belgium

1860
The Geysers, California, opens resort for therapeutic hot spring bathing

1861
French scientist A. Mouchot patents world's first solar steam engine

1868
First modern focusing solar power plant heats water for steam engine in Algiers

1870
Z. Gramme perfects dynamo, making it the first workable electrical generator

1874
Power plant in England burns garbage for electrical production (biomass energy)

1876
N. Otto perfects first practical internal-combustion engine (later used in autos)

1876
California's first "commercial" oil well drilled near Newhall, California

1878
T. Edison develops method to transfer electricity for common use

ENERGY TIMELINE (continued)

1879
T. Edison makes incandescent electric light practical

1881
J. d'Arsonval originates idea of using ocean as energy source

1882
Electric power stations go on-line in London and New York

1884
C. Parson develops first practical steam turbine electricity generator

1885
C. Benz develops the first working motorcar powered by gasoline

1886
Swede J. Ericsson invents first parabolic trough solar energy collector

1886
Up to 50 small hydropower plants generate electricity in America

1887
Stockton becomes first California city supplied with natural gas sent through pipelines

1888
First wind machine for electricity built in America

1890
Electricity begins to replace use of natural gas for lighting

1890
First dependable electric motor cars developed in France and Great Britain

1891
U.S. inventor C. Kemp patents first commerical solar water heater

1891
Huge hydroelectric power stations built in Frankfurt, Germany and Niagara Falls, U.S.

1891
Tessla coil invented, producing first high-voltage electricity

1891
First long distance electrical lines completed in Germany

1892
P. LaCour, Denmark, designs efficient machine that generates electricity from wind

1893
First Ford gasoline buggy driven by inventor, H. Ford

1894
Texas oil discovered while drilling for water

1894
Pneumatic (air-filled) tires introduced in France by A. and E. Michelin

1896
First U.S. offshore oil wells (built on wooden piers) drilled near Summerland, California

1896
Niagara Falls hydropower plant sends first long distance electricity in U.S.

1897
C. Parsons outruns every ship in the water with his steam-driven boat

1897
30 percent of homes in Pasadena, California, use Kemp's solar water heaters

1898
Garbage burned specifically for energy in New York (biomass energy)

1900
Power plants driven by hydropower or fossil fuels dot the U.S.

1900
Calistoga, California, hosts over 30 hot springs resorts

1904
Electricity generated from geothermal steam in Larderello, Italy

1905
A. Einstein publishes relativity theory, revolutionizing understanding of energy

1908
First cheap, mass-produced car, the Model T, is available

1910
Coal accounts for three-fourths of all fuel used in United States

1916
Einstein's unifying theory interrelates mass, energy, magnetism, electricity, and light

1918
Denmark produces electricity from over 100 wind generators

1920
Midwest farms in U.S. widely use wind turbines for electricity

1920
Decade begins with oil and gas shortages in California

1928
More than 3 million American families own two cars

1929
After major discoveries, decade ends with surplus of oil and gas in California

1930
Iceland begins to work on large-scale geothermal district heating project

1930
Solar water heaters supply hot water to homes throughout Miami, Florida

ENERGY TIMELINE (continued)

1930
Propeller-type wind generators perfected by M. Jacobs in use all around U.S.

1932
Francis Bacon, Great Britain, develops first successful fuel cell

1935
Rural electrification brings power to remote areas in U.S.; replaces most wind turbines

1936
America's Hoover Dam (for hydropower) completed

1939
Europeans O. Hahn, and L. Meitner unveil process of nuclear fission for energy

1940
First U.S. superhighway opens in Pennsylvania

1941
Almost 60,000 solar water heaters in use in Florida

1942
E. Fermi, using Einstein's theories, produces first controlled nuclear chain reaction in the U.S.

1943
132 MW produced from geothermal fields, Larderello, Italy

1944
U.S. National System of Interstate Highways established

1945
First nuclear bomb detonated in New Mexico

1945
5,000 U.S. homes have television sets

1947
Diesel-electric trains replace steam locomotives in U.S.

1948
One million U.S. homes have television sets

1950
Work-saving appliances and tools use increasing amounts of energy

1952
First U.S. hydrogen bomb detonated with 700 times force of fission bomb

1954
First solar cells used for electric generation developed in U.S.

1954
First Russian nuclear power plant opens

1954
Advanced European steel-manufacturing method introduced in Detroit

1954
First fuel cells used in NASA space program

1955
First U.S. town powered by nuclear energy in Idaho

1958
First major offshore oil-drilling platform built in the Pacific Ocean near Summerland, California

1960
Commercial electricity first produced from geothermal energy at "The Geysers," in California

1960
Environmental concerns increasingly relate to energy use and pollution

1960
German U. Huttrer perfects electrical wind turbine design, later adopted in U.S.

1963
First commercial nuclear power plant opens in New Jersey

1965
Historic electrical blackout in northeastern North America

1966
Partial meltdown at nuclear power plant in Detroit

1966
La Rance tidal power plant built at the Rance estuary in France

1967
First microwave for home use introduced

1968
78 million U.S. homes have television sets

1969
France begins large district-heating projects with geothermal energy

1970
First Earth Day signals worldwide concern about environmental damage

1970
Solar water heating well established in Israel, Japan, Australia

1971
P. McCabe, Great Britain, and M. McCormick, U.S., began development of first wave energy system

1973
Oil embargo opens up new era of electricity produced from renewable sources in U.S.

1973
Japan begins experiments with Ocean Thermal Energy Conversion (OTEC)

1974
J. Lindmayer, U.S., develops silicon photovoltaic cell for harnessing solar power

1977
Solar panels installed on the White House

ENERGY TIMELINE (continued)

1978
Public Utility Regulatory Policies Act, PURPA, encourages small and renewable power producers

1979
Partial meltdown of nuclear reactor at Three Mile Island, Pennsylvania

1979
Experimental OTEC project begins producing electricity in Hawaii

1980
Europe and Asia invest widely in generation of electricity from wind power

1980
Nuclear power generates more electricity than oil in U.S.

1980
Large, powerful wind generators emerge as result of fuel shortages

1982
Solar One in southern California proves that solar thermal power for electricity is feasible

1983
Three out of every four power plants in U.S. burn fossil fuels

1983
World's largest hydroelectric power plant opens in Brazil/Paraguay

1983
First solar thermal "trough" power plan opens in southern California

1984
Large scale biomass power plant opens in Vermont

1986
Worst nuclear meltdown with nuclear fallout occurs at Chernobyl, Ukraine

1990
More than half of world's wind-generated electricity produced in California

1992
6,000 MW of electricity being generated from geothermal in 21 countries

1992
World's top electricity-generating countries are U.S., Canada, Brazil, Russia, and China

1993
Nuclear power provides about one-fifth of U.S. electricity

1997
Hydropower now produces only 10 percent of U.S. electricity

1999
U.S. consumption of petroleum reaches all-time high, more than half for transportation

2000
Injection of wastewater into The Geysers geothermal reservoir boosts electricity production

2000
Renewable energy technologies gain wider acceptance in many parts of world, including U.S.

2000
Utility deregulation in some U.S. states results in ups and downs in opening up the energy production market

2000
Electricity generation produces almost 40 percent of all carbon dioxide emissions in U.S.

2000
State-of-the-art, multi-megawatt wind turbines replacing older models in U.S. and Europe

2000
State-of-the-art waste-to-energy biomass power plants throughout U.S. resolve some pollution and landfill capacity concerns

2000
Solar technology gains popularity in U.S.

2000
Run-of-river hydropower plants produce electricity without disturbing stream flow in many parts of the world

2000
Marine current and wave energy systems gain wider acceptance

2000
Renewable resources contribute 9 percent of electricity in U.S. and 18 percent globally

2000
Nuclear energy provides 20 percent of all U.S. electricity

2000
Fossil fuels (coal, oil, gas) provide 71 percent of all electricity production in U.S.

2000
99 percent of U.S. households have a color television

Note: Suggestions for the Energy Timeline are always welcome. Please send them to energyforkeeps@aol.com.

