17.4 Generating Electricity

Hoover Dam, near Las Vegas, Nevada, towers more than 200 meters above the raging Colorado River. This gigantic concrete structure is known as one of the greatest engineering projects in the world. Hoover Dam is called a *hydroelectric plant* because it turns the energy of falling water into electricity. In this section, you will learn more about ways to generate electricity.

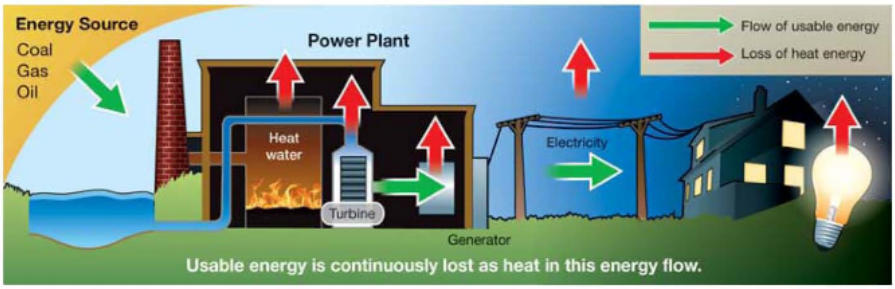
JOURNAL

Do some research and find out how far the nearest power plant is from your house. What is the name of the power plant? What energy source is used to make electricity at this power plant? How is the power transported to your house?

Making and transporting electricity

Starting at the power plant To find out how electricity is made and transported, let's trace the energy pathway. Electricity is made in a power plant (see below). Most power plants burn coal, oil, or natural gas to produce heat (later in this section, you will learn about alternative ways to produce heat). Next, this heat is used to boil water. The steam from the boiling water turns a turbine. The turbine turns a generator which produces electricity.

Electricity is carried by wires Electricity leaves the power plant and is carried to buildings by wires. The fuel energy from the coal, oil, or natural gas changes its form several times on the way to the buildings. With each change, some energy is converted to heat. In fact, most of the energy that is transferred from fuels such as coal, oil, and natural gas will eventually become heat energy. Some will be used, but most will be unusable.

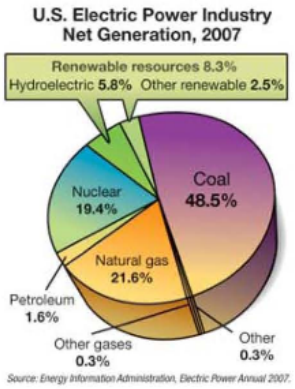


Electricity from fossil fuels

What is a nonrenewable resource?

A **nonrenewable resource** is not replaced as it is used. **Fossil fuels** are good examples of nonrenewable resources. Fossil fuels are found within the rocks of Earth's surface. They are called fossil fuels because they were formed hundreds of millions of years ago by processes acting on dead plants and animals. The three major fossil fuels are coal, petroleum, and natural gas.

Fossil fuels



Earth's coal, petroleum, and natural gas deposits took hundreds of millions of years to form. Because it takes so long for these resources to form, they are not replaced as they are used and are considered nonrenewable resources. Natural gas is pumped out of gas pockets both onshore and offshore. Coal is a solid fossil fuel that is mined from the ground. Petroleum (oil) is drilled out of natural deposits both onshore and offshore. Petroleum deposits are located in many parts of the world, including the United States. Petroleum, coal, and natural gas can all be used to make electricity.

Downsides of using fossil fuels to generate electricity

Since nonrenewable resources are not replaced as they are used, someday we will not have enough fossil fuels to produce the electricity we need. Besides being nonrenewable, fossil fuels pose additional problems. Burning fossil fuels produces sulfur oxide emissions that reduce air quality. Carbon dioxide is also produced when fossil fuels are burned. The amount of carbon dioxide in the atmosphere has increased by about 30 percent since the 1800s, and Earth's average surface temperature has increased 0.6 to 1.2°F over that same time period. These increases are not huge, but they are enough to have warmed the North Pole and caused the sea level to rise 4 to 10 inches. These consequences, and the possibility of global climate change, are causing scientists to look for alternative ways to produce electricity.

VOCABULARY

nonrenewable resource - a natural resource that is not replaced as it is used.

fossil fuel - substance found in Earth's crust that was formed over millions of years from the remains of dead organisms.

SOLVE IT!

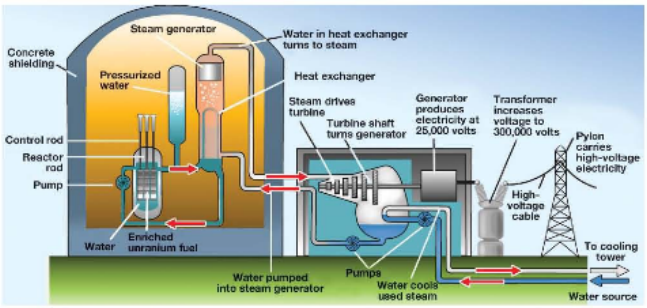
Study the pie chart at the left and answer the following questions.

