Electricity

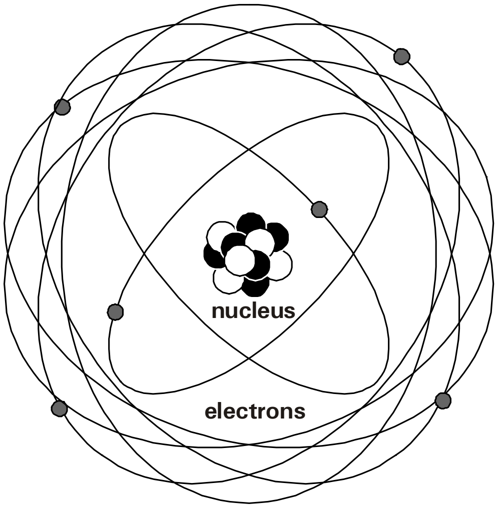
ELECTRICITY: THE MYSTERIOUS FORCE

What exactly is the mysterious force we call electricity? It is simply moving electrons. And what exactly are electrons? They are tiny particles found in atoms.

Everything in the universe is made of atoms—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. Atoms are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles. The center of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but electrons are much, much smaller. **Electrons** spin around the nucleus in shells a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be the size of the Empire State Building. Atoms are mostly empty space.

If you could see an atom, it would look a little like a tiny center of balls surrounded by giant invisible bubbles (or shells). The electrons would be on the surface of the bubbles, constantly spinning and moving to stay as far away from each other as possible. Electrons are held in their shells by an electrical force.



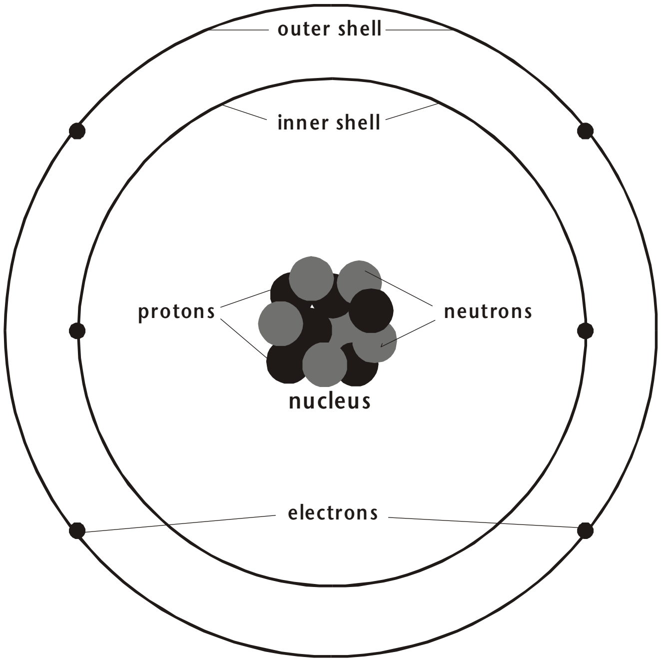
Atom of Carbon

The protons and electrons of an atom are attracted to each other. They both carry an **electrical charge**. An electrical charge is a force within the particle. Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. When an atom is in balance, it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary.

The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance in which all of the atoms are identical. Every atom of hydrogen, for example, has one proton and one electron, with no neutrons. Every atom of carbon has six protons, six electrons, and six neutrons. The number of protons determines which element it is.

SEVERAL COMMON ELEMENTS

ELEMENT	SYMBOL	PROTONS	ELECTRONS	NEUTRONS
HYDROGEN	H	1	1	0
CARBON	C	6	6	6
OXYGEN	O	8	8	8
COPPER	Cu	29	29	34
SILVER	Ag	47	47	51
GOLD	Au	79	79	118
URANIUM	U	92	92	146



Carbon atom with six protons and six neutrons in the nucleus, two electrons in the inner shell and four electrons in the outer shell.

Electrons usually remain a constant distance from the nucleus in precise **shells**. The shell closest to the nucleus can hold two electrons. The next shell can hold up to eight. The outer shells cans hold even more. Some atoms with many protons can have as many as seven shells with electrons in them.