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GLOSSARY

A

acid precipitation (acid rain): any precipitation that primarily contains damaging sulfuric and nitric acids; may harm and/or destroy natural land or water habitats and corrode human structures including roads, buildings, and bridges

active solar: any system for collecting, storing, and releasing solar energy that requires an outside source of energy to operate system equipment, such as fans or pumps

A.D.: any year after the birth of Jesus Christ; from the Latin, *anno Domini*, meaning "in the year of our Lord;" from 20 B.C. to 50 A.D. is 70 years

alloy: a mixture of different metals; for example, bronze, a mix of copper and tin; some alloys include metals mixed with non-metals (e.g., some kinds of steel are made of several metals plus carbon, a non-metal)

alternating current (AC): an electric current that reverses direction at regular intervals; caused by an alternating electromotive force (the force that produces en electric current)

alternative energy: an older term, the use of which is diminishing, as renewable energy becomes better known and more widely accepted; once defined as a source of energy other than fossil fuels, hydropower, or nuclear

alternator: an electric generator that produces alternating current

ampere (amp): a measure of the amount of current, or electrons, flowing in a wire over time; one ampere = 6.25×10^{18} electrons per second

anaerobic digestion: the breakdown of organic materials by bacteria in the absence of oxygen; results in the production of gases, primarily methane and carbon dioxide; occurs naturally or can be caused to occur under controlled conditions

anemometer: a device for measuring wind speed

anode: the positively charged electrode in an electrical circuit or in an electrochemical reaction

aquafarming: the cultivation of fish and other water-dwelling organisms under controlled conditions

array: in general, a symmetrical arrangement of a large group, as in rows; in solar energy, usually refers to an arrangement of a large group of photovoltaic (solar) panels or mirrors

atom: the smallest particle of an element that retains the chemical properties of that element; composed of protons, neutrons, and electrons

B

balance of trade: the difference in value over a period of time between a country's imports and exports

barrage: an artificial obstruction, such as a dam or an irrigation channel, built in a river or other waterway to increase depth or divert flow

baseload power: the amount of power needed to supply the minimum anticipated demand for electricity at any given time

B.C.: any year before the birth of Jesus Christ; from 20 B.C. to 50 A.D. is 70 years

binary power plant: geothermal power plant that uses a heat exchanger to transfer heat to a second (binary means two) liquid that flashes to vapor and drives a turbine-generator

biomass: anything that is, or was once, alive; organic material

blackout: the loss of electricity, caused intentionally or by an electrical power failure

blast furnace: a furnace in which the combustion of a fuel is intensified using blasts of air or pure oxygen

brine: water containing large amounts of salts, particularly sodium chloride

brownout: a reduction in electric power; may be the result of a shortage or mechanical failure, or may be intentional in response to excessive consumer demand

GLOSSARY (continued)

byproduct: something produced in the making of something else; a secondary product produced from the production of a primary product

C

capacity: in electricity generation, the maximum electrical output that a turbine or turbines in a power plant are rated (by the manufacturer) to generate

carbon cycle: the chemical cycle in which the element carbon naturally circulates in various forms throughout the living and nonliving systems of the earth over time

carbon monoxide: a gaseous molecule composed of one atom of carbon and one atom of oxygen; is highly toxic to animals and humans

carbon sink: components of the global ecosystem that store carbon; includes all plants, the ocean, old-growth forest floor litter (duff), soils, fossil fuels, and certain minerals such as limestone

carbon-based compound: element whose atomic structure causes it to join with a variety of other elements, forming the basis of many different compounds; the basis of all living things, as well as for fossil fuels (hydrocarbons) and many other substances, including diamonds and graphite

cathode: the negatively charged electrode in an electrical circuit or in an electrochemical reaction

centigrade (C): also Celsius; the temperature scale that registers the sea-level boiling point of water as 100° and the freezing point as 0°

central receiving tower: a concentrating solar power technology; a tall structure with a top section that contains a liquid, such as molten salt, water, or liquid metal, that has a high heat capacity; this liquid is heated by the reflection of solar energy from concentrating mirrors aimed at the tower's focal point

chain reaction: in physics, a method of releasing energy from the atom in a multistage nuclear reaction, in which the release of neutrons from the splitting of one atom leads to the splitting of others

charcoal: a material containing large quantities of carbon, formed by heating wood or other organic material in the absence of air

Clean Air Act (CAA): federal law designed to protect public health by setting standards and enforcement regulations regarding polluting air emissions from energy production and other human activities

cogeneration: the process of doing work utilizing two forms of energy, usually thermal (heat) energy and electrical energy, both produced simultaneously from one source

coke: a fuel that burns very hot; used primarily in metal production; produced by removing mainly the sulfur (which makes iron brittle when smelted) from coal

combined cycle power plant: power plant in which two different turbines — most commonly a gas turbine accompanied by a steam turbine — work in succession to produce electricity; most gas-fired power plants are combined cycle plants

combustion: the process of burning, which is a chemical change requiring the presence of oxygen that results in the production of heat and light

complete circuit: a complete and circular path for an electric current to follow as it moves through wires and electrical devices

compound: substance made of two or more elements that are bonded together chemically

concentrating solar power: any of the solar energy systems (solar dish engines, parabolic troughs, and central receiving towers) that focus, or concentrate, the energy of the sun for energy production or storage

condenser: a device that uses a cooling process to cause a vapor to condense to a liquid

conduction: the transmission of electric charge or heat through a conductor

conductor: in electricity, a substance or medium that conducts, or transmits, an electric charge; in thermal energy, a medium that allows the movement of heat through it

GLOSSARY (continued)

conservation: the controlled use and systematic protection of natural resources such as water, minerals, forests, and soil; also, the practice of avoiding and reducing waste, as in the production of or use of electricity

containment vessel: at a nuclear power plant, a large structure that houses the reactor core, its radiation shield, and the reactor core's maintenance equipment; the containment vessel is surrounded by an outer concrete building designed to prevent the escape of radiation in the event of an internal power plant accident or by an external event such as an airplane crash

control rod: in a nuclear power plant, a long rod made of material that absorbs neutrons; a number of these are inserted amidst the fuel rods in the reactor core; control rods are raised and lowered as needed to control the nuclear chain reaction, and thus the amount of heat energy produced

controller: in a wind turbine, a computerized device that receives information from all the sensors on the turbine (including anemometers, blade positions, temperatures, fault conditions, loads, vibration etc.) and uses this information to determine how to control all the various devices on a turbine

crude oil: unprocessed oil (petroleum) that varies in color and in thickness (viscosity); contains many different compounds, which can be separated and used for a variety of products, including energy fuels such as gasoline, heating oil, and butane

crust: in geology, the relatively thin, outermost rock layer of the earth

D

decompose: to become broken down into basic components or elements; to rot

deflect: to cause to turn aside

demand: in electrical power, the amount of electricity needed at any given time, based on the amount being used by all electrical devices connected to the power supply through the power grid

dense (density): the amount of mass, or matter, that is in a given volume of something; e.g., the molecules of a substance that is very dense are packed very closely together

deplete: to use up or consume

direct current (DC): an electric current that flows only in one direction

direct use geothermal: systems that use geothermal resources directly for heat energy rather than for producing electricity; includes space heating, greenhouse and fish farm operations, bathing and swimming at health spas, and industrial applications such as food and timber drying

disclosure: the act or process of revealing or uncovering; in energy management, the ready provision of information by a power provider regarding which energy resources are being used to produce electricity

distributed generation: supplying on-site electricity using small generating units; can be comprised of similar systems or a variety of different system types; distributed generation is used to manage peak loads, to add extra power for a region without having to build a large power plant, to provide electricity for remote locations or for a vital industry such as a hospital that needs power at all times, even when grid power is unavailable

dry steam power plant: geothermal power plant that uses steam directly from a steam-filled geothermal reservoir

dynamo: an electric generator that usually produces direct current

E

ebb: to fall away or recede

ecological: pertaining to the science of the relationships between organisms and their environments

ecosystem: the community of all organisms living in an area and their interactions with the physical environment; an exchange of materials between the living and non-living parts

GLOSSARY (continued)

electric current: the flow of charged particles through a conductive material

electrical energy: the energy of electrical charges, usually electrons in motion

electrochemical: the interaction of electrical and chemical phenomena

electrode: a solid electric conductor, such as a piece of metal, through which an electric current enters or leaves a solution containing an electrolyte; also, a collector or emitter of electric charge, such as found in a fuel cell

electrolysis: chemical reaction caused by passing an electric current through a liquid containing an electrolyte, resulting in the break down of the liquid's molecules; the electrolysis of water releases hydrogen and oxygen

electrolyte: a chemical compound which, when molten or dissolved, usually in water, will conduct an electric current; an electrolyte solution

electromagnetic spectrum: radiated energy waves as described in terms of their wavelengths and frequencies, including gamma rays, X-rays, ultraviolet, visible light, infrared radiation, microwaves, radar, television, and radio; the sun is the largest natural source of electromagnetic radiation

electromagnetism: the study of the relationship between magnetism and electricity; the phenomena of producing electricity using magnetism and vice versa

electron: a negatively charged component of an atom; exists outside of and surrounding the atom's nucleus; can either be free or bound to a nucleus

element: the simplest possible chemical, made up of its own particular kind of atom; most elements occur naturally, though some have also been made artificially

encroach: to advance beyond usual or proper limits

energy conservation: the planned management of energy resources and energy use in order to prevent waste and to ensure future availability

energy conversion (transformation): the process of changing energy from one form to another

energy farm: a farm that grows plants specifically as biomass energy crops

estuary: a river mouth broadening into the sea; if undisturbed, estuaries are very fertile and provide habitat for a variety of wildlife

exempt: excused or released from a requirement

F

Fahrenheit (F): the temperature scale that registers the sea-level boiling point of water as 212°F and the freezing point as 32°F

fissionable: in nuclear power, an unstable element that is capable of being split; in a nuclear power plant, fissionable material — primarily one form of uranium (U-235) — is used to produce a nuclear chain reaction

fissure: in geology, an extensive crack, break, or fracture in rock

fixed-speed wind turbine: a wind turbine that always turns at the same speed, regardless of how fast the wind is blowing; the machinery of a fixed-speed wind turbine is simpler than that in a variable-speed turbine

flash power plant: a geothermal power plant that uses a process in which geothermal water is converted to steam to drive a turbine

fossil fuels: coal, oil, natural gas, and products made from them; fossil fuels are the remains of once-living (organic) plants and animals formed underground and subjected to intense heat and pressure over millions of years; have high concentrations of carbon and hydrogen and can be burned, producing energy as well as polluting emissions

fuel rod: at a nuclear power plant, pellets of uranium (U-235) that are arranged in long rods, which are collected together into bundles and placed in the reactor core

fumarole: steam and gas, venting from the earth's crust

GLOSSARY (continued)

