



# 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 energy levels 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 clouds (energy levels). The electrons would be on the surface of the clouds, constantly spinning and moving to stay as far away from each other as possible. Electrons are held in their levels by an electrical force.

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. Neutrons carry no charge, and their number can vary.

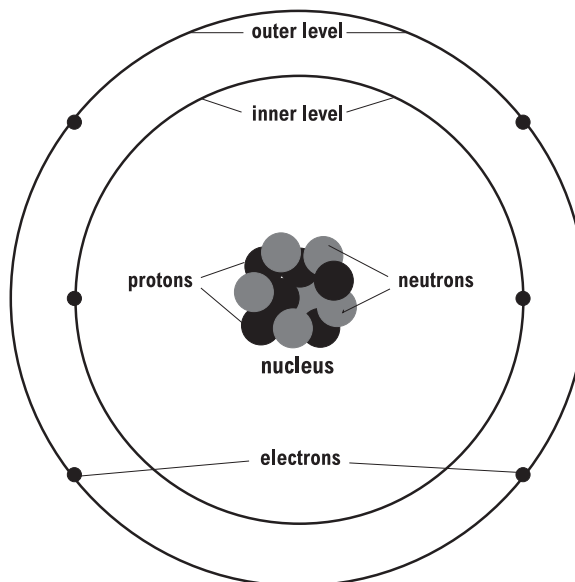
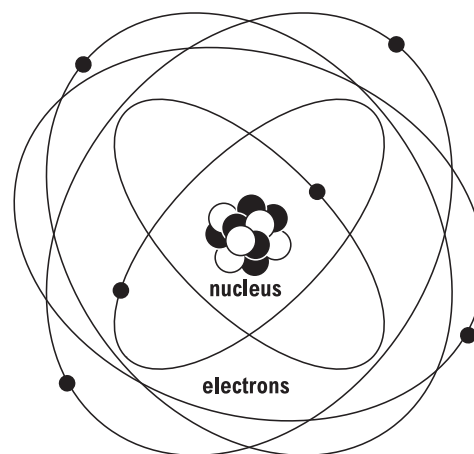
The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance in which all of the atoms are identical. Every atom of hydrogen, for example, has one proton and one electron, with no neutrons. Every atom of carbon has six protons, six electrons, and six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

### SEVERAL COMMON ELEMENTS

ELEMENT	SYMBOL	PROTONS	ELECTRONS	NEUTRONS
Hydrogen	H	1	1	0
Lithium	Li	3	3	4
Carbon	C	6	6	6
Nitrogen	N	7	7	7
Oxygen	O	8	8	8
Magnesium	Mg	12	12	12
Copper	Cu	29	29	34
Silver	Ag	47	47	51
Gold	Au	79	79	118
Uranium	U	92	92	146

Electrons usually remain a relatively constant distance from the nucleus in well defined regions called energy levels. The level closest to the nucleus can hold two electrons. The next level can hold up to eight. The outer levels can hold even more, but the outermost level can hold no more than eight. Some atoms with many protons can have as many as seven levels with electrons in them.

### CARBON ATOM



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

The electrons in the levels closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in the outermost levels 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.

## Magnets

In most objects, the molecules are arranged randomly. They are scattered evenly throughout the object.

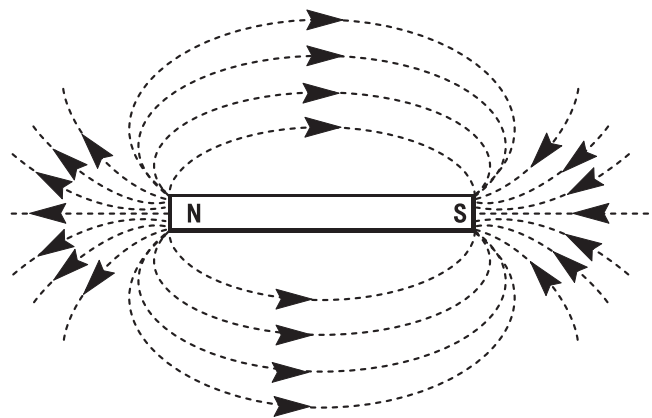
Magnets are different—they are made of molecules that have north-and south-seeking poles. Each molecule is really a tiny magnet. The molecules in a magnet are arranged so that most of the north-seeking poles point in one direction and most of the south-seeking poles point in the other. This creates a magnetic field around the magnet.