The electrons in the shells closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in the outermost shells do not. These electrons can be pushed out of their orbits. Applying a force can make them move from one atom to another. These moving electrons are electricity.

STATIC ELECTRICITY

Electricity has been moving in the world forever. Lightning is a form of electricity. It is electrons moving from one cloud to another or jumping from a cloud to the ground. Have you ever felt a shock when you touched an object after walking across a carpet? A stream of electrons jumped to you from that object. This is called **static electricity**.

Have you ever made your hair stand straight up by rubbing a balloon on it? If so, you rubbed some electrons off the balloon. The electrons moved into your hair from the balloon. They tried to get far away from each other by moving to the ends of your hair.

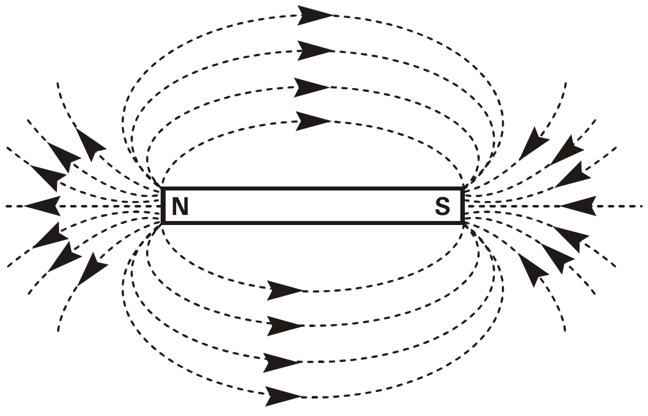
They pushed against each other and made your hair move—they repelled each other. Just as opposite charges attract each other, like charges repel each other.

MAGNETS ARE SPECIAL

In most objects, all of the forces are in balance. Half of the electrons are spinning in one direction; half are spinning in the other. These spinning electrons are scattered evenly throughout the object.

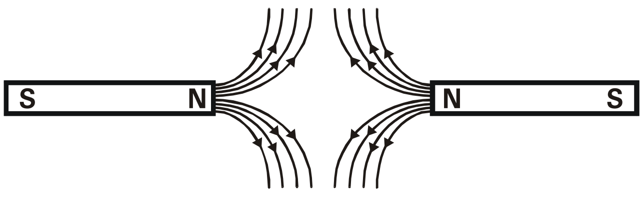
Magnets are different. In magnets, most of the electrons at one end are spinning in one direction. Most of the electrons at the other end are spinning in the opposite direction.

This creates an imbalance in the forces between the ends of a magnet. This creates a **magnetic field** around a magnet. A magnet is labelled with North (N) and South (S) poles. The magnetic force in a magnet flows from the North pole to the South pole.



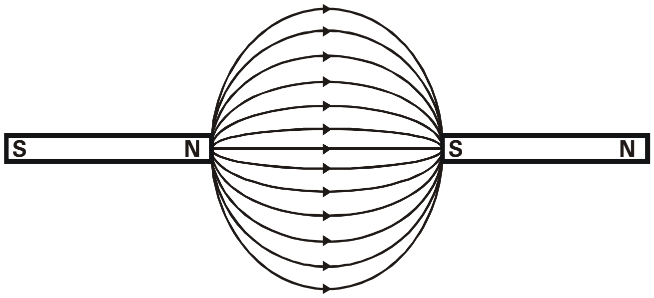
BAR MAGNET

Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the South poles together, they repel each other. Two North poles also repel each other.



Like poles of magnets (N-N or S-S) repel each other.

Turn one magnet around and the North (N) and the South (S) poles are attracted to each other. The magnets come together with a strong force. Just like protons and electrons, opposites attract.



Opposite poles of magnets (N-S) attract each other.

MAGNETIC FIELDS CAN PRODUCE ELECTRICITY

We can use this special property of magnets to produce electricity. Moving magnetic fields can pull and push electrons. Some metals, like copper, have electrons that are loosely held. They can be pushed from their shells by moving magnets.