G

gas turbine: power plant turbine that is driven by a continuous blast of hot gas from the combustion of natural gas combined with high-pressure air

gasification: the process of converting into or becoming a gas

generator: a machine that transforms (converts) mechanical energy into electrical energy

geothermal reservoir (hydrothermal aquifer): a large volume of underground water saturating (filling) porous and permeable rock, superheated by the hot rock and hot magma nearby

geothermal: the heat of the earth's interior; the earth's natural heat emanating from its core outward and from the radioactive decay of certain elements in the crust

global climate change: long-lasting changes in Earth's weather patterns and systems, resulting in dramatic, possibly harmful, changes in habitats and ecosystems worldwide; is thought by many researchers to be caused by the overall (global) warming of the planet, resulting from an excess of greenhouse gases in the atmosphere

green energy: any energy source considered to be environmentally friendly; commonly associated with renewable energy sources, but also sometimes used when referring to nonrenewable sources that produce few pollutants

green pricing: offering customers the choice of paying additional fees on their utility bill in order to support the production of renewable energy; in some cases some, or all, of the electricity that these customers actually receive has been produced by renewable energy sources; in others, renewable generation elsewhere is paid for by green pricing

green waste: yard trimmings (usually leaves, grass clippings, and tree and bush trimmings) that are collected in specially designated containers and used for various purposes, including as a source of biomass energy

greenhouse effect: the trapping of heat energy from the sun in Earth's atmosphere, notably by water vapor and greenhouse gases such as carbon dioxide, nitrous oxide, and methane; the resulting heat energy warms the planet's surface

greenhouse gas: any gas in the atmosphere that contributes to the greenhouse effect

grid: the interconnected system that distributes electricity, including power plant(s), transmission and distribution lines, towers, substations, and transformers

groundwater: water that collects underground, mostly from surface water that has seeped down through cracks and pores in rock

H

habitat: the place that is natural for the life and growth of an organism

head: in hydropower, the distance that water falls before it hits a turbine generator

heat (thermal) energy: the energy that flows from one body to another because of a temperature difference between them; the effects of heat energy result from the motion of molecules

heat engine: any device that converts heat energy into mechanical energy; typical heat engines include steam engines, steam and gas turbines, internal combustion (vehicle) engines, and Stirling engine

heat exchanger: device used to transfer thermal (heat) energy from a liquid flowing on one side of a barrier to a liquid flowing on the other side

heliostat: an instrument in which a mirror is automatically moved so that it reflects sunlight in a constant direction

high and low tide: the rise and fall of the earth's oceans, caused mainly by gravitational forces of the moon and the sun

horsepower: originally the power exerted by a horse when pulling; now, a unit of power equal to 745.7 watts per minute

GLOSSARY (continued)

hot dry rock: a potential source of heat energy within the earth's crust; a geothermal resource created when hot but impermeable (does not allow water to pass through) underground rock structures are fractured to allow infiltration of water, thus creating an artificial geothermal reservoir

hydrocarbon: any compound made up of hydrogen and carbon; will combine with oxygen when burned, producing heat energy; includes all the fossil fuels

hydrogen gas: colorless, combustible gas that can be used as an energy source; does not occur naturally by itself, and must be separated from another substance, such as from water, biomass, or a fossil fuel

hydrogen sulfide: a gas with a disagreeable odor, frequently dissolved in geothermal waters in small amounts; toxic at high concentrations

hydropower: methods of producing electricity using the energy of rapidly flowing or falling water

I

impoundment: a structure which allows the accumulation and storage of water in a reservoir; a dam placed across a river

incandescent light bulb: a glass bulb of inert gas (gas that is not readily reactive) that emits visible light as a result of passing electricity through a filament found inside the bulb, causing it to heat and glow

indirect (hidden) costs: the costs of producing a product (including electricity) that are not directly accounted for by an industry or utility, but are borne by other sectors of society

Industrial Revolution: the shift to large-scale factory production brought about by the extensive use of machinery, often driven by steam engines; generally thought to occur between the 1750s to the mid to late 1800s; resulted in dramatic social, environmental, and economic changes

industrial: the practice of making goods; often implies the production of large quantities of manufactured items, as found in factories

infrared: heat radiation; part of the electromagnetic spectrum radiated from the sun and other hot objects

internal combustion engine: an engine, used primarily in vehicles, in which fuel is burned within the engine itself, rather than fuel being burned in an external furnace, as in a steam engine

J

jet stream: a narrow belt of westerly winds found at high altitude that can reach speeds of up to 230mph (370 km/h)

K

kilowatt: 1,000 watts

kilowatt-hour: the energy expended when 1,000 watts of electrical power are used for one hour

M

magma: hot, thick, molten rock found beneath the earth's surface; formed mainly in the mantle; some estimate its temperature to reach over 2,100ºF (1,200ºC)

magnetic field: a condition found in the region around a magnet or an electric current where a detectable magnetic force is found at every point in the region and where there are distinguishable magnetic poles

mantle: the zone of the earth below the crust and above the core, primarily filled with a mixture of molten and solid rock

manufacture: to make a finished product, often using large-scale industrial operations

marine (ocean) current: movement of ocean water: either two-way (tidal) or one-way (like the Gulf Stream)

mass: in physics, the measure of the quantity of matter that an object or body contains

mass-produce: to manufacture in large quantities, often using assembly lines

GLOSSARY (continued)

mechanical energy: the energy of an object as represented by its movement, position, or both

medieval: relating to a period in European history, usually between ancient cultures and the Renaissance (A.D. 476 to 1453), during which scientific and philosophical innovations were often suppressed

megawatt: 1,000 kilowatts

methane gas: an odorless, colorless, combustible gas that can be used as an energy source; the primary component of natural gas and a source for hydrogen gas

microbe: a microorganism; microscopic life form

modular: designed with standardized equipment and dimensions designed for flexible arrangement and the ability to add more units

module: in solar energy, a group of photovoltaic (solar) cells wired together into a single unit that can be grouped in any combination with other modules; in geothermal, a turbine-generator unit

mud pot: a type of hot spring containing boiling mud

multi-megawatt turbine: very tall wind turbine with huge blades that catch the faster wind speeds found higher from the ground; ones most commonly used can generate between 1-2.5 megawatts of electricity; more advanced designs may produce up to 5 megawatts

N

nacelle: in a wind turbine, a covered housing that protects the gear box, high– and low–speed shafts, generator, controller, and brake

NASA: the National Aeronautics and Space Administration; United States' space exploration agency; many scientific and technological advances that originated at NASA have been introduced into other industries

negative charge: one of two kinds of electric charge, the kind carried by an electron (a positive charge is carried by a proton)

net metering: a program offered by power producers that encourages grid-connected consumers to generate some or all of their own electricity using specific, usually renewable, resources; in many cases, this type of program allows the consumer's meter to turn backwards when they are producing more power than they are using, and some utilities will pay the consumer for the net excess power generated

neutron: an electrically neutral subatomic particle

nitric acid: a transparent, colorless to yellowish, corrosive substance; one of the components of acid precipitation

nitrogen oxides: gases formed mainly from nitrogen and oxygen; one of the damaging components of acid precipitation

nonrenewable energy: energy sources that do not regenerate themselves in a useful amount of time, including fossil fuels and nuclear fuels

nuclear fission: a reaction in which an atomic nucleus is split into fragments, releasing large quantities of energy

nuclear fuels: minerals, such as uranium, from which energy is liberated by a nuclear reaction or by radioactive decay

nuclear fusion: a reaction in which nuclei are combined (fused) to form a more massive nucleus, accompanied by the release of energy

nucleus: the positively charged central region of an atom (plural: nuclei)