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**.

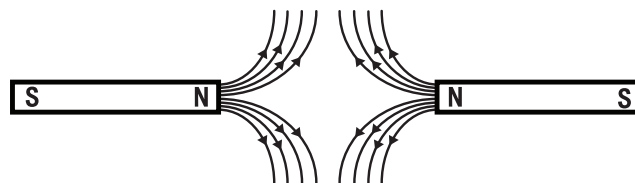
Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the south poles together, they repel each other. Two north poles also repel each other.

If you turn one magnet around, 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.

### BAR MAGNET

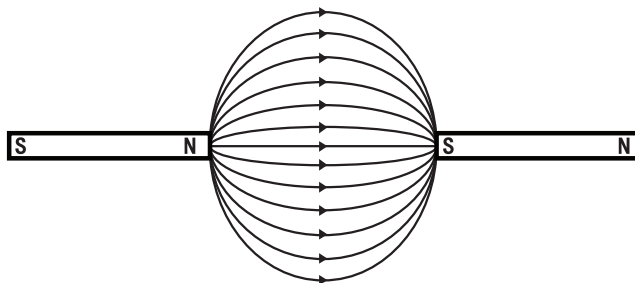


### LIKE POLES



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

### OPPOSITE POLES



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



# Electricity

## Magnets Can Produce Electricity

We can use magnets to make electricity. A magnetic field can move electrons. Some metals, like copper, have electrons that are loosely held; they are easily pushed from their shells.

Magnetism and electricity are related. Magnets can create electricity and electricity can produce magnetic fields. Every time a magnetic field changes, an electric field is created. Every time an electric field changes, a magnetic field is created. Magnetism and electricity are always linked together; you can't have one without the other. This phenomenon is called **electromagnetism**.

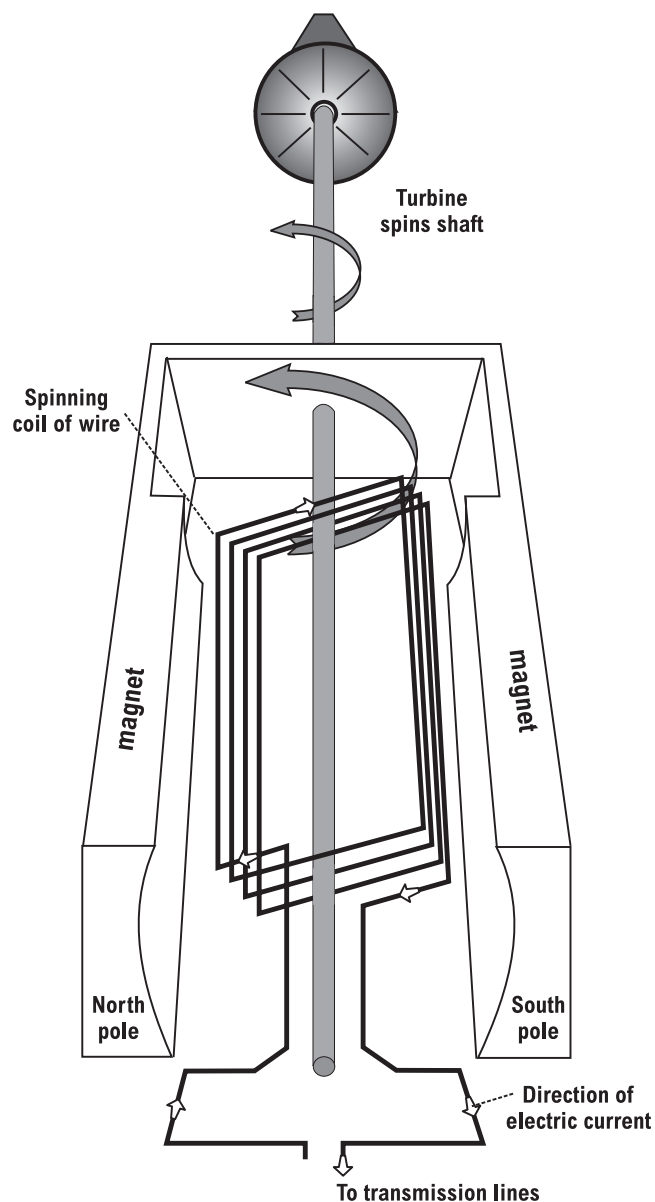
Power plants use huge turbine generators to make the electricity that we use in our homes and businesses. Power plants use many fuels to spin **turbines**. They can burn coal, oil, or natural gas to make steam to spin turbines. Or they can split uranium atoms to heat water into steam. They can also use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