Power plants use huge turbine generators to make the electricity that we use in our homes and businesses. Power plants use many fuels to spin a **turbine**. They can burn coal, oil, or natural gas to make steam to spin a turbine. Or they can split atoms of uranium to heat water into steam. They can also use the power of rushing water from a dam or the energy in the wind to spin the turbine.

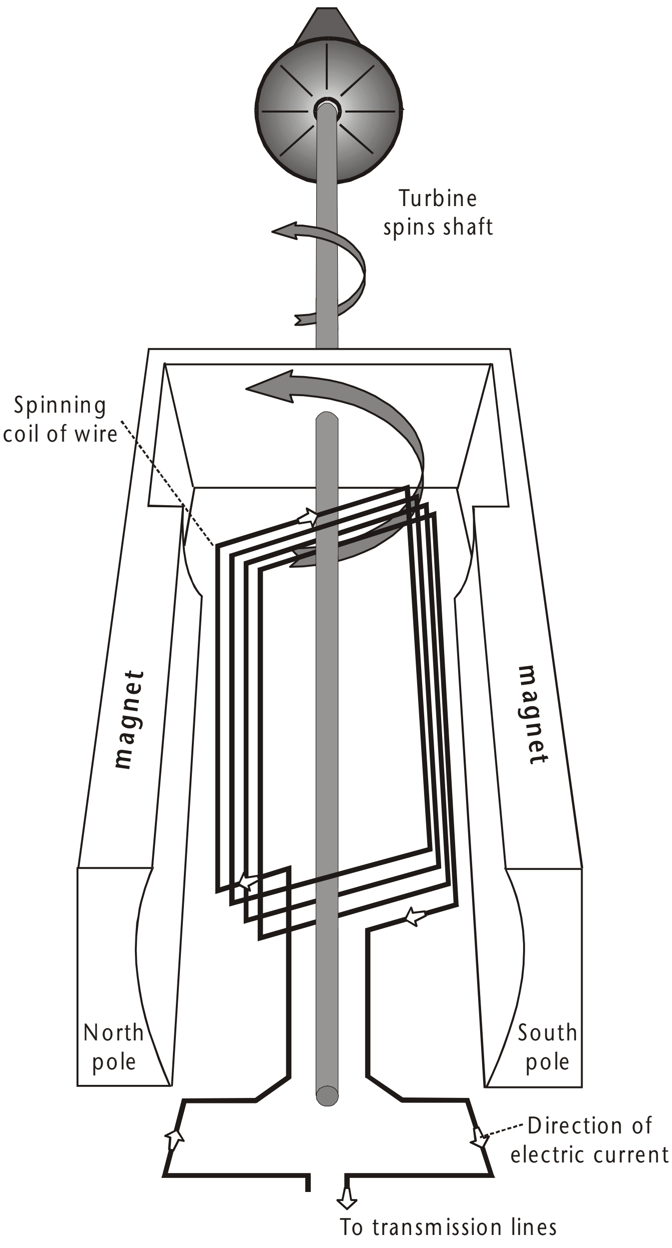
The turbine is attached to a shaft in the **generator**. Inside the generator are magnets and coils of copper wire. The magnets and coils can be designed in two ways—the turbine can spin the magnets inside the coils or can spin coils inside the magnets. Either way, the electrons are pushed from one copper atom to another by the moving magnetic field.

Coils of copper wire are attached to the turbine shaft. The shaft spins the coils of wire inside two huge magnets. The magnet on one side has its North pole to the front. The magnet on the other side has its South pole to the front.

The magnetic fields around these magnets push and pull the electrons in the copper wire as the wire spins. The electrons in the coil flow into transmission lines.

These moving electrons are the electricity that flows to our houses. Electricity moves through the wire very fast. In just one second, electricity can travel around the world seven times.