O

Ocean Thermal Energy Conversion (OTEC): ocean energy technology that produces electricity — sometimes along with clean drinking water — by taking advantage of the temperature difference between warm surface ocean water and cold water from the ocean depths

oil refinery: factory where crude oil is separated into various components and cleaned to remove some impurities

GLOSSARY (continued)

oil rig: large collection of machines, hoists, and power equipment, established on land or on platforms or barges in open water; used to drill down into oil reserves found in underground rock

old-growth forest: forest having a mature ecosystem, including presence of old woody plants (mainly trees), and the wildlife and smaller plants associated with them; typically old-growth forest floors are made up of "duff," a rich layer of debris, decomposing matter, and leaves

one-way marine currents: deep oceanic currents that result from varying conditions of ocean water including differences in temperature and water density

organic decay: the breakdown of organic matter as a result of bacterial or fungal action; rot

organic: derived from living organisms

oscillating: to swing back and forth with a steady, uninterrupted rhythm

ozone: a highly reactive molecule made of three atoms of oxygen; high in the atmosphere ozone forms a protective layer that filters out harmful ultraviolet radiation; is formed at the earth's surface as a harmful component of photochemical smog

P

parabolic: a curved geometric shape based on the parabola; when radiant energy, such as sunlight, hits a parabolic surface and is reflected back, all the reflected radiant waves pass through one area of space in front of the parabolic surface known as the focus; in solar energy, parabolic surfaces, such as parabolic mirrors, are used to concentrate radiant waves from the sun

parabolic trough: a concentrating solar power technology that utilizes a long, trough-shaped parabolic reflector to focus the sun's energy onto a pipe that contains a liquid that boils to produce steam

particulates: solid particles and liquid droplets suspended in the air, including smoke, soot, dust, and ash

passive solar: techniques using the structure of a building for heating or cooling that require no collectors, pumps, or other devices; examples include large, south-facing windows to allow solar energy in to warm the house, or awnings to block solar radiation to cool the house

peak load: the time(s) of day when consumers demand (use) the most electricity

peaking power: the electricity demand, or need, that exceeds the amount of baseload power available at any given time

penstock: a conduit or pipe that carries water from a storage reservoir or from upriver to a turbine

photochemical smog: a complex mixture of air pollutants, produced in the lower atmosphere by the reaction of hydrogen and nitrogen oxides when exposed to sunlight; is unsightly, damages vegetation, and leads to eye and respiratory ailments in animals and humans

photon: tiny bundles of electromagnetic radiation that move rapidly from one place to another at the speed of light; sometimes considered a flow of particles; the sun emits huge quantities of photons

photovoltaic: refers to the ability to convert photons into electrical energy; photons are used to dislodge electrons from atoms of silicon or other materials, causing them to migrate, producing an electric current

policy: a plan or general set of guidelines that reflects a particular set of values and influences specific actions and decisions

porous: able to hold water in spaces within rock

positive charge: one of two kinds of electric charge, the kind carried by a proton

proton: a positively charged subatomic particle found in all nuclei

pumped storage: a system of generating electricity using water pumped from a lower reservoir to a higher storage site and later released to fall back to the lower reservoir when electricity is needed; used as a method of "storing" energy; generally, surplus electric power is used to lift the water when demand is low

GLOSSARY (continued)

R

radiant energy: energy transmitted in the form of rays, waves, or particles

radioactive: emitting radiation, either from unstable (fissionable) nuclei or from a nuclear chain reaction

reactive: an element or compound that tends to participate readily in chemical reaction

reactor core: in a nuclear power plant, the contained assembly of fuel rods, around which a liquid or gas flows in pipes to remove the resulting heat energy

rebate: return of a percentage of the cost of an item

regenerate: to renew the supply of something, such as an energy resource

renewable energy: any energy resource that can be used without being exhausted

Renewable Portfolio Standards: a set of standards, adopted by a government, designed to ensure that a certain percentage of various renewable energy resources be included in the portfolio (assorted collection) of its power providers or sources

resistance: opposition to the passage of electric current, causing electric energy to be transformed into heat

rotor: the rotating part (the blades and hub) of an electrical or mechanical device

run-of-river (diversion): hydropower system that produces electricity while still maintaining the natural or near-natural flow of a river (as opposed to creating an impoundment to hold the river back to form a reservoir); most run-of-river systems divert some of the water through an electrical powerhouse and then return it to the river

S

scrubber: an apparatus used to remove impurities from gaseous emissions

silicon: one of the most abundant elements on Earth; always occurs in combination with other elements; high heat is required to isolate it; widely used in products such as glass, ceramics, computer microchips, and solar photovoltaic cells

sluice: an artificial channel for conducting water

smelt: to melt ore (rock containing valuable minerals, especially metals) in order to separate the metal from the rock

solar cell: a photovoltaic device that converts solar energy into electrical energy using an electrochemical reaction in which electrons are caused to move, creating an electrical current

solar dish engine: a concentrating solar power technology that uses either one large, dish-shaped parabolic mirror, or a group of these mirrors, to concentrate the thermal (heat) energy of solar radiation onto a receiver; a heat engine in the receiver converts the concentrated heat into mechanical energy to drive an electrical generator

solar energy: the radiant energy from the sun received by the earth

solar panel: a group of around 10 solar, or photovoltaic, modules (see solar cell) that are assembled together into a panel

spent fuel: fissionable material left over from a nuclear reaction; spent nuclear fuel is still radioactive, therefore toxic; classified as hazardous waste, and must be handled and stored properly for safety

stand-alone wind turbine: a wind turbine that is not part of a wind farm; most commonly used in remote or rural locations, and is often not connected to the electrical grid

static electricity: an accumulation of electric charge (as opposed to the movement of electric charge known as electric current); imbalance between positive and negative charges

steam reforming: a form of fuel processing often used to produce hydrogen gas, frequently from natural gas or biomass; uses a special process involving heat and a catalyst (substance that increases the rate of a chemical reaction without being consumed in the process)

GLOSSARY (continued)

Stirling engine: an engine that has a sealed chamber where heat is focused on one side, causing the air inside to expand and push down on a piston; as the piston moves, air flows to the cold side of the engine where it is cooled; a second piston pushes the cooled air back to the hot side

strait: a narrow channel joining two larger bodies of water

subatomic particle: any of various units of matter below the size of an atom, including neutrons, protons, and electrons

substation: in electrical transmission, the location of the transformer equipment that decreases the voltage of electric current after it has traveled through high-voltage transmission lines

sulfur oxides: pungent, colorless gases formed mainly by the combustion of fossil fuels; considered a major air pollutant

sulfuric acid: a colorless to dark brown, highly corrosive, dense liquid; sulfur oxide dissolved in water

sustainable: a process, system, or technology that does not deplete resources or cause environmental damage and thus lasts indefinitely; a school of thought that advocates preserving meaningful choices, such as of energy resources, for future generations

synthetic: not natural; the combination (synthesis) of materials to form a product that may or may not occur naturally

system efficiency: input (of energy or work) versus output (of energy or work) of a system, often expressed as a ratio (energy in divided by energy out); theoretically, the ratio is never one-to-one

T

tailrace: the part below a water wheel or water turbine through which the used (spent) water flows

tectonic plates: the large sections of the earth's crust that are slowly moving over the mantle; the plates interact with one another at their boundaries, causing a variety of geologic phenomena including earthquake and volcanic activity

telegraph: apparatus historically used to communicate Morse code at a distance over a wire using electrical impulses

temperate zone: a region with a moderate climate, characterized by being neither too hot nor too cold

terrain: the surface features of an area of land

textile: cloth, especially that manufactured by weaving or knitting

thermal energy: see heat energy

tidal currents: the two-directional, in and out and up and down movements of the ocean along coastlines

tidal fence: an ocean energy technology that uses a long, connected series of underwater turbines that utilize the tides to produce electricity

tidal power plant: marine current energy technology that uses the mechanical energy of ocean tides to produce electricity; traditional tidal systems situate turbines in a barrage (dam) through which the tides come in and out; newer designs use free-standing, generally submerged, turbines located at or near shorelines

town gas: gas (composed mainly of hydrogen) that is manufactured from raw materials such as coal, coke, or oil; is distinguished from natural gas, which occurs naturally in underground deposits; during the 1800s town gas was widely distributed through pipelines to many cities and towns in Europe and America for light and heat

transformer: device used to "step-up" (increase) or "step-down" (decrease) the voltage of electric current

transmission lines: long distance wires through which high-voltage electricity travels

transmit: to send from one place to another

turbine: bladed, wheel-like device caused to spin by the force of pressurized steam or gas, wind, or moving water; used in electricity production to drive an electrical generator

GLOSSARY (continued)