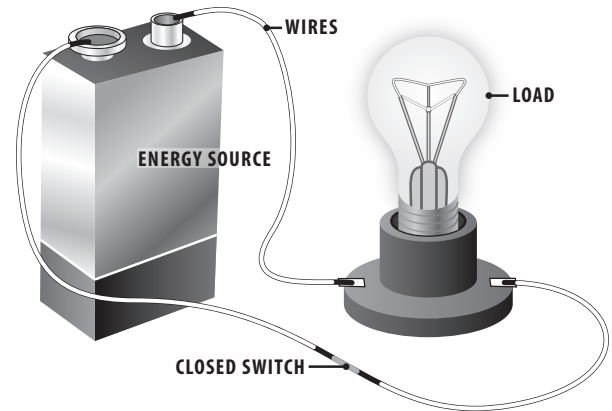
## Electricity Travels in Circuits

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.

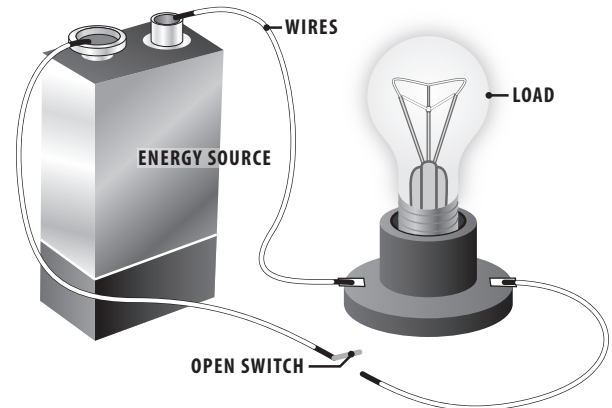
When we turn on the TV, electricity flows through wires inside the set, producing pictures and sound. Sometimes electricity runs motors—in washers or mixers. Electricity does a lot of work for us. We use it many times each day.

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, DVD players, video games, and computers. It cooks our food and washes the dishes. It mows our lawns and blows the leaves away. It can even run our cars.

### ELECTRICAL CIRCUITS



A **closed circuit** is a complete path allowing electricity to flow from the energy source to the load.



An **open circuit** has a break in the path. There is no flow of electricity because the electrons cannot complete the circuit.



# Electricity

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

## Generating 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. Thermal power plants use coal, biomass, petroleum, or natural gas to superheat water into steam, which powers a generator to produce electricity. Nuclear power plants use fission to produce the heat. Geothermal power plants use heat from inside the earth.

Wind farms use the kinetic energy in the wind to generate electricity, while hydropower plants use the energy in moving water.

## Moving Electricity

We use 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. There is also a standard system in place so that all of our machines and appliances can operate on electricity. Electricity makes our lives simpler and easier.

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.