1. Which fossil fuel is used the most to make electricity?
2. Which fossil fuel do you think is found in the largest amount in the United States?
3. What resources do you think make up the "other" category? (Hint: Read ahead to learn about renewable resources that can be used to make electricity.)

Electricity from nuclear energy

What is nuclear energy?

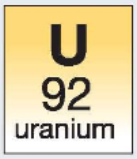
The United States gets about 19 percent of its electricity production from nuclear power plants. As an interesting comparison, France leads the world with 75 percent of its electricity coming from nuclear energy. According to the U.S. Nuclear Energy Institute, as of 2009, there are 104 operating nuclear power plants in 31 states. The fuel used in nuclear power plants is *uranium*, an extremely high-energy source of heat. Uranium atoms split apart in the nuclear reactor and the energy released is used to heat water and make steam. The steam drives a turbine, which spins a generator to produce electricity.



Advantages and disadvantages of nuclear energy

The main advantage of using nuclear energy to produce electricity is that it doesn't pollute the air like fossil fuel power plants do. Interestingly, there has not been a single nuclear power plant built in the United States since 1973. This slowdown in progress is due to two major disadvantages of nuclear energy. One disadvantage is that used uranium fuel from a reactor stays dangerously radioactive for a long time. Also, storage of nuclear waste has always been a major disadvantage of nuclear power plants. A joint effort between the federal government and private industry was launched in 2002. Called the Nuclear Power 2010 Program, this effort is meant to support a renewed interest in building nuclear power facilities. In fact, several nuclear power plants are on schedule to be built in the U.S. in the coming years.

KEYWORDS



Uranium is an element, and you can find it listed on the periodic table of elements. Elements are the most basic substances. Uranium has characteristics that make it very useful as a fuel for nuclear reactors. Uranium is naturally radioactive, and it releases particles from its atoms that have a lot of energy.

Do some research on uranium.

1. How is uranium used to produce electricity? (Hint: If you can describe the process shown in the picture to the left, you will have your answer!)
2. Nuclear power plants do not pollute the air like fossil fuel plants do. However, there are some big drawbacks to nuclear power plants. Discuss these drawbacks.

Electricity from renewable resources

Renewable resources

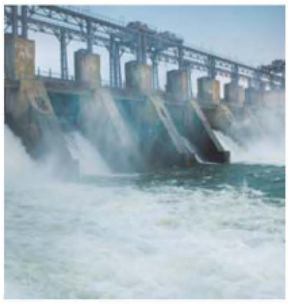
A **renewable resource** can be replaced naturally in a relatively short period of time. Falling water, energy from the Sun, and wind energy are examples of renewable resources that can be used to make electricity. The Energy Information Administration (EIA) predicts that by 2010, 12 percent of the electricity generated in the United States will be from renewable resources (as compared to 9.4 percent in 2006). Figure 17.23 shows how the 12 percent renewable resource contribution in 2010 will be allocated.

VOCABULARY

renewable resource - a natural resource that can be replaced.

hydroelectric - a type of power plant that generates electricity from the energy of falling water.

Hydroelectric: impoundment and pumped storage



A **hydroelectric** (or hydropower) plant uses energy from falling water to generate electricity. The two most common types of hydroelectric power plants are impoundment (a dam is used), and pumped storage. An *impoundment* facility (see photo at the left) dams up river water and stores it in a reservoir. The water falls from the reservoir and turns a turbine, which spins a generator and produces electricity. Instead of holding back river water in a reservoir, a *pumped storage* facility actively pumps water from a lower reservoir to a higher reservoir (during off-peak or low-demand hours) and then releases it back to the lower reservoir during high-demand hours. Again, the energy of the falling water is used to generate electricity. Hydroelectric power generation has advantages and disadvantages, like any other energy resource. This method of generating electricity does not pollute the air, it is considered renewable (the Sun constantly drives the water cycle), and it is sufficiently available in the United States (as opposed to fossil fuels which require some imports). However, hydroelectric plants are known to negatively impact fish populations, they can be vulnerable to drought, and they can directly impact the flow and quality of water in the surrounding area. Researchers must continue to find ways to offset these disadvantages in order to make hydroelectric a more viable solution to long-term energy needs.