U

U.S. Environmental Protection Agency (EPA): a federal agency of the United States whose mission is to protect the nation's natural environment; establishes and enforces regulations through a network of regional offices

ultraviolet: radiant waves that are part of the electromagnetic spectrum; are invisible to the human eye; solar ultraviolet radiation comes in several wavelengths, one of which is harmful to biological life, but most of which is absorbed by upper atmospheric ozone layer

unburned hydrocarbons: air pollutants that come from the incomplete combustion of fossil fuels and from the evaporation of petroleum fuels, industrial solvents, painting and dry cleaning chemicals

uranium: a heavy, silvery-white metallic element that is radioactive and toxic; exists in 14 different forms, or isotopes; is extracted from ores for use in research, nuclear fuels, and nuclear weapons

V

vaporize: to convert into a vapor, the gaseous state of a substance

variable-speed wind turbine: turbine that can respond to wind speed changes to take advantage of a wide range of energy production from wind

voltage: the measure of the electrical force that "pushes," or drives, an electric current

W

wastewater: the collective discharge from toilets, sinks, showers, washing machines, storm-sewers, etc.; can be cleaned, or "treated," to remove most of the toxic components and then used for purposes other than consumption by animals or humans

water cycle: the natural process of the movement of Earth's water as it evaporates from bodies of water, condenses, precipitates (rains, sleets, hails, snows) and returns to those bodies of water, in a continuous cycle

watt: the rate of electrical current flow, when one ampere is driven, or "pushed," by one volt

watt-hour: the energy expended when one watt of electrical power is used for an hour

Wave Energy Conversion Systems (WECS): any of a variety of ocean energy systems that employ the moving (mechanical) energy of waves to produce electricity; can be located along shorelines or in the open sea.

wet-cell battery: a battery, or "cell," in which an electrochemical reaction occurs in an electrolyte

wetland: a lowland area, such as a marsh, swamp, or estuary, that is saturated with moisture; provides a rich habitat for wildlife; absorbs heavy metals and filters out toxins, releases oxygen into the air while removing carbon dioxide and other greenhouse gases; provides flood control and is a significant factor in the recharge of groundwater

wind farm: a cluster of wind turbines located in areas with reliably favorable wind speeds, such as on high windy mountain passes or gusty open plains; can also be situated on farms or ranches alongside other uses such as crop-growing or ranching

ADDITIONAL INFORMATION RESOURCES

There is a wealth of information available on all aspects of energy use. Space constraints limited what we could include here. However, many of the sources listed below include great website links and suggestions for additional materials. And check our website (www.energyforkeeps.org) occasionally for more postings of educational resources.

GENERAL

Organizations and Websites

Acorn Naturalists
800-422-8886
www.acornnaturalists.com

Books and other teaching materials on many topics including environmental education, outdoor education, science inquiry, interpreting cultural and natural resources, "GEMS" ("Great Explorations in Math and Science"), earth science, ecology, plant and animal studies, and the ocean.

Alliance to Save Energy
202-857-0666
www.ase.org

Advocacy organization promoting energy efficiency; energy efficiency programs, including "Energy Science Fair," "Green Schools," "New School Construction," and "Downloadable Educator Lesson Plans;" links for teachers and students.

Ask an Energy Expert
1-800-DOE-3732
www.eere.energy.gov/askanenergyexpert

A division of U.S. DOE Office of Energy Efficiency and Renewable Energy; answers questions ranging from how to make your school more energy efficient to specifics on the use of renewable energy.

Bonneville Power Administration (BPA)
800-282-3713
www.bpa.gov

"Resources for Teachers" includes curriculum units, booklets, activities, posters, videos, films; kids site. General information on water, hydroelectricity, energy conservation, electric safety, resource planning and BPA history; links for other information.

California Energy Commission (CEC)
General: 916-654-4287
CEC Renewable Energy and
Consumer Energy Efficiency Information
Toll Free in California: 1-800-555-7794
Outside California: 916-654-4058
www.energy.ca.gov

Consumer Energy Center Website; information about energy efficiency, energy statistics, and renewable energy; rebate information news releases; programs include energy efficiency, renewable energy development, alternative fuel vehicles. Highly recommended kids website: "Energy Quest."

California Energy Commission Kids Site: Energy Quest
www.energyquest.ca.gov

"Timeline of Energy History," "The Energy Story" (all aspects of energy and energy resources, including all the renewables), games, energy terms, "How Things Work," science projects, "Ask Professor Questor," teacher and parent resources.

California Mineral Education Foundation
916-655-1050
www.calmineraled.org

Charitable education corporation developed to provide mineral education programs for K-12 teachers. Covers wide variety of geological topics, as well as mining and processing of minerals. Curriculum materials, educational programs, grants, and extensive links.

Center for Energy Efficiency and Renewable Technologies (CEERT)
916-442-7785
www.ceert.org

Based in Sacramento, public interest coalition working towards policy change and public education regarding the use of sustainable, environmentally sound methods to meet California's energy needs. Up-to-date information on renewable energy technologies, energy efficiency, and energy policy.

ADDITIONAL INFORMATION RESOURCES (continued)

Chelsea Green: Books for Sustainable Living
800-639-4099
www.chelseagreen.com

Wide range of sustainable living books and some videos on topics such as energy-efficient homes, stand-alone renewable energy systems, ecological architectural design, and renewable energy.

Energy Ant: DOE Kids Zone
www.eia.doe.gov/kids

Energy history, articles on various energy topics, "What is Energy," "Kids Corner," "Energy Quiz," teacher resources, links.

The Franklin Institute Science Museum
214-448-1200
www.fi.edu

Museum online resource; science history; energy information; online study unit topics include wind, plate tectonics, oceans; links to many other resources; "Community Science Action Guides" include global warming, fossil fuel depletion, nuclear energy, energy resources, and visual animations of energy at work.

How Stuff Works
www.howstuffworks.com

Reliable information source on just about every topic, including many specific energy-related topics.

National Energy Education Development (NEED)
703-257-1117
www.need.org

Partner with U.S. DOE's Rebuild America and "Energy Smart Schools." Information about energy resources, including how their use impacts the environment; K-12 curriculum material including hands-on activities about the science of energy, electricity, efficiency and conservation; training and professional development; photo gallery.

National Energy Foundation
801-908-5800
www.nef1.org

Information about renewable energy, efficiency, and conservation. Materials catalog, NEF Academy for professional development, Energy Action Programs (energy awareness and energy management for schools, community, home), student programs include "Academy of Energy," "Fueling the Future," and "Igniting Creative Energy;" links to many energy-related topics for teachers and for students.

National Renewable Energy Laboratory (NREL)
303-275-3000
www.nrel.gov/education

U.S. DOE's laboratory for renewable energy and energy efficiency research and development; general information on state-of-the-art renewable energy technologies; Office of Education Program provides renewable energy and energy efficiency curriculum, activities, projects; student competitions; teacher training, including direct access to current renewable energy research.

National Science Resources Center
Smithsonian Institution/The National Academies
www.si.edu/nsrc

Many educational resources on all topics, including energy; publications; science newsletter; links to many resources; science curriculum units for both middle school and K-6.

National Science Teachers Association
World of Energy
www.nsta.org/Energy

Library of energy resources; interactive decision making simulation; energy facts and figures.
The Science Store has many resources including curriculum units on electricity, magnetism, chemistry, geology, and oceanography. Interdisciplinary titles include "American History Through Earth Science," "Reinvent the Wheel" (stories behind key inventions with hands-on science activities), "Mixing it Up: Integrated, Interdisciplinary Intriguing Science," and "The New Science Literacy: Using Language Skills to Help Students." Links to recommended energy education sites.

ADDITIONAL INFORMATION RESOURCES (continued)

Northeast Sustainable Energy Association
413-774-6051
www.nesea.org

Education section provides interdisciplinary K-12 curriculum materials on energy, transportation, and the environment, links, other educator materials, access to "Junior Solar Sprint Model Solar Car Competition," links to "Information on Clean Energy," and "Green Buildings."

NOVA Science in the News
Australian Academy of Science
www.science.org.au/nova

Up-to-date linked information on various science topics, geared for high school level; categories include environment, physical sciences, and technology; includes links to such topics as climate, electromagnetism, and plate tectonics.

Renewable Energy Policy Project (REPP)
www.crest.org

Information on renewable energy; energy and the environment, efficiency, and policy issues; Library archives; "Global Energy Marketplace," e-mail newsletter; up to date news; recent trends.

Renewable Energy Project Kits
Pembina Institute, Canada
www.re-energy.ca

Provides background information on selected renewable energy resources (including wind, hydropower, solar, biomass) then includes detailed directions for building your own working model related to those energy resources; each resource section includes links to other information sources.