TURBINE GENERATOR



BATTERIES PRODUCE ELECTRICITY

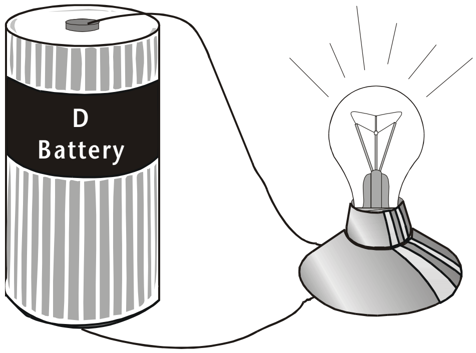
A battery produces electricity using two different metals in a chemical solution. A **chemical reaction** between the metals and the chemicals frees more electrons in one metal than in the other.

One end of the battery is attached to one of the metals; the other end is attached to the other metal. The end that frees more electrons develops a positive charge and the other end develops a negative charge. If a wire is attached from one end of the battery to the other, electrons flow through the wire to balance the electrical charge.

A **load** is a device that does work or performs a job. If a load—such as a lightbulb—is placed along the wire, the electricity can do work as it flows through the wire. In the picture above, electrons flow from the negative end of the battery through the wire to the lightbulb. The electricity flows through the wire in the lightbulb and back to the battery.

ELECTRICITY TRAVELS IN CIRCUITS

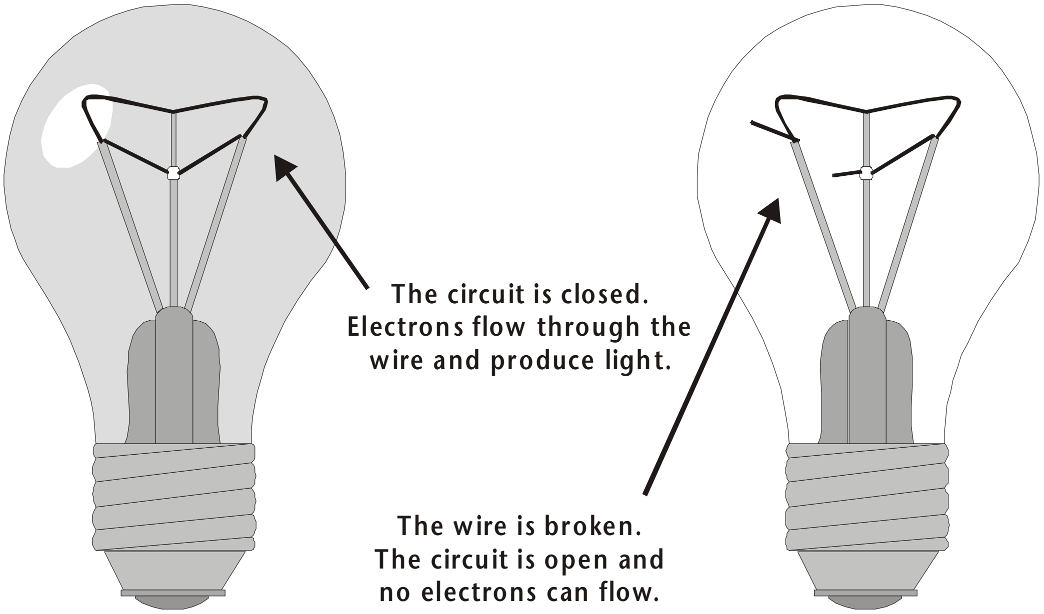
Electricity travels in closed loops, or **circuits** (from the word circle). It must have a complete path before the electrons can move. If a circuit is open, the electrons cannot flow. When we flip on a light switch, we close a circuit. The electricity flows from the electric wire through the light and back into the wire. When we flip the switch off, we open the circuit. No electricity flows to the light.



When we turn a light switch on, electricity flows through a tiny wire in the bulb. The wire gets very hot. It makes the gas in the bulb glow. When the bulb burns out, the tiny wire has broken. The path through the bulb is gone.

When we turn on the TV, electricity flows through wires inside the set, producing pictures and sound. Sometimes electricity runs motors—in washers or mixers. Electricity does a lot of work for us. We use it many times each day.