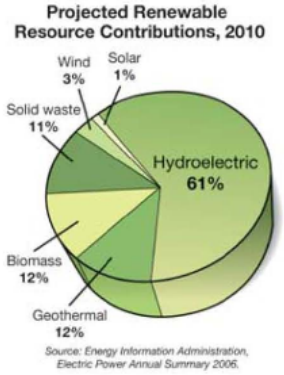


Figure 17.23: *The EIA predicts that 12% of U.S. electricity generation will be from renewable resources in 2010. This graph shows how each resource will contribute to this projection.*

Geothermal and biomass

Geothermal reservoirs

Iceland is a country of contrasts. Glaciers cover 11 percent of Iceland, yet there are also many places where molten rock is close to the surface. At these hot spots, where geothermal reservoirs are located, wells have been drilled to tap into the hot water. **Geothermal** power plants use Earth's internal heat energy, in the form of water or steam, to produce electricity. Iceland produces most of its electricity from geothermal energy. Geothermal power plants can be found all over the world, including Alaska, Hawaii, and some western parts of the United States.

Heat pump systems

Geothermal energy can even be used to heat homes in places that are not geologically as active as Hawaii or Iceland. A geothermal **heat pump system** takes advantage of the relatively constant temperature of Earth's shallow ground. In winter, heat from the relatively warmer ground goes through a heat exchanger into the house. In summer, warmer air from the house is pulled through the heat exchanger into the cooler ground. This heat can even be used to heat water in the summer. Geothermal power plants and heat pump systems are clean, and Earth's heat energy is almost unlimited. However, in the United States, geothermal power plants are limited to a relatively small number of geologically active sites.

Biomass

Biomass is organic material from plants or animals. For thousands of years, people have used wood, a type of biomass, for space and water heating. Now, new technology allows farmers to grow crops, such as corn, specifically to be used for biomass energy. Biomass can also come from municipal waste, industrial waste, or agricultural and forestry leftovers. But how is biomass used to produce electricity? In waste-to-energy plants, renewable solid waste is burned to produce steam, which is used to generate electricity. This creates some air pollution, but not as much sulfur oxide as fossil fuels produce (sulfur oxides contribute to acid rain). Biomass, such as harvested corn, can even produce liquid transportation fuels (biofuels) such as ethanol and biodiesel. Plants used to make biomass can be grown over and over, so biomass is considered a renewable resource. Burning biomass does produce carbon dioxide (a greenhouse gas), but as living plants, the biomass originally *consumed* carbon dioxide during its growth process.

VOCABULARY

geothermal - describes energy from Earth's internal heat.

heat pump system - takes advantage of Earth's constant shallow ground temperature for seasonal heating and cooling of buildings and homes.

biomass - organic material from plants and animals.

TECHNOLOGY

From Biomass to Electricity

The McNeil generating station in Burlington, Vermont, uses waste wood from forestry and used wood shipping pallets to produce electricity. In 1989, a natural-gas-burning system was added to the plant. The heat energy from the combustion of both wood and gas is fed into the same boiler. This unique power plant has been fully operational since 2000. Some interesting McNeil station facts:

- turbine spins at 3,600 rpm
- steam temperature is 950°F
- uses 76 tons of wood per hour
- uses 550,000 cubic feet of gas per hour
- generates enough electricity for almost the entire city of Burlington; 50 megawatts at full capacity

Wind and solar energy

Wind energy A wind energy system captures the energy of motion from moving air and turns the energy into electricity. California was the first U.S. state to build large **wind farms**. Today, Texas produces more electricity from wind energy than any other state, followed by Iowa and California. Wind is the world's fastest-growing energy source used to make electricity. According to the National Renewable Energy Laboratory, as of 2008, the United States has the largest wind energy production capacity in the world, followed closely by Germany (who was the leader until 2008).

Wind energy challenges Wind is a clean, plentiful fuel source, but what disadvantages are there to using wind as an energy source? The wind does not always blow when electricity is needed, and right now, the cost of building a wind farm is greater than the cost of building a power plant that uses fossil fuel to make electricity. Also, some argue that wind farms can have a negative effect on the environment. Wind farms can disturb natural habitats, and can perhaps scar a large area of scenery (although some see wind farms as majestic, welcome sights in the landscape). Scientists, engineers, and policy-makers are addressing these challenges to make wind energy more widely accepted, cost effective, and useful.

Solar energy The Sun is our biggest source of light and heat. In fact, 99 percent of the energy used to heat Earth and all of our buildings comes from the Sun. The Sun's energy is often called **solar energy**. A solar cell (also known as a photovoltaic cell) can convert solar energy to electricity (Figure 17.24).

Solar energy challenges A big challenge to using solar energy for electricity production is that a backup energy source must be used on cloudy days. Also, solar energy is very spread out, so it must be collected from a huge area to be used to generate electricity for a power grid. Currently, solar technology is very expensive, much more so than even wind technology. The Solar America Initiative (SAI) is a partnership between the U.S. Department of Energy (DOE) and industry; universities; federal, state, and local government; and nongovernmental agencies. The goal of SAI is to develop lower-cost solar technologies to produce large amounts of electricity in the future.