Renewable Energy World
www.jxj.com/magsandj/rew

Website containing many articles from magazine of same title; global coverage of state-of-the-art renewable energy projects and policy issues; information is rather technical, but students can skim for general information; one of the best sources for up-to-date information; check to see if it will give you free subscription to the print-version magazine.

Sustainable Energy Coalition
202-293-2898
www.sustainableenergy.org

Advocacy organization that promotes federal support for energy efficiency and renewable energy technologies; members include Union of Concerned Scientists, American Wind Association, National Hydropower Association and many others; energy facts and statistics; energy policy information; links to many energy experts.

Tennessee Valley Authority Kids Site
www.tvakids.com

Information on protecting the environment, making electricity, "Green Power," electrical safety, TVA history; teacher resources include a K-12 renewable energy curriculum and "Energy Sourcebooks" with teacher guides and energy education activities.

Union of Concerned Scientists
National Headquarters
Phone: 617-547-5552
West Coast Office
Phone: 510-843-1872
www.ucsusa.org

Partnership of scientists and citizens for scientific analysis, policy development and citizen advocacy promoting practical and sustainable environmental solutions in many areas including energy use and pollution; programs include support for renewable energy development and policies.

U.S. Department of Energy (DOE)
Energy Information Administration
202-586-8800
www.eia.doe.gov

Ask an Expert; Energy data, analyses, forecasts, and publications about specific energy resources, as well as general publications such as "Monthly Energy Review," the "Annual Energy Review," the "Short-Term Energy Outlook," and the "Annual Energy Outlook."

ADDITIONAL INFORMATION RESOURCES (continued)

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
202-586-9220
www.eere.energy.gov

Kids site: Dr. E's Energy Lab; "Ask an Energy Expert;" portals to related U.S. DOE offices, as well as to many other programs related to energy efficiency and renewable energy; energy education programs include energy curriculum, science projects and activities, student competitions, and student resources; oversees "EnergySmart Schools" and "Rebuild America" programs.

Books

Brennan, Richard P. **Dictionary of Scientific Literacy**. New York: John Wiley and Sons, Inc, 1992.

Brower, Michael. **Cool Energy: Renewable Solutions to Environmental Problems**. Cambridge, MA: The MIT Press, 1998. (teacher reference only)

Challoner, Jack. **Eyewitness Science: Energy**. London: Dorling Kindersley, 1993.

Christensen, John W. **Global Science**. Dubuque, IA: Kendall/Hunt Publishing Co., 2000.

Christianson, Gale E. **Greenhouse: The 200-year Story of Global Warming**. New York: Penguin Books, 1999. (teacher reference only)

Farndon, John. **Dictionary of the Earth**. London: Dorling Kindersley, 1994.

Macaulay, David. **The New Way Things Work**. Boston: Houghton Mifflin Company, 1998.

Technologies and Sustainable Living. White River Junction, Vermont: Chelsea Green Publishing Co., 2001. (catalog for ordering various products, plus general information)

Science Supply Houses

Carolina Science and Math
800-334-5551
www.carolina.com
Edmund Scientifics
800-728-6999
scientificsonline.com

Nasco Science
800-558-9595
www.nascofa.com

CHAPTER 1: ENERGY HISTORY

California Energy Commission
Energy Time Machine
www.energyquest.ca.gov/time machine

Extensive timeline of energy history from the dawn of history to present day.

Celebrating California's Sesquicentennial with 150 Years of Energy Pictures
California Energy Commission
www.energy.ca.gov/photos

Virtual photo gallery with images of California energy use over last 150 years.

Milestones in the History of Energy and Its Uses
EIA Energy Ant Kids Site
www.eia.doe.gov/kids/milestones

Traces significant events in the history of energy; links to "Pioneers in Energy" and "Energy in the United States, 1635-2000."

Newspapers in Education
515-823-3501
www.abqtrib.com/nie

Offers resources such as "Creating a Classroom Newspaper" and "Science in the News." These and other specific newspaper-related resources are offered through this Albuquerque Tribune NIE website. NIE products are also offered through a number of other newspaper websites; products vary from site to site.

ADDITIONAL INFORMATION RESOURCES (continued)

Pacific Northwest Newspaper Association
206-632-7913
www.pnna.com

Trade association that provides support for use of the newspaper in the classroom, among other projects. Go to Hot Links and look for the "Newspapers in Education" links to various newspaper and educational sites.

Visions of Power
Image Galleries
Smithsonian Institution
americanhistory.si.edu/csr/powering/visions

Virtual gallery with energy images, historical images, and electric power ads of yesterday.

See General category for more history info.

Books

Grun, Bernard. **The Timetables of History**. New York; Simon and Schuster, 1991.

James, Peter and Nick Thorpe. **Ancient Inventions**. New York: Ballantine Books, 1994.

Ochoa, George and Melinda Corey. **The Timeline Book of Science**. New York: Ballantine Books, 1995.

Platt, Richard. **Smithsonian Visual Timeline of Inventions**. London: Dorling Kindersley, 1994.

CHAPTER 2: ELECTRICITY

Electricity and Magnetism Learning Resources
Exploratorium Teacher Institute, San Francisco, CA
www.exploratorium.edu/ti/resources/electricityand magnetism

Resources selected by the Exploratorium's Teacher Institute and Information Resources staff; dozens of print publications, video resources, and internet links.

Electricity Online
ThinkQuest
www.thinkquest.org

Explores the physics, practical applications, and history of electricity in an interactive, online format.

See General category beginning on page 205 for more resources on electricity.

CHAPTER 3: BIOMASS

California Biomass Energy Alliance
805-386-4343
www.calbiomass.org

General biomass information; specific information on California biomass power plants; ask an expert; links.

National Renewable Energy Laboratory (NREL)
Clean Energy Basics
About Biomass Energy
www.nrel.gov/clean energy/bioenergy

Information about state-of-the-art biomass technologies; general information on using biomass for energy.

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
Biopower Division
www.eere.energy.gov/biopower

Information on all aspects of using biomass for energy; links to related organizations and information sources; library; photo gallery.

CHAPTER 3: GEOTHERMAL

Geo-Heat Center
Oregon Institute of Technology
541-885-1750
geoheat.oit.edu

General information on geothermal energy, especially its use at lower temperatures; where geothermal resources are located and being used; access to experts; links to other information sources.

ADDITIONAL INFORMATION RESOURCES (continued)

Geothermal Education Office
415-435-4574
800-866-4436
geothermal.marin.org

Provides educational materials on all aspects of geothermal energy; products include geothermal curriculum unit, videos, maps; links to other resources; access to experts; outstanding website with great "Introduction to Geothermal" slide show.

Books

Ford, Brent. **Project Earth Science: Geology**. Arlington VA: National Science Teachers Association, 1998.

Duffield, Wendell and Sass, John. **Geothermal Energy — Clean Power from the Earth's Heat**. Circular 1249. U.S. Department of the Interior and U.S. Geological Servey, 2003.
(This report and any updates to it are available at http://geopubs.wr.usgs.gov/circular/c1249/

CHAPTER 3: HYDROPOWER

Bonneville Power Administration (BPA)
See page 205.

Bureau of Reclamation Power Program Hydropower Information
www.usbr.gov/power

Topics covered include history of hydropower in the United States; background information on hydropower, major hydropower producers; links to other sources of information; educational materials for K-8, including "Nature of Water Power."

Foundation for Water and Energy Education
800-279-6375
www.fwee.org

Many educational materials on hydropower; information on all aspects of hydropower including environmental impacts.

National Hydropower Association
202-682-1700
www.hydro.org

Advocacy organization promoting the widespread use of hydropower; access to basic hydropower information.

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
Hydropower Division
www.eere.energy.gov/RE/hydropower

Information on all aspects of hydropower; links to other hydropower resources and organizations.

CHAPTER 3: OCEAN

Ocean Energy
CEC Site
www.energy.ca.gov/development/oceanenergy

Basic information on ocean energy and extensive links to government and industry sites.

Ocean Thermal Energy Conversion Fact Sheet
Natural Energy Laboratory of Hawaii Authority
www.hawaii.gov/dbedt/ert/otec

Explanation of OTEC; links to other OTEC reports and other sites with OTEC information.

Practical Ocean Energy Management Systems (POEMS)
619-224-6732
www.poemsinc.org

Advocacy organization dedicated to educating the general public about ocean energy; portal to many different resources related to ocean energy.

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
Ocean Topics
www.eere.energy.gov/RE/ocean

Information on all aspects of ocean energy and links to other ocean energy sites.

ADDITIONAL INFORMATION RESOURCES (continued)

CHAPTER 3: SOLAR

American Solar Energy Society
303-443-3130
www.ases.org

Advocacy organization promoting widespread use of solar energy; information on all aspects of solar energy; magazine: *Solar Today*; Solar Guide Fact Base; publications; educational materials: videos, slides, activities.