In the United States, we use more electricity every year. We use electricity to light our homes, schools and businesses. We use it to warm and cool our homes and help us clean them. Electricity runs our TVs, VCRs, video games, computers, and fax machines. It cooks our food and washes the dishes. It mows our lawns and blows the leaves away. It can even run our cars.


The circuit is closed.
Electrons flow through the wire and produce light.

The wire is broken.
The circuit is open and no electrons can flow.

SECONDARY ENERGY SOURCE

Electricity is different from primary sources of energy. Unlike coal, petroleum, or solar energy, electricity is a **secondary** source of energy. That means we must use other energy sources to make electricity. It also means we can't classify electricity as renewable or nonrenewable.

Coal, which is a nonrenewable energy source, can be used to make electricity. So can hydropower, a renewable energy source. The energy source we use to make electricity can be renewable or nonrenewable, but electricity is neither.

MAKING ELECTRICITY

Most of the electricity we use in the United States is generated by large power plants. These plants use many fuels to produce electricity. Many power plants use coal, uranium, or natural gas to produce heat to superheat water into steam.

The high pressure of the steam turns the blades of a turbine. The blades are connected to a generator, which houses a coil of copper wire surrounded by large magnets. The blades spin the coil of wire rapidly, rotating the coil inside magnetic fields of the magnets to produce electricity.

MOVING ELECTRICITY FROM POWER PLANTS TO HOMES

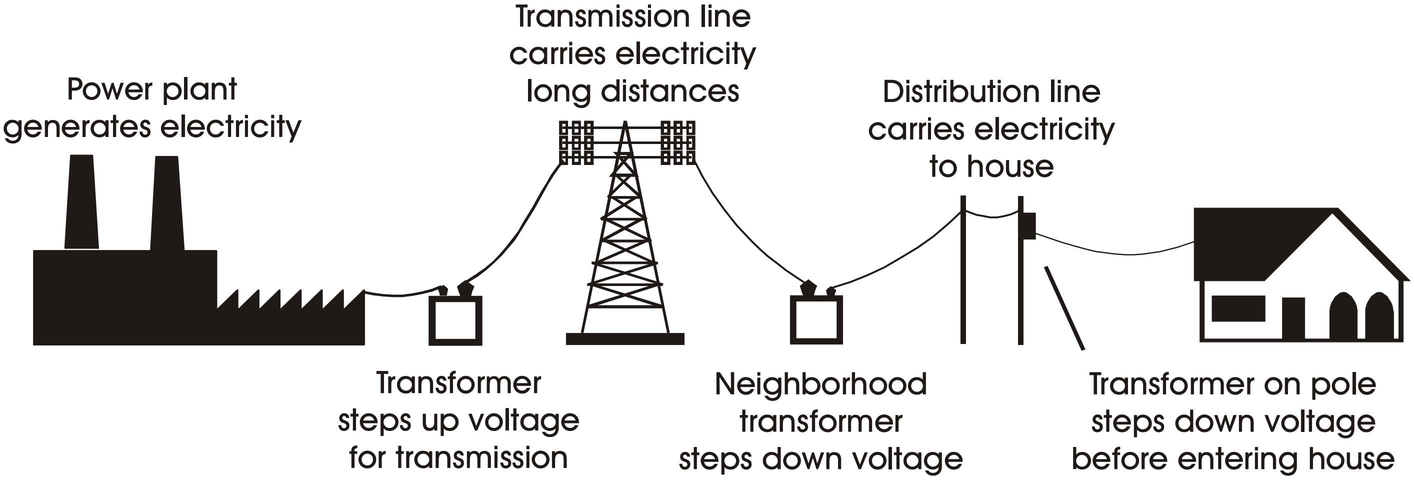
We use more and more electricity every year. One reason we use so much electricity is that it's easy to move from one place to another. It can be made at a power plant and moved long distances before it is used. Let's follow the path of electricity from a power plant to a light bulb in your home.

First, the electricity is generated at a power plant. It travels through a wire to a **transformer** that **steps up** the **voltage**. Power plants step up the voltage because less electricity is lost along the power lines when it is at higher voltage. The electricity is then sent to a nationwide network of **transmission lines**. Transmission lines are the huge tower lines you see along the highway. The transmission lines are interconnected, so if one line fails, another can take over the load.

