Electricity

If someone mentions energy, do you automatically think about electricity? If so, you're not alone. You probably do not pay much attention to electricity until there is a power outage. Electricity is behind almost everything we do in modern life, from keeping us warm and safe to entertaining us.

Electrons

Everything is made of atoms. Atoms contain three particles within them: **protons**, which have a positive charge; **neutrons**, which have no electric charge; and **electrons**, which have a negative charge. At the center, an atom has a **nucleus** made of protons and neutrons, and electrons that are moving around the nucleus a significant distance away. The electrons are the particles that transfer energy when we use electricity.

Electrons are always moving. In a conductor like a wire, electrons can easily pass energy from one atom to another. This transfer of energy through moving electrons is electric current. The more electrons passing energy through the wire, the higher the current.

Electrons and Magnets

If you lay two flat **magnets** on a table and begin to push one toward the other, at some point the magnets will jump together. What allows one magnet to know another is nearby? The answer is a **magnetic field**. This is a region surrounding a magnet that pulls on anything else magnetic, like a nail or another magnet. We label magnets with poles that show us how the magnetic field is arranged. One pole is north, and the other is south. The magnetic field moves away from the north pole and toward the south pole.

Any moving, charged particle creates a magnetic field. Because electrons have an electric charge and are always moving, each electron acts like a tiny magnet. In most materials, these tiny magnets point in different directions and cancel each other out. In some materials, many of them line up in the same direction, creating a magnet.

Moving charged particles create magnetic fields, and magnetic fields can move charged particles. This relationship is called **electromagnetism**. Magnetism and electricity are always linked together; you cannot have one without the other; you cannot have one without the other.

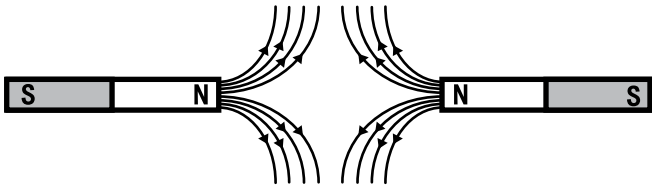
Generating Electricity

A **generator** is a device that transforms rotational motion into electricity. Generators have coils of wire and magnets. The magnets move in relation to the coils of wire, which forces electrons to move inside the wire coils. The wires are often made of a material like copper—a conductor with electrons that are able to move freely or are loosely held. This is how electricity is generated at a power plant regardless of the energy source (except in solar cells). The **turbine** spins, the magnetic field changes, and electricity is generated.

The difference in power plants is not in the generator, but what spins the generator. Two items can be used to provide spinning motion—steam or direct force. In thermal power plants, a fuel is used to heat water into high-pressure steam. Natural gas, coal, uranium, biomass, and geothermal energy are used in thermal power plants. The steam pushes on blades of a turbine, causing it to spin. That spinning motion is transferred into the generator. The other option is to just push on the turbine directly with water or air—hydropower or wind energy. In a hydroelectric plant, water pushes on enormous turbine blades inside the plant. In a wind turbine, the long, narrow blades are pushed by moving air. Whether a thermal power plant, a hydropower plant, or a wind turbine, the electricity delivered to our homes and schools is generated this way.

