MAKING AND DELIVERING ELECTRICITY

Electricity

Electricity at a Glance, 2009

Secondary Source of Energy, Energy Carrier

Major Energy Sources Used to Generate Electricity:
- coal, uranium, natural gas, hydropower

U.S. Energy Consumption:
- 40.5%

Net U.S. Electricity Generation:
- 3,814.3 BkWh

Major Uses of Electricity:
- manufacturing, heating, cooling, lighting

The Nature of Electricity

Electricity is a little different from the other sources of energy that we talk about. Unlike coal, petroleum, or solar energy, electricity is a **secondary source of energy**. That means we must use other primary sources of energy, such as coal or wind, to make electricity. It also means we can't classify electricity as a renewable or nonrenewable form of energy. The energy source we use to make electricity may be renewable or nonrenewable, but the electricity is neither.

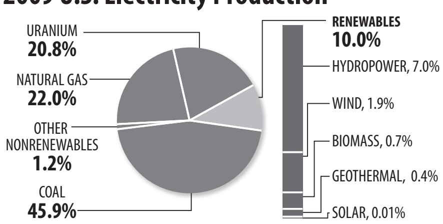
Making Electricity

Almost all electricity made in the United States is generated by large, central power plants. There are about 5,400 power plants in the U.S. Most power plants use coal, nuclear fission, natural gas, or other energy sources to superheat water into steam in a boiler. The very high pressure of the steam (it's 75 to 100 times normal atmospheric pressure) turns the blades of a turbine. (A **turbine** turns the linear motion of the steam into circular motion.) The blades are connected to a **generator**, which houses a large magnet surrounded by a coiled copper wire. The blades spin the magnet rapidly, rotating the magnet inside the coil producing an **electric current**.

The steam, which is still very hot but at normal pressure, is piped to a condenser, where it is cooled into water by passing it through pipes circulating over a large body of water or cooling tower. The water then returns to the boiler to be used again. Power plants can capture some of the heat from the cooling steam. In old plants, the heat was simply wasted.

Not all power plants use thermal energy to generate electricity. Hydropower plants and wind farms use motion energy to turn turbines, turning a generator, which produces electricity. Photovoltaic plants use radiant energy to generate electricity directly.

2009 U.S. Electricity Production



Data: Energy Information Administration

Moving Electricity

We are using more and more electricity every year. One reason that electricity is used by so many consumers is that it's easy to move from one place to another. Electricity can be produced 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 the power plant. Next, it goes by wire to a **transformer** that "steps up" the voltage. A transformer steps up the voltage of electricity from the 2,300 to 22,000 volts produced by a generator to as much as 765,000 volts (345,000 volts is typical). Power companies step up the voltage because less electricity is lost along the lines when the voltage is high.

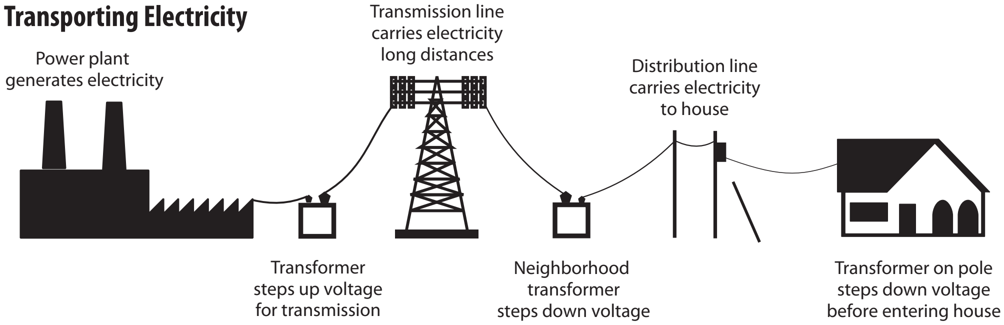
The electricity is then sent on a nationwide network of **transmission lines** made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway. The lines are interconnected, so should one line fail, another will take over the load.

Step-down transformers located at substations along the lines reduce the voltage to 12,000 volts. Substations are small buildings in fenced-in areas that contain the switches, transformers, and other electrical equipment. Electricity is then carried over distribution lines that bring electricity to your home. Distribution lines may either be overhead or underground. The overhead distribution lines are the electric lines that you see along streets.

Before electricity enters your house, the voltage is reduced again at another transformer, usually a large gray can mounted on an electric pole. This transformer reduces the electricity to the 120 volts, the amount needed to run the appliances in your home.