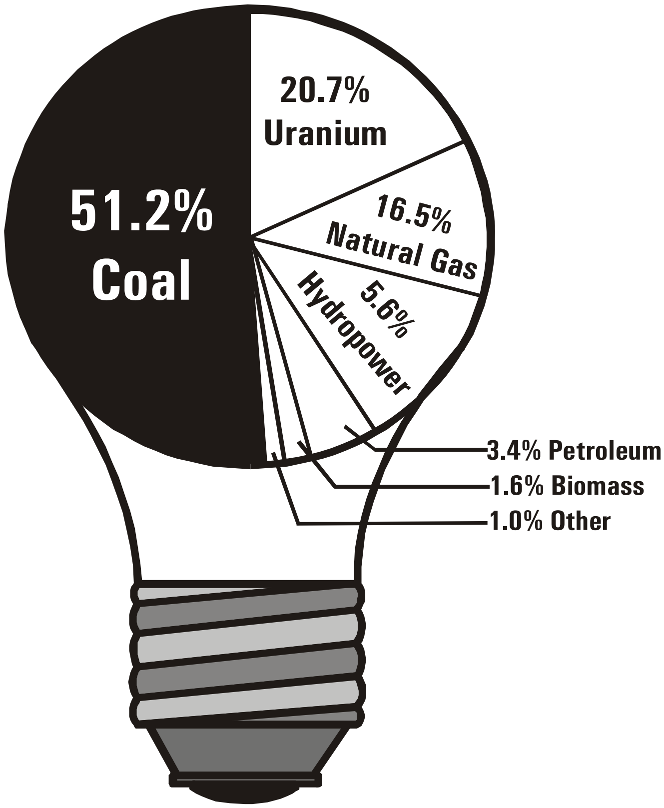
Step-down transformers, located at substations along the lines, reduce the voltage from 350,000 volts to 12,000 volts. **Substations** are small fenced-in buildings that contain transformers, switches, and other electrical equipment.

The electricity is then carried over **distribution lines** that deliver electricity to your home. These distribution lines can be located overhead or underground. The overhead distribution lines are the power lines you see along streets.

TRANSPORTING ELECTRICITY



U.S. ELECTRICITY PRODUCTION



Before the electricity enters your house, the voltage is reduced again at another transformer, usually a large gray metal box mounted on an electric pole. This transformer reduces the electricity to the 120 volts that are used to operate the appliances in your home.

Electricity enters your house through a three-wire cable. Wires are run from the circuit breaker or fuse box to outlets and wall switches in your home. An electric meter measures how much electricity you use, so the utility company can bill you.

FUELS THAT MAKE ELECTRICITY

Three kinds of power plants produce most of the electricity in the United States: fossil fuel, nuclear, and hydroelectric. Coal plants make more than half of the electricity we use. There are also wind, geothermal, trash-to-energy, and solar power plants, which generate about three percent of the electricity produced in the United States.

FOSSIL FUEL POWER PLANTS

Fossil fuel plants burn coal, natural gas, or oil to produce electricity. These energy sources are called fossil fuels because they were formed from the remains of ancient sea plants and animals. Most of our electricity comes from fossil fuel plants.

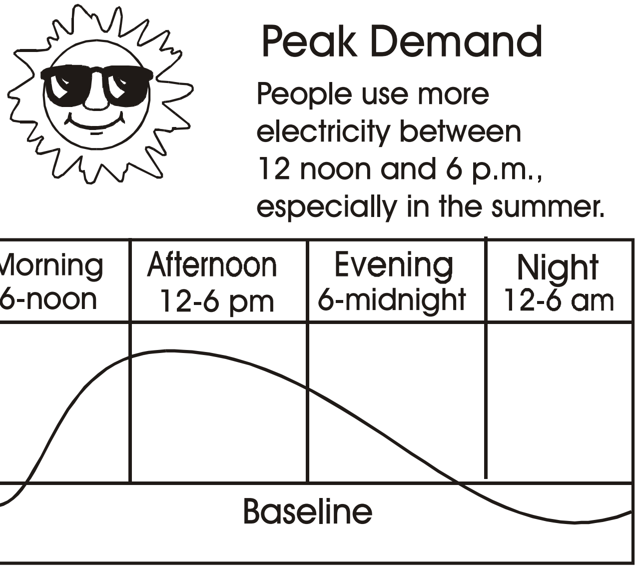
Power plants burn the fossil fuels and use the heat to boil water into steam. The high-pressure steam spins a turbine generator to make electricity. Fossil fuel power plants produce emissions that can pollute the air.