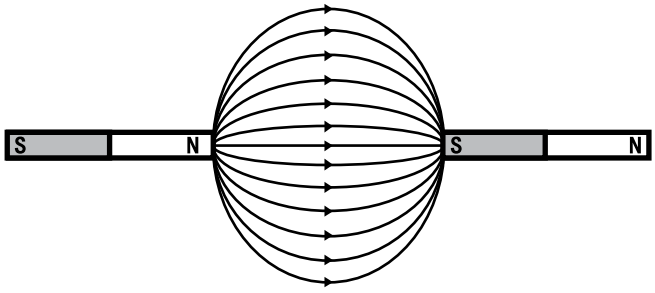
Magnets with Like Poles

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

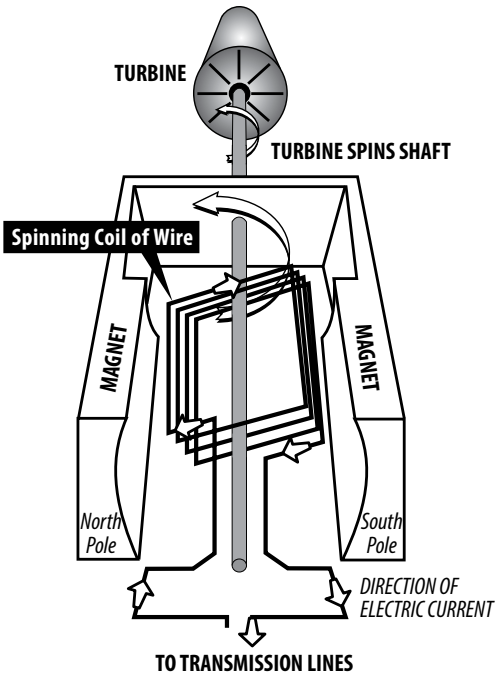


Magnets with Opposite Poles

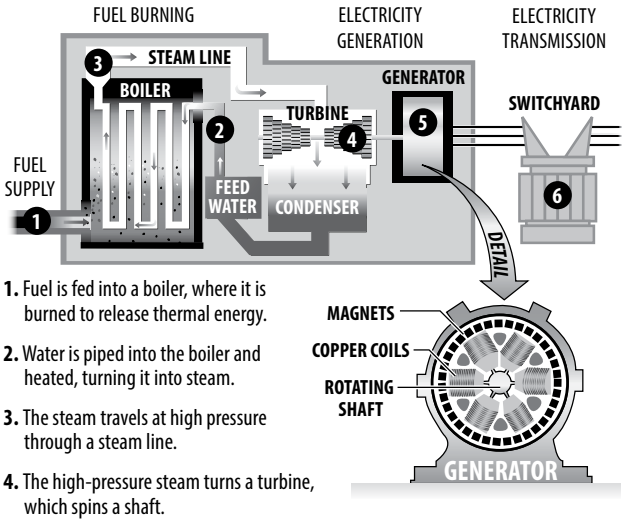
Opposite poles of magnets (N-S) attract each other.



Turbine Generator



Thermal Power Plant



1. Fuel is fed into a boiler, where it is burned to release thermal energy.
2. Water is piped into the boiler and heated, turning it into steam.
3. The steam travels at high pressure through a steam line.
4. The high-pressure steam turns a turbine, which spins a shaft.
5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

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 because it attracts the free, negatively charged electrons. 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 light bulb—is placed along the wire, the electricity can do work as it flows through the wire. In the Electric Circuits diagram to the right, electrons flow from the negative end of the battery through the wire to the light bulb. The electricity flows through the wire in the light bulb and back to the battery.

Electric Circuits

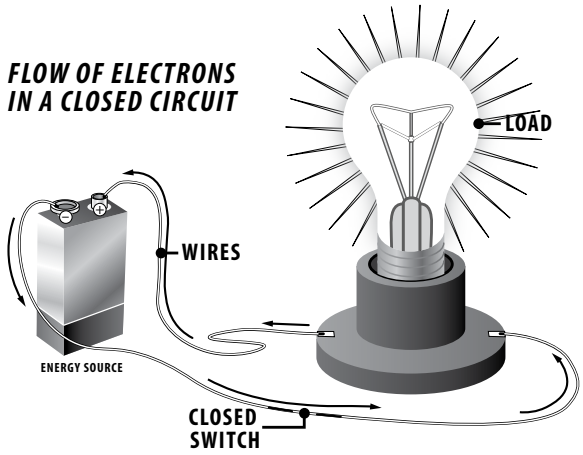
Electricity travels in pathways or closed loops of conducting wire called **circuits**. Electrons cannot move through a circuit unless there is a complete path for them to follow. An open circuit is a loop with a gap or break in it. Switches are commonly used to open or close circuits, turning devices off or on. The simplest circuit has one power source, like a battery, and one device to power, like a small light bulb. Your home's wiring is a somewhat complicated collection of wired circuits that are located in the walls or between floors and all connect to a breaker box or fuse box, where electricity enters your home. Circuits can be series, where everything is in the same loop, one after another. Circuits can also be parallel, where there are many loops connected to the same power supply. Circuits can also be both series and parallel, especially when multiple devices are connected to the same power supply.

BATTERIES

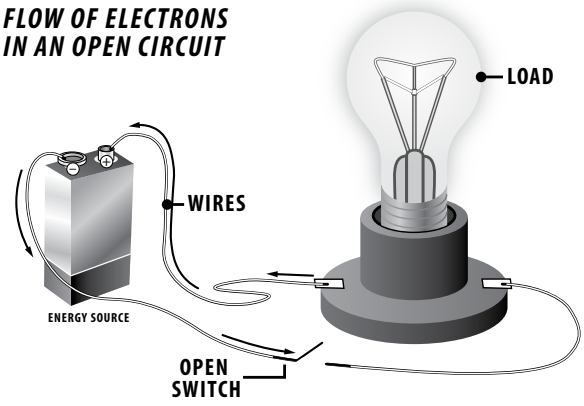


Image courtesy of Adobe Stock

Electric 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.