Electricity enters your house through a three-wire cable. The "live wires" are then brought from the circuit breaker or fuse box to power outlets and wall switches in your home. An electric meter measures how much electricity you use so the utility company can bill you. The time it takes for electricity to travel through these steps—from power plant to the light bulb in your home—is a tiny fraction of one second.

Transporting Electricity



Power to the People

Everyone knows how important electricity is to our lives. All it takes is a power failure to remind us how much we depend on it. Life would be very different without electricity—no more instant light from flicking a switch, no more television, no more refrigerators, or stereos, or video games, or hundreds of other conveniences we take for granted. We depend on it, business depends on it, and industry depends on it. You could almost say the American economy runs on electricity.

It is the responsibility of electric utility companies to make sure electricity is there when we need it. They must consider reliability, capacity, base load, peak demand, and power pools.

Reliability is the capability of a utility company to provide electricity to its customers 100 percent of the time. A reliable electric service is without blackouts or brownouts. To ensure uninterrupted service, laws require most utility companies to have 15 to 20 percent more capacity than they need to meet peak demand. This means a utility company whose peak load is 12,000 MW (megawatts) must have 14,000 MW of installed electrical capacity. This ensures that there will be enough electricity to meet demand even if equipment were to break down on a hot summer afternoon.

Capacity is the total quantity of electricity a utility company has on-line and ready to deliver when people need it. A large utility company may operate several power plants to generate electricity for its customers. A utility company that has seven 1,000 MW plants, eight 500 MW plants, and 30 100 MW plants has a total capacity of 14,000 MW.

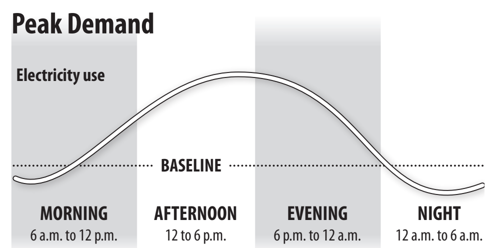
Base load power is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Base load power stations usually run at full or near capacity.

When many people want electricity at the same time, there is a **peak demand**. Power companies must be ready for peak demands so there is enough power for everyone. During the day's peak, between 12:00 noon and 6:00 p.m., additional generators must be used to meet the demand. These peak load generators run on natural gas, diesel, or hydropower and can be put into operation in minutes. The more this equipment is used, the higher our utility bills. By managing the use of electricity during peak hours, we can help keep costs down.

The use of **power pools** is another way electric companies make their systems more reliable. Power pools link electric utilities together so they can share power as it is needed. A power failure in one system can be covered by a neighboring power company until the problem is corrected. There are nine regional power pool networks in North America. The key is to share power rather than lose it.

The reliability of U.S. electric service is excellent, usually better than 99 percent. In some countries, electric power may go out several times a day for several minutes or several hours at a time. Power outages in the United States are usually caused by such random occurrences as lightning, a tree limb falling on electric wires, or a fallen utility pole.

Peak Demand



Peak load is the maximum load during a specified period of time.

Demand-Side Management

Demand-side management is all the things a utility company does to affect how much people use electricity and when. It's one way electric companies manage those peak load periods.

We can reduce the quantity of electricity we use by using better conservation measures and by using more efficient electrical appliances and equipment.

What's the difference between conservation and efficiency? Conserving electricity is turning off the water in the shower while you shampoo your hair. Using electricity more efficiently is installing a better showerhead to decrease water flow.

Demand-side management can also affect the timing of electrical demand. Some utility companies give rebates to customers who allow the utility company to turn off their hot water heaters or set their thermostats (via radio transmitters) during extreme peak demand periods, which occur perhaps 12 times a year. One East Coast power company gives participating customers a $4 per month rebate.

America's Electric Grid

When you walk into a room and flip the switch on the wall, the lights come right on, just as you expected. But did you ever think how the electricity got to your house to give you the power for those lights and the many electrical appliances and products you use at home, ranging from your DVD player to your refrigerator?

Today there are more than 9,000 electric utility companies and other generating units all over America that produce and distribute more than one million megawatts of electricity to homes, businesses, and other energy users.

To get that electricity to its users, there are more than 300,000 miles of high-voltage electric transmission lines across the U.S. They take the electricity produced at power plants to transformers that step up the voltage to reduce energy loss while it travels along the grid to where it is going to be used.

Generating Electricity

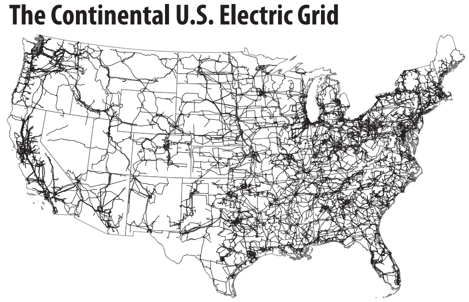
Three basic types of power plants generate most of the electricity in the United States—fossil fuel, nuclear, and hydropower. There are also wind, geothermal, trash-to-energy, and solar power plants, but they generate only about 3.0 percent of the electricity produced in the United States.