Fossil fuel plants are sometimes called **thermal power plants** because they use heat energy to make electricity. (*Therme* is the Greek word for heat.) Coal is used by most power plants because it is cheap and abundant in the United States. There are many other uses for petroleum and natural gas, but the main use of coal is to produce electricity. About ninety percent of the coal mined in the United States is sent to power plants to make electricity.

NUCLEAR POWER PLANTS

Nuclear power plants are called thermal power plants, too. They produce electricity in much the same way as fossil fuel plants, except that the fuel they use is **uranium**, which isn't burned.

Uranium is a mineral found in rocks underground. A nuclear power plant splits the nuclei (centers) of uranium atoms to make smaller atoms in a process called **fission** that produces enormous amounts of heat energy. The heat is used to turn water into steam, which drives a turbine generator. Nuclear power plants don't produce air polluting emissions, but their waste is radioactive.



Peak Demand

People use more electricity between 12 noon and 6 p.m., especially in the summer.

HYDROPOWER PLANTS

Hydro (*water*) power plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

WHAT'S A WATT?

We use electricity to perform many tasks. We use units called watts, kilowatts, and kilowatt-hours to measure the electricity that we use.

A **watt** is a measure of the electric power an appliance uses. Every appliance requires a certain number of watts to work correctly. Light bulbs are rated by watts (60, 75, 100), as well as home appliances, such as a 1500-watt hairdryer.

A **kilowatt** is 1,000 watts. It is used to measure larger amounts of electricity.

A **kilowatt-hour** measures the amount of electricity used in one hour. Sometimes it's easier to understand these terms if you compare them to water in a pool. A kilowatt is the *rate* of electric flow, or how fast the water goes into a pool. A kilowatt-hour is the *amount* of electricity, or how much water is added to the pool. We pay for the electricity we use in kilowatt-hours. Our power company sends us a bill for the number of kilowatt-hours we use every month. Most residential consumers in the United States pay a little more than eight cents per kilowatt-hour of electricity. With the power shortages in California, people there will be paying much more.

COST OF ELECTRICITY

How much does it cost to make electricity? It depends on several factors:

Fuel Cost The major cost of generating electricity is the fuel. Many energy sources can be used. Hydropower is the cheapest way and solar cells are probably the most expensive way.

Building Cost Another key is the cost of building the power plant itself. A plant may be very expensive to build, but the low cost of the fuel it uses can make the electricity economical to produce.

Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is very cheap. Coal-fired plants, on the other hand, are less expensive to build, but their fuel—coal—is more expensive.

Efficiency When figuring cost, you must also consider a plant's efficiency. **Efficiency** is the amount of useful energy you get out of a system. A totally efficient machine would change all the energy put in it into useful work, not wasting a single unit of energy. Changing one form of energy into another always involves a loss of usable energy.

In general, today's power plants use three units of fuel to produce one unit of electricity. Where do the other two units of energy go? They don't disappear. We just can't use them as a practical source of energy.

Most of the energy is lost as waste heat. You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on some power plants. A typical coal plant burns about 8,000 tons of coal each day. About two-thirds of the chemical energy in the coal (5,300 tons) is lost as it is converted first to heat energy, and then into electrical energy.

ENERGY EFFICIENCY

Most power plants are about 35% efficient. That means for every 100 units of energy that go into a plant, 65 units are lost as one form of energy is converted to other forms. Thirty-five units are produced to do usable work.