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Electricity

Moving Electricity

Using electricity as much as we do is possible because we can easily move it from one place to another. Power plants generate electricity and electric utilities deliver it to your home several miles away. 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, or increases, the **voltage**. Power plants step up the voltage because less electricity is lost along the power lines when it is at a higher voltage.

The electricity is then sent to a nationwide network of **transmission lines**. This is called the **electric grid**. 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 for safe distribution through local power lines. 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 or 240 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.

Measuring Electricity

The utility electric meter measures how much electrical energy we use. Electrons are far too small to count directly, so scientists developed other ways to measure electricity.

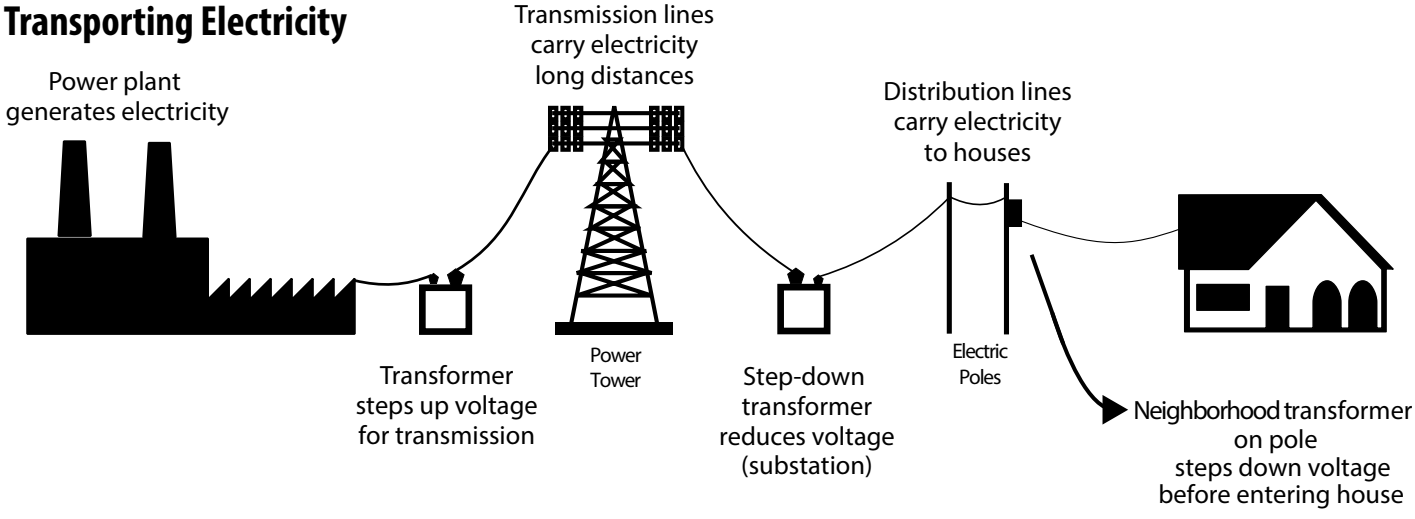
One important measurement is **current**, which describes how many electrons are moving through a circuit, measured in **amperes** or amps. Another is voltage, measured in volts, voltage, which describes how much energy each electron can transfer. Some devices need a large number of electrons moving through them, while others need each electron to carry a lot of energy. Some devices, like large air conditioners, need both. Voltage and current work together to determine **power**, which describes how quickly electrical energy is transferred or used. Power is measured in **watts (W)**. A **kilowatt (kW)** is 1,000 watts.

Electrical energy depends on both power and time. A device that uses a lot of power for a short time may use the same amount of electrical energy as a device that uses less power for a longer time. Electric utilities measure electrical energy in **kilowatt-hours (kWh)**, which is the unit used on electric bills.