Fossil Fuel Power Plants: Fossil fuel plants burn coal, natural gas, or oil. These plants use the chemical energy in fossil fuels to superheat water into steam, which drives a **turbine generator**. Fossil fuel plants are sometimes called **thermal power plants** because they use heat to generate electricity. Coal is the fossil fuel of choice for most electric companies, producing 45.9 percent of total U.S. electricity. Natural gas plants produce 22.0 percent. Petroleum produces 0.9 percent of the electricity in the U. S.

Nuclear Power Plants: Nuclear plants generate electricity much as fossil fuel plants do, except that the furnace is called a **reactor** and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller elements, producing heat in the process. The heat is used to superheat water into high-pressure steam, which drives a turbine generator. Like fossil fuel plants, nuclear power plants are called thermal plants because they use heat to generate electricity. Nuclear energy produces 20.9 percent of the electricity in the U. S.

Hydropower Plants: Hydropower plants use the gravitational force of falling water to generate electricity. Hydropower is the cheapest way to produce electricity in this country, but there are few places where new dams can be built economically. There are many existing dams that could be retrofitted with turbines and generators. Hydropower is called a renewable energy source because it is renewed continuously during the natural water cycle. Hydropower produces five to ten percent of the electricity in the U. S., depending upon the amount of precipitation. In 2009, hydropower generated 7.0 percent of U.S. electricity.

The Continental U.S. Electric Grid



TRANSMISSION LINES

These transmission lines—whether they are located on poles above ground or buried underground—make up the most visible part of what is called the **electric grid**. The grid consists of the power generators, the power lines that transmit electricity to your home, the needed components that make it all work, and your family and the other homes and businesses in your community that use electricity.

The process starts at the power plant that serves your community, and ends with wires running from the distribution lines into your home. Outside your home is a meter with a digital read-out or a series of dials that measure the flow of energy to determine how much electricity you are using. Of course, there are many more parts to this process, ranging from substations and wires for different phases of current to safety devices and redundant lines along the grid to ensure that power is available at all times. You can see why the U.S. National Academy of Engineering has called America's electric grid "the greatest engineering achievement of the 20th century."

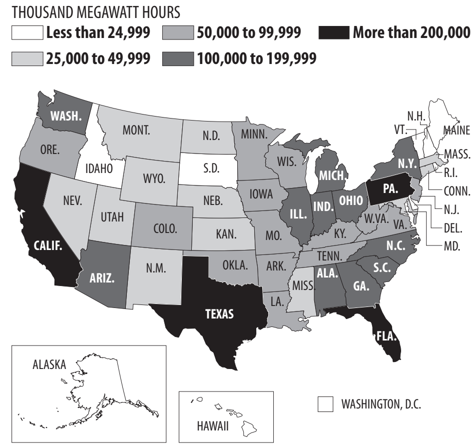
While this basic system of electricity transmission has worked well since the late 1880s, the increase in electric use in recent years has put a strain on the country's electric grid. The grid we use today was designed and put into place in the 1950s and 1960s, with much of the equipment planned to handle far smaller electrical use. More than 50 years later, a great deal of the equipment is reaching the end of its lifespan. At the same time, our electricity use has increased tremendously, putting a huge load on the system. Just look around your home at the TV sets, CD and DVD players, computers, lamps, air conditioners, and all the other appliances found in the typical home today, and you'll see a tremendous demand for electricity far above the basic lights and products used in homes back when today's system was set up.

The surge in demand for electricity has far exceeded the creation of new transmission facilities and equipment over the years. Compounding the problem is the fact that about two-thirds of the electricity produced in our power plants never reaches potential users because of losses in energy conversion and transmission. Because of the complexity and importance of the country's electric grid, many new governmental regulations increase the time needed to plan and install additional equipment to meet today's demands.

In the past few years, many parts of the country have experienced brief "brown-outs" or longer periods of power outages, increasing public concern about the future of the system we use today. Think about this: right now, our electric grid is actually 99.97 percent reliable, meaning the power is usually there when we want it. But that very tiny percentage of time when the grid isn't working at its full capability costs consumers an estimated $150 billion each year, including stoppages in automated equipment, computers that crash, and even the brief interruptions in the flow of energy and information in today's digital world that affect our work and our leisure activities.