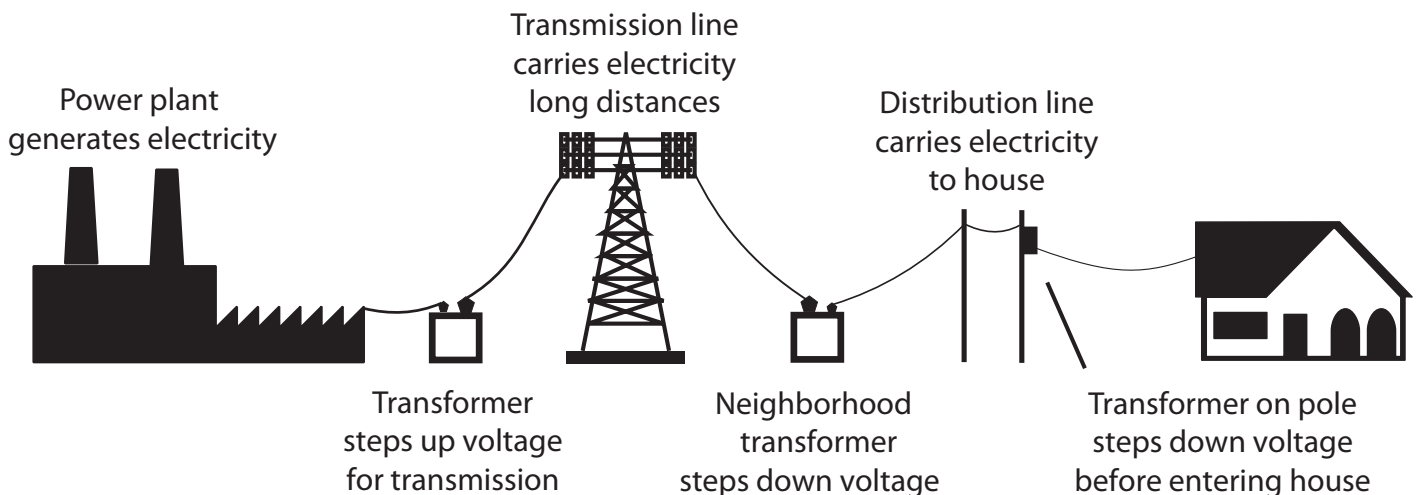
**Step-down transformers**, located at substations along the lines, reduce the voltage from 350,000 volts to 12,000 volts. **Substations** are small fenced-in buildings that contain transformers, switches, and other electrical equipment.

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.

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 home 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 that the utility company can bill you.

### TRANSPORTING ELECTRICITY



## Fuels that Make Electricity

Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydroelectric. Coal plants generate almost half of the electricity we use. There are also wind, geothermal, trash-to-energy, and solar power plants, which generate more than two 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 steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants produce emissions that can pollute the air and contribute to global climate change.

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. Almost 93 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. The heat is used to turn water into steam, which drives a turbine generator.

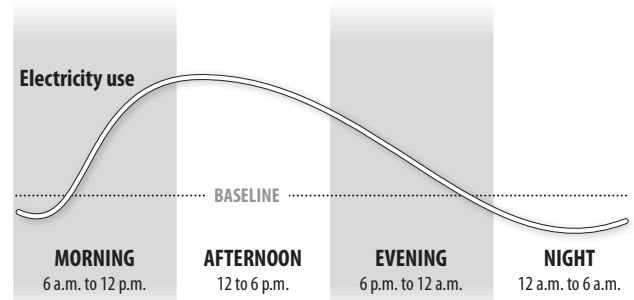
Nuclear power plants don't produce carbon dioxide emissions, but their waste is radioactive. Nuclear waste must be stored carefully to prevent contamination of people and the environment.

### ■ Hydropower Plants

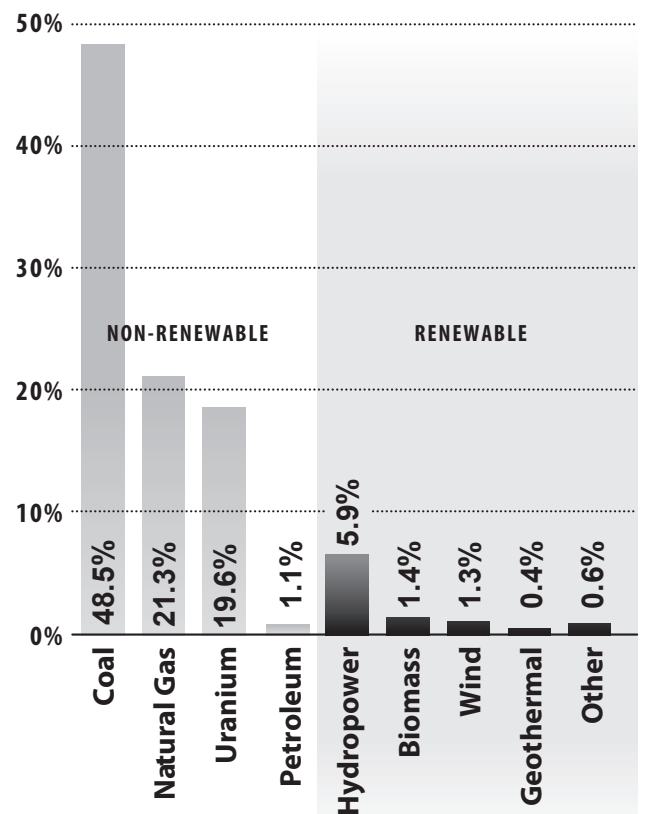
Hydropower plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