Florida Solar Energy Center Teacher Resources
www.fsec.ucf.edu/ed/teachers

Information on all aspects of solar energy; student contests such as Junior Solar Sprint and Hydrogen Sprint; offers many teaching resources including units on energy in general, solar energy, alternative fuels, and environmental issues; links to many other resources.

Project Sol
Arizona Public Service (APS)
http://projectsol.aps.com

A solar education site developed by APS (an Arizona power supplier); topics include energy from the sun, electrical energy, inside PV systems, power for the future; solar data; virtual tour of a photovoltaic cell.

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
Roofus' Solar and Efficient Neighborhood
www.eere.energy.gov/roofus

Interactive website for kids covering various topics, including solar energy and energy efficiency; teacher resources.

CHAPTER 3: WIND

American Wind Energy Association
202-383-2500
www.awea.org

Advocacy organization promoting widespread use of wind energy; information on all aspects of wind energy; online bookstore; "Wind Energy Weekly" covers wind industry, global climate change, and energy policy; resource library; information on specific wind energy projects.

U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy
Wind Energy Program
www.eere.energy.gov/wind

Information on wind energy basics, including how wind turbines work; wind turbine research, and wind energy projects; links to other organizations; resources for teachers and students; photo gallery.

Wind Energy Resource Atlas of the United States
National Renewable Energy Laboratory
http://rredc.nrel.gov/wind/pubs/atlas

Atlas showing the quality of wind energy resources in various parts of the United States.

CHAPTER 3: HYDROGEN

Fuel Cell Store
303-237-3834
www.fuelcellstore.com

Fuel cell products for classroom and for the general public; products include fuel cell demonstration kits, fuel cell systems and accessories; resources for students and teachers, including fuel cell experiments, books, posters, and videos.

National Hydrogen Association
202-223-5547
www.hydrogenus.org

Advocacy organization promoting the widespread use of hydrogen fuel; basic information on hydrogen fuel; resources for students and educators.

Schatz Energy Research Center
707-826-4345
www.humboldt.edu/~serc

Working in affiliation with Humboldt State University's Environmental Resources Engineering program, develops and promotes renewable energy technologies, especially hydrogen fuel cells, zero emission vehicles, and solar hydrogen power systems; information on all aspects of hydrogen and fuel cells; educational materials; links to other related resources.

ADDITIONAL INFORMATION RESOURCES (continued)

CHAPTER 3: FOSSIL FUELS

Petroleum Education
Paleontological Research Institution
607-273-6623
www.priweb.org/ed

"From the Ground Up: The World of Oil" covers all aspects of oil including geology basics, oil history, hydrocarbon systems, daily uses of oil; links to other energy resources.

U.S. Department of Energy (DOE)
Fossil Energy Division
www.fe.doe.gov

Extensive information on all aspects of fossil fuel production and use in the United States and globally; recent fossil fuel news items; clean coal and natural gas technologies; "For Students" section.

CHAPTER 3: NUCLEAR

Nuclear Energy Institute
202-739-8000
www.nei.org

Advocacy organization promoting the use of nuclear energy; information on nuclear technologies; public policy issues; nuclear data; library; "NEI Science Club," teachers and kids site that includes games, information, curricular materials, links.

U.S. Department of Energy (DOE)
Office of Nuclear Energy, Science and Technology
www.ne.doe.gov

Information on all aspects of nuclear energy; nuclear power research; space and defense power programs; nuclear facilities management; nuclear fuel supply security; public information; video: "Splitting Atoms: An Electrifying Experience."

CHAPTER 4: ENERGY, HEALTH, AND THE ENVIRONMENT

Earth Island Institute
415-788-3666
www.earthisland.org

Institute researching and promoting a wide variety of projects on conservation, preservation, and restoration both nationally and globally; "Earth Island Journal," many publications; news and citizen action alerts; information on starting your own action project.

National Oceanic and Atmospheric Administration
202-482-6090
www.noaa.gov

Researches and disseminates information on all aspects of climate, weather, and the oceans; weather forecasting satellite imagery; ocean exploration; fisheries; climate research; air quality; coastal services; undersea laboratory; library and archives; photo library.

See General and Chapter 5 categories for more resources on the environment.

Books

Gutnik, Martin J. **Ecology**. New York: Franklin Watts, Inc., 1984.

Ranger Rick's NatureScope: Pollution — Problems and Solutions. New York: Learning Triangle Press (for National Wildlife Federation), 1998.

Pollock, Steve. **Eyewitness: Ecology**. London: Dorling Kindersley, 2000.

CHAPTER 5: ENERGY POLICY AND MANAGEMENT

Alliance to Save Energy
(*see page 205*)

ADDITIONAL INFORMATION RESOURCES (continued)

American Council for an Energy-efficient Economy
202-429-2248
www.aceee.org

Organization dedicated to advancing energy efficiency; advises on and provides educational information on energy policy, energy efficient buildings, industry, transportation; publications and other consumer information. Look for "Consumer Guide to Home Energy Savings."

Astronomy Picture of the Day (APOD)
National Aeronautics Space Administration
http://antwrp.gsfc.nasa.gov/apod/ap001127.html

Satellite composite photo taken Nov. 27, 2000, shows "Earth at Night": highlights developed or populated areas of the earth's surface; can be used for topics of discussion such as cultural geography and the differences in resource consumption between developed and developing nations.

Cleaner and Greener
Leonardo Academy, Madison, WI
877-977-9277
www.cleanerandgreener.org

Interdisciplinary program to improve the environment through education, analysis, consumer programs, and public policy initiatives; energy efficiency information; K-12 resources; emissions calculators; reports on greenhouse gases, green energy programs.

Redefining Progress: Sustainability Program
510-444-3041
www.rprogress.org/programs/sustainability

Partnership of organizations dedicated to sustainability; calculate your own ecological footprint; ecological footprint concepts and methods; sustainability education resources; publications; links to other sustainability sites.

Rocky Mountain Institute
970-927-3851
www.rmi.org

Investigates and fosters sustainable social, economic, and environmental practices; information on energy, climate, water, transportation, energy efficient buildings; Kids site; educational materials; newsletter, bookstore.

Union of Concerned Scientists
See page 207.

U.S. Environmental Protection Agency (EPA)
www.epa.gov

Federal government health and environment regulatory agency; information on many topics including laws and regulations, environmental management, health topics, pollution prevention, economics, compliance and enforcement; educational resources; extensive Global Warming Site, including Kids site and educator materials and information.

Worldwatch Institute Resource Center
202-452-1999
www.worldwatch.org

Independent research organization advocating environmental sustainability; resource center topics include energy resources, climate change, transportation pollution, biodiversity, food, population, and water issues; publications and news alerts.

See General category for more resources on sustainability and energy management/policy.

STANDARDS CORRELATIONS

CALIFORNIA CONTENT STANDARDS

- This unit has been correlated to all the California Content Standards that are applicable to the unit's content. As of this publication date, the correlation has been done for grades 6-8. Correlations for grades 9-12, when completed, will be posted on the Educators for the Environment website, www.energyforkeeps.org. They will also be included in future editions of this unit.
- The California Content Standards Correlation has been organized by chapter and by grade level. The Standards listed include topics covered anywhere in the chapter, including the discussion section and the accompanying activity(ies). The exception to this is Chapter 3, where you will find the standards correlations broken down into subcategories by energy source.
- Here you will find an Overview for each chapter. On our website, energyforkeeps.org, you will find the complete wording of each standard to which that chapter applies, as well as corrections or additions to the overviews.
- The actual content standards for each discipline have unique organization and numbering systems. We have copied them exactly as they appear in the state documents (see California Department of Education website: www.cde.ca.gov/standards).

NATIONAL SCIENCE STANDARDS

Following the Overviews of the California Content Standards you will find a matrix showing an overview of National Science Standards to which this unit applies. A double asterisk (**) indicates that that Standard is addressed in this unit.