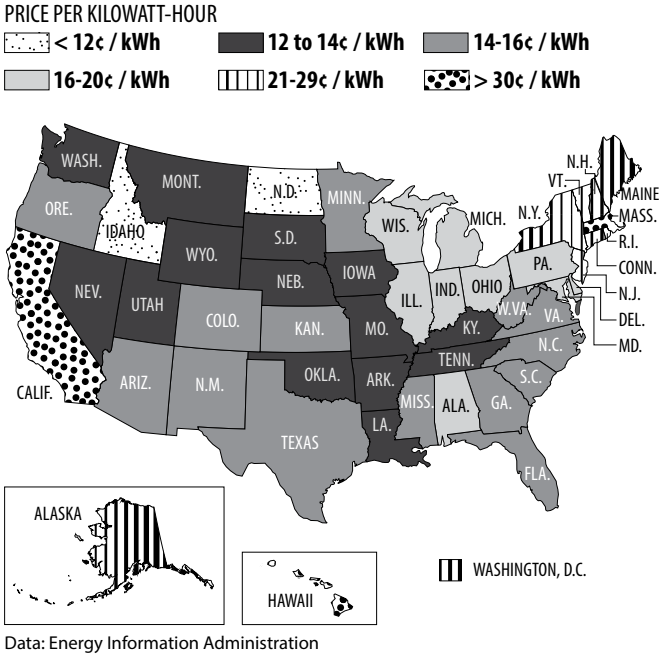
Paying for Electricity

The electricity delivered to homes and businesses across the country may be standardized, but the price is not. The price paid by electric utility customers depends on the cost of the fuel, the location, the cost of the building, power lines, and other equipment, and the efficiency of the system. Most electricity in the U.S. is generated using natural gas, uranium, coal, and wind. Each of these energy sources has different costs, and the power plants using them have different construction costs. Nuclear power plants and dams for hydropower are very expensive to build, but uranium fuel is very inexpensive compared to natural gas and coal. Flowing water and the wind are free! Even though sunlight is free, the cost to purchase, install, and maintain large solar systems can keep the cost of electricity from solar in line with other fuels.

Transporting Electricity



Average Residential Price for Electricity, 2025



Data: Energy Information Administration

The amount of electricity a customer uses will also influence the price paid for each kilowatt-hour. Industrial customers use an enormous amount of electricity, while residential customers tend to use the least. The average price residential customers in the United States pay is about 17 cents per kilowatt-hour, but the price ranges from as little as 12 cents in North Dakota to as much as 41 cents in Hawaii. State and local regulations, the number of customers, availability of energy sources, and other factors determine how much a customer pays. Commercial customers, like government buildings, schools, and businesses, pay about 13 cents per kilowatt-hour, and industrial customers pay about nine cents.

How Much Is a Watt?



1 WATT
Small LED flashlight



1.5 KILOWATTS = 1500 WATTS
Blow dryer



3 TO 5 MEGAWATTS = 3,000,000 to 5,000,000 WATTS
Diesel-electric locomotive engines



2 GIGAWATTS = 2,000,000,000 WATTS
Peak output of the Hoover Dam

You may now be wondering what a kilowatt-hour means in daily life. Let's calculate the cost of watching TV. To find the amount of energy consumed, multiply the power needed to run the TV by the amount of time you used it.

Energy (E) = Power (P) x Time (t)

If your TV uses 200 watts, and you watch TV for three hours, you would use the formula as follows:

energy = power x time (E = P x t)

energy = 200 W x 3 hour = 600 Wh

One watt-hour is a very small amount of electrical energy. Usually, we measure electric power in larger units called kilowatt-hours (kWh) or 1,000 watt-hours (kilo = thousand). To calculate the cost of watching TV for three hours, you would change the watt-hours into kilowatt-hours, then multiply the kilowatt-hours used by the cost per kilowatt-hour, as shown below:

$$600\ \text{Wh} \times \frac{1\ \text{kW}}{1{,}000\ \text{W}} = 0.600\ \text{kWh}$$

$$0.600\ \text{kWh} \times \$0.17 = \$0.102 \approx \$0.10$$

Therefore, it would cost about a dime to watch TV for three hours.

The cost of electricity looks like it's very inexpensive for one kilowatt-hour of electricity. And truthfully, 10 cents to watch a movie on TV isn't much. However, if you watch TV for three hours every day for a year, the electricity would be $36.50. Add taxes and other service charges to that. Now think about every device running in your home—appliances, electronics, the microwave, hair styling appliances—many of these devices use a lot more than 200 watts. The cost adds up quickly! That is why adults are always reminding kids to turn off the lights when they leave a room.

TRANSMISSION LINES



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