For many years, America's electric grid has been a shining example of our technology and ability, and a major part of the country's prosperity, comfort, and security. To meet the country's growing electricity needs today and in the future, changes are needed in how the grid operates and the equipment and technologies it uses.

U.S. Electric Power Generation, 2009



Data: Energy Information Administration

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (68 percent), the cost of transmission (7 percent), and local distribution (24 percent). The average cost of electricity is twelve cents per kWh for residential customers and a little over seven cents for industrial customers. A major key to cost is the fuel used to generate the power. Electricity produced from natural gas, for example, costs more than electricity produced from coal or hydropower.

Another consideration is how much it costs to build a power plant. A plant may be very expensive to construct, but the cost of the fuel can make it competitive to other plants, or vice versa. 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 much less expensive to build than nuclear plants, but their fuel—coal—is more expensive.

When calculating costs, a plant's efficiency must also be considered. In theory, a 100 percent energy efficient machine would change all the energy put into the machine into useful work, not wasting a single unit of energy. But converting a primary energy source into electricity involves a loss of usable energy, usually in the form of heat. In general, it takes three units of fuel to produce one unit of electricity from a thermal power plant.

In 1900, most power plants were only four percent efficient. That means they wasted 96 percent of the fuel used to generate electricity. Today's power plants are over eight times more efficient with efficiency ratings around 35 percent. Still, this means 65 percent of the initial heat energy used to make electricity is lost. You can see this waste heat in the clouds of steam pouring out of giant cooling towers on newer power plants. A modern coal plant burns about 8,000 tons of coal each day, and about two-thirds of this is lost when the chemical energy in coal is converted into thermal energy, then into electrical energy. A hydropower plant, on the other hand, is about 90 to 95 percent efficient at converting the kinetic energy of moving water into electricity.

Electricity

Write the word that best describes each definition in the blank space. Use each word only once.

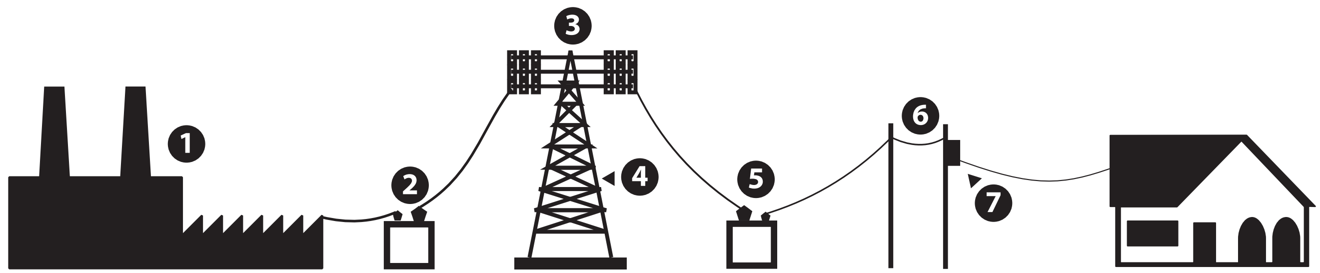
1. A device that changes voltage. ________________________
2. A device that changes linear motion into circular motion. ________________________
3. Allowing competition in the power industry. ________________________
4. Managing how and when consumers use electricity. ________________________
5. The total amount of electricity a power plant can deliver. ________________________
6. Times when many customers need electricity. ________________________
7. How well a utility delivers electricity at all times. ________________________
8. Electricity produced at all times to meet basic demand. ________________________
9. A merged network of electric utilities. ________________________
10. Reducing energy usage through behavioral changes. ________________________
11. A measurement of the amount of electricity used by consumers. ________________________
12. Power plants that burn fuel to produce electricity. ________________________
13. A material with little resistance to electric current. ________________________
14. A device measuring electricity consumption that allows for two-way wireless communication between the utility and consumer. ________________________
15. A source of energy that requires another source to produce it. ________________________
16. Manufacturing a product and producing electricity. ________________________
17. Reducing the amount of energy consumed by devices through advances in technology. ______________________

Word Bank

- baseload
- capacity
- cogeneration
- conservation
- demand-side management
- deregulation
- efficiency
- generator
- kilowatt-hour
- peak demand
- power pool
- reliability
- secondary
- smart meter
- superconductor
- thermal
- transformer
- turbine

Transporting Electricity

Explain what each of the components numbered below does to get electricity from the generator to the consumer.



1. **Power plant:**

2. **Step-up transformer:**

3. **Transmission line:**

4. **Power tower:**

5. **Step-down transformer:**

6. **Distribution line:**

7. **Neighborhood transformer:**