Chapter 1: A Brief History of Energy

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension - Structural Features 2.1-2.4
1.0 Writing Strategies 1.1-1.6
2.0 Writing Applications 2.1-2.3
1.0 Listening and Speaking Strategies 1.1-1.7
HISTORY AND SOCIAL SCIENCE
6.1 #1
SCIENCE
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a
Resources 6a-c

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension - Structural Features 2.1-2.4
1.0 Writing Strategies 1.1-1.7
2.0 Writing Applications 2.3-2.5
1.0 Written and Oral English Language Conventions 1.1-1.7
1.0 Listening and Speaking Strategies 1.1-1.8
2.0 Speaking Applications 2.3
HISTORY AND SOCIAL SCIENCE
7.8 #4 and #5
7.10 #1- #3

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension - Structural Features of Informational Materials 2.1-2.4
1.0 Writing Strategies 1.1-1.6
2.0 Writing Applications 2.3-2.5
1.0 Listening and Speaking Strategies 1.1-1.7
2.0 Speaking Applications 2.1 and 2.3
HISTORY AND SOCIAL SCIENCE
Standard 8.12 #1 and #9

Chapter 2: Energy and Electricity

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing: Organization and Focus 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.5
1.0 Listening and Speaking Strategies 1.4-1.7
2.0 Speaking Applications 2.4a-d and 2.5a-b

MATH
Reinforcement of learned (prior) skills, use of compass and ruler to create pieces needed to complete the activity

SCIENCE
Heat/Thermal Energy 3a-d
Resources 6a-c
Investigation and Experimentation 7b-d

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.7
1.0 Listening and Speaking Strategies 1.1-1.6

MATH
Reinforcement of learned (prior) skills, use of compass and ruler to create pieces needed to complete the activity

SCIENCE
Investigation and Experimentation 7a-e

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.6
1.0 Listening and Speaking Strategies 1.1-1.7

MATH
Reinforcement of learned (prior) skills, use of compass and ruler to create pieces needed to complete the activity

SCIENCE
Structure of Matter 3a
Reactions 5d
Investigation and Experimentation 9a-c

Chapter 3: Energy Sources for Electricity Generation Chapter Overview

GRADE 6

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4
1.0 Writing: Organization and Focus 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.5
2.0 Speaking Applications 2.4-2.5

MATH

Reinforcement of learned (prior) skills, e.g. understanding percentages and pie graphs

SCIENCE

Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2a-c
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution

GRADE 7

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4

MATH

Reinforcement of learned (prior) skills, e.g. understanding percentages and pie graphs

SCIENCE

Earth and Life History 4a-f
Physical Principles in Living Systems 6a, e, f

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4

MATH

Reinforcement of learned (prior) skills, e.g. understanding percentages and pie graphs

SCIENCE

Structure of Matter 3a, d
Reactions 5a, c, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Biomass

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Physical Principles in Living Systems 6a, e, f
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

SCIENCE
Reactions 5a, c, d
Structure of Matter 3a, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a
Investigation and Experimentation 9a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Geothermal

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2c
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Resources 6a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Earth and Life History 4a-f
Physical Principles in Living Systems 6a, e, f
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Density and Buoyancy 8a
Structure of Matter 3c, d
Reactions 5c, d
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Hydropower

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Shaping Earth's Surface 2a-c
Energy in the Earth System 4a, d, e
Resources 6a-b
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Shaping Earth's Surface 2a-c
Energy in the Earth System 4a, d, e
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Density and Buoyancy 8a
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Ocean

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Plate Tectonics and Earth's Structure 1a, c
Shaping Earth's Surface 2c
Heat/Thermal Energy 3a, c, d
Energy in the Earth System 4a, d, e
Resources 6a-b
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Earth and Life History 4a
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Density and Buoyancy 8a
Motion 1b-e
Forces 2a-e
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Solar

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Heat/Thermal Energy 3a, c, d
Energy in the Earth System 4a, b, d, e
Ecology 5 a,b
Resources 6 a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Physical Principles in Living Systems 6a, e, f
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
SCIENCE
Reactions 5a, c, d
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Wind

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. measurement, the metric system, and place value.
SCIENCE
Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2a-c
Heat/Thermal Energy 3a, c, d
Energy in the Earth System 4a-e
Resources 6 a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of temperature, measurement, the metric system, and place value.
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. measurement, the metric system, and place value.
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Hydrogen

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Physical Principles in Living Systems 6a, e, f
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Structure of Matter 3a, d
Reactions 5a, c, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Fossil Fuels

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of measurement, the metric system, and place value.
SCIENCE
Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2a-c
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of measurement, the metric system, and place value.
SCIENCE
Earth and Life History 4a-f
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
MATH
Reinforcement of learned (prior) skills, e.g. understanding of measurement, the metric system, and place value.
SCIENCE
Structure of Matter 3a, d
Reactions 5a, c, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Nuclear

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Heat/Thermal Energy 3a-d
Resources 6a-c
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
SCIENCE
Structure of Matter 3a, d
Reactions 5a, c, d
GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation Watt's My Line?

GRADE 6

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4
1.0 Writing: Organization and Focus 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.5
1.0 Listening and Speaking Strategies 1.4-1.7
2.0 Speaking Applications 2.4-2.5

MATH

Reinforcement of learned (prior) skills or introduction to new ideas, e.g. understanding of pie graphs and charts, measurement, percentages, the metric system, temperature, place value.
Measurement and Geometry 1.0-1.3

SCIENCE

Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2a-c
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c
Investigation and Experimentation b-d

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4
1.0 Writing: Organization and Focus 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.7
1.0 Listening and Speaking Strategies 1.1-1.6

MATH

Reinforcement of learned (prior) skills or introduction to new ideas, e.g. understanding of pie graphs and charts, measurement, percentages, the metric system, temperature, place value.

SCIENCE

Earth and Life History 4a-f
Physical Principles in Living Systems 6a, e, f
Investigation and Experimentation 7a-e

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 3: Energy Sources for Electricity Generation
Watt's My Line? (continued)

GRADE 8

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.6
1.0 Listening and Speaking Strategies 1.1-1.7

MATH

Reinforcement of learned (prior) skills or introduction to new ideas, e.g. understanding of pie graphs and charts, measurement, percentages, the metric system, temperature, place value.

SCIENCE

Structure of Matter 3a, d
Reactions 5a, c, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a
Investigation and Experimentation 9a-c

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 4: Energy, Health, and the Environment

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.5
1.0 Listening and Speaking Strategies 1.4-1.7
2.0 Speaking Applications 2.4-2.5

MATH
Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE
Heat/Thermal Energy 3a-d
Resources 6a-c
Investigation and Experimentation 7b-d

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.7
1.0 Listening and Speaking Strategies 1.1-1.6

MATH
Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE
Investigation and Experimentation 7a-e

GRADE 8

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.6
1.0 Listening and Speaking Strategies 1.1-1.7

MATH
Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE
Reactions 5d
Investigation and Experimentation 9a-c
Structure of Matter 3a, 5d

Chapter 5: Energy Policy and Management

GRADE 6

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing: Organization and Focus 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.5
1.0 Listening and Speaking Strategies 1.4-1.7
2.0 Speaking Applications 2.4-2.5

MATH
Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE
Plate Tectonics and Earth's Structure 1a-c, e, f
Shaping Earth's Surface 2a-c
Heat/Thermal Energy 3a-d
Energy in the Earth System 4a-e
Ecology 5a, b
Resources 6a-c
Investigation and Experimentation 7b-d

GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

GRADE 7

ENGLISH LANGUAGE ARTS
2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.7
1.0 Listening and Speaking Strategies 1.1-1.6

MATH
Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE
Earth and Life History 4a-f
Physical Principles in Living Systems 6a, e, f
Investigation and Experimentation 7a-e

GOVERNMENT
Understanding of regulatory agencies and laws that govern production of environmental pollution.

Chapter 5: Energy Policy and Management (continued)

GRADE 8

ENGLISH LANGUAGE ARTS

2.0 Reading Comprehension 2.1-2.4
1.0 Writing Strategies 1.1-1.3
1.0 Written and Oral English Language Conventions 1.1-1.6
1.0 Listening and Speaking Strategies 1.1-1.7

MATH

Reinforcement of learned (prior) skills, e.g. estimating and averaging as well as creation of graphs to display information

SCIENCE

Structure of Matter 3a, d
Reactions 5a, c, d
Chemistry of Living Systems 6a, b
Density and Buoyancy 8a
Investigation and Experimentation 9a-c

GOVERNMENT

Understanding of regulatory agencies and laws that govern production of environmental pollution.

NATIONAL SCIENCE CONTENT STANDARDS GRADES 5-8 Standards followed by a double asterisk are addressed in part by the activities within *Energy for Keeps: Electricity from Renewable Energy*.			
Unifying Concepts and Processes ■ Systems, order, and organization** ■ Evidence, models, and explanation** ■ Change, constancy, and measurement** ■ Evolution and equilibrium** ■ Form and Function**	**Science as Inquiry** ■ Abilities necessary to do scientific inquiry** ■ Understandings about scientific inquiry**	**Physical Science** ■ Properties and changes of properties in matter** ■ Motion and forces** ■ Transfer of energy**	**Life Science** ■ Structure and function in living systems** ■ Reproduction and heredity ■ Regulation and behavior ■ Populations and ecosystems ■ Diversity and adaptations of organisms
Earth and Space Science ■ Structure of the earth system** ■ Earth's history** ■ Earth in the solar system	**Science and Technology** ■ Abilities of technological design** ■ Understandings about science and technology**	**Science in Personal and Social Perspectives** ■ Personal health ■ Populations, resources, and environments** ■ Natural hazards** ■ Risks and benefits** ■ Science technology in society**	**History and Nature of Science** ■ Science as a human endeavor** ■ Nature of science ■ History of science**