VOCABULARY

wind farm - a collection of wind turbines.

solar energy - energy from the Sun.

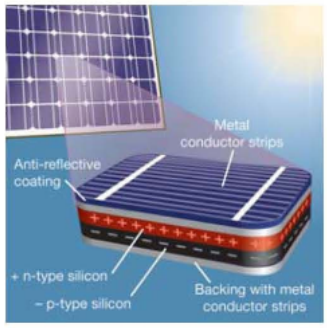


Figure 17.24: *A photovoltaic (PV) cell (sometimes called a solar cell) like this one from a solar calculator can convert light energy into a small amount of electrical energy. When light energy strikes the PV cell, electrons from specially treated silicon atoms become free to flow within the electric field set up by the differently charged silicon layers. As you know, a flow of charge like this produces current, which can be directed in a circuit to do work, such as operating a simple calculator.*

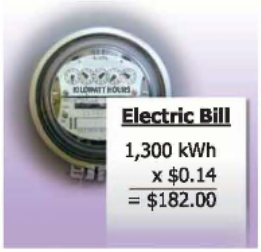
Electricity and power

A watt is a unit of power

Electrical power is measured in watts, just like mechanical power. Electrical power is the rate at which electrical energy is changed into other forms of energy such as heat, sound, or light. Anything that "uses" electricity is actually converting electrical energy into some other type of energy. The *watt* is an abbreviation for one joule per second. A 100-watt light bulb uses 100 joules of energy *every second*. Figure 17.25 shows some typical power ratings for common devices.

Kilowatt-hours

Utility companies charge customers for the number of **kilowatt-hours** (kWh) used each month. One kilowatt-hour means that a kilowatt of power has been used for one hour. A kilowatt-hour is not a unit of power but a unit of *energy*, like a joule. A kilowatt-hour is a relatively large amount of energy, equal to 3.6 million joules. If you leave a 1,000-watt hair dryer on for 1 hour, you have used 1 kilowatt-hour of energy. You could also use one kilowatt-hour by using a 100-watt light bulb for 10 hours. The number of kilowatt-hours used equals the number of kilowatts multiplied by the number of hours the appliance was turned on. Electric companies charge for kilowatt-hours used monthly. Your home is connected to a meter that keeps track of the kilowatt-hours used.



Save money on electricity

How can you save money on your household's electric bill? Use less electricity, of course! There are many simple things you can do to use less electricity. When added up, these simple things can mean many dollars of savings each month, which adds up to a large amount of money over a one-year period. What can you do? Make sure your windows are locked so they seal properly. Turn off lights when you are not using them. Switch off electronic equipment that uses standby power. Electric utility companies will send an energy consultant to your home to give suggestions on how to conserve electricity. Conserving electricity means lower bills and a cleaner environment.

VOCABULARY

electrical power - the rate at which electrical energy is changed into other forms of energy.

kilowatt-hour - a unit of energy equal to one kilowatt of power used for one hour. One kilowatt-hour equals 3.6 million joules.

Appliance	Power (watts)
Electric stove	3,000
Electric heater	1,500
Toaster	1,200
Hair dryer	1,000
Iron	800
Washing machine	750
Television	300
Light	100
Small fan	50
Clock radio	10

Figure 17.25: *Typical power usage of some common appliances.*

Section 17.4 Review

1. Some of the energy that comes from burning a fossil fuel can be turned into electricity, but most of the energy is lost. Explain why this is a true statement and identify the unusable or lost energy.
2. Define the terms *nonrenewable resource* and *renewable resource* and give three examples of each.
3. Create a table like the one started below. Include a row for each of these energy sources: fossil fuels, nuclear, hydroelectric, geothermal, biomass, wind, and solar. List the advantages and disadvantages for each one.

Advantages and Disadvantages of Energy Sources

Energy Source	Advantages	Disadvantages
fossil fuels		
nuclear		

4. How much energy does a 1,500-watt hair dryer use every second?
5. Which of the following does the electric utility company charge for each month?
   a. electrical power used
   b. electrical energy used
   c. electrical current used
6. A student used three appliances in her dormitory room: a 1,200-watt iron, which she uses 3.5 hours per month; a lamp with a 100-watt bulb, which she uses 125 hours per month; and a 700-watt coffee maker, which she uses 15 hours per month.
   a. How many kWh of electrical energy are consumed in one month by each appliance?
   b. If the local utility company charges $0.15 cents per kWh of electrical energy consumed, how much does it cost per month to operate each appliance?

CHALLENGE

Predict the Future

Study the pie graph below. Redraw your own version of this graph as it will most likely look 50 years from now. Information from the Energy Information Administration's web site will be helpful. You can also get information from the United States Department of Energy. Explain the reasoning behind your graph, and don't forget to list your sources.