## ELECTRICITY USAGE THROUGHOUT THE DAY

Electricity usage is at its peak during the afternoon hours, especially in the summer.



## U.S. ELECTRICITY PRODUCTION, 2008



Source: Energy Information Agency



# Electricity

## 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 about 11 cents per kilowatt-hour of electricity. With the power shortages in California, people there will be paying much more.

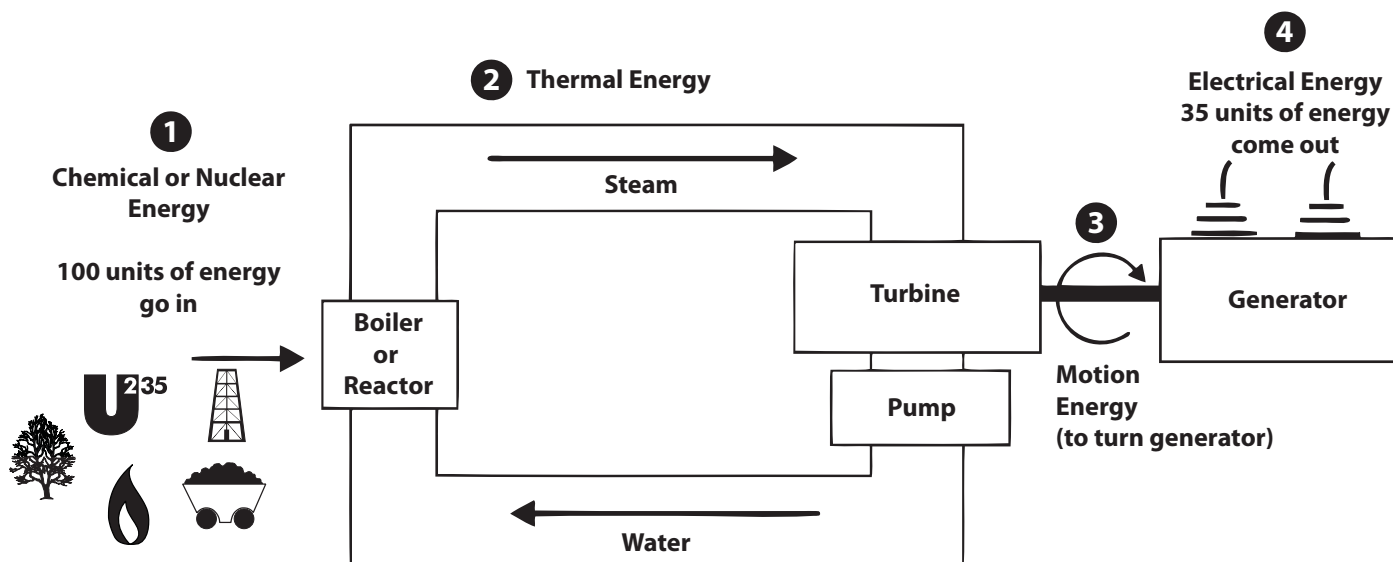
## Cost of Electricity

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

- **Fuel Cost:** The major cost of generating electricity is the cost of the fuel. Many energy sources can be used. Hydropower is the cheapest way and solar cells are probably the most expensive way to generate power.
- **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 can make the electricity economical to produce. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is inexpensive. Coal-fired plants, on the other hand, are cheaper 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. 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. Most of the lost energy is 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.

### EFFICIENCY OF A POWER PLANT



Most power plants are about 35% efficient. 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 of energy are produced to do usable work.