ELECTRICITY

Electricity

2002 Facts at a Glance

Classification: Secondary Source of Energy

Major sources used to produce electricity: coal, nuclear power, natural gas and hydropower.

Percent of energy consumed in U.S.: 39.2%

U.S. electricity production: 3,839 billion kWh
(includes utilities and independent producers)

Major uses: 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**—not primary—source of energy. That means we must use other (primary) sources of energy 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. These plants typically 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. (At a hydroelectric plant, the force of falling water turns the blades.) 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.

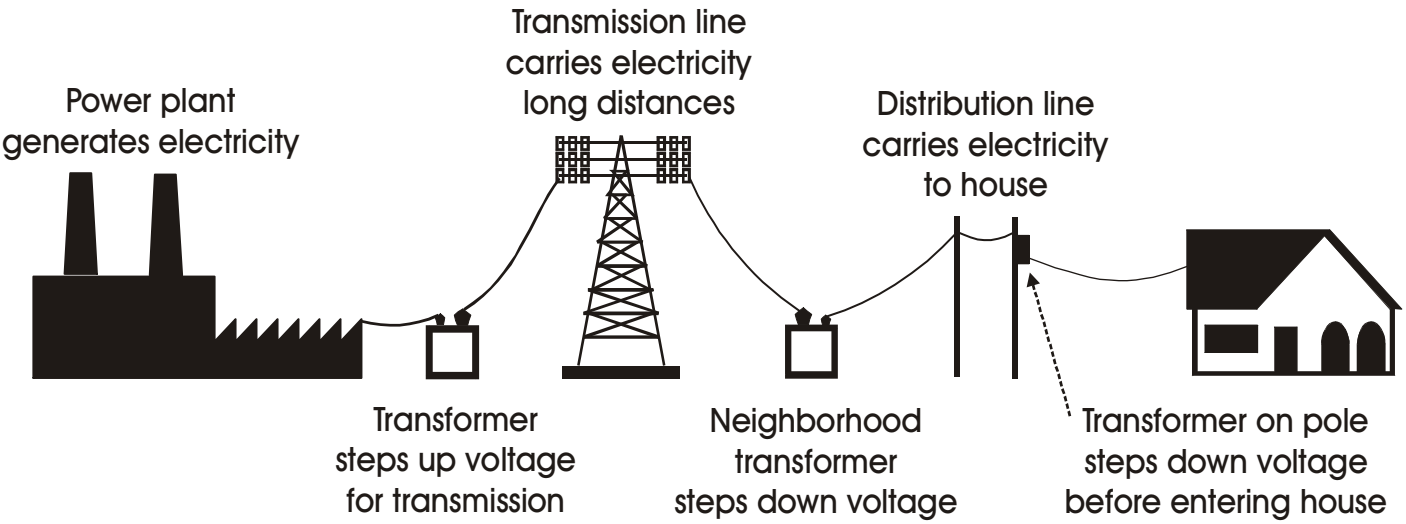
Moving Electricity from Power Plants to Homes

We are using more and more electricity every year. One reason electricity is used so much is 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 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.

TRANSPORTING ELECTRICITY



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 which 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 that are needed to run the light bulb 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.

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's the business of electric utility companies to make sure electricity is there when we need it. How do they do it? First, some terms: reliability; capacity; base load; power pools, and peak demand.

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 electric service, laws require most utility companies to have 15 to 20 percent more capacity than they need to meet peak demands. This means a utility company whose peak load is 12,000 MW, would need to have about 14,000 MW of installed electrical capacity. This helps ensure there will be enough electricity to go around even if equipment were to break down on a hot summer afternoon.

Capacity is the total quantity of electricity a utility company has online 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 (megawatt) 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 hydro 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.

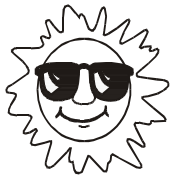
Power outages in the United States are usually caused by such random occurrences as lightning, a tree limb falling on electric wires, or a car hitting a utility pole.

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.

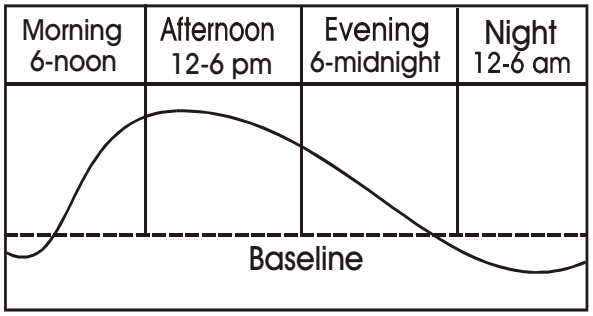
We can reduce the quantity of electricity we use by using better conservation measures and by using more efficient electrical appliances and equipment.

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



PEAK DEMAND

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



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 (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.

Appliance Efficiency

Most homes contain dozens of appliances, from essential ones like stoves and refrigerators, to convenience extras like food processors and deep fryers. Any one appliance may not use much electricity, but there are billions of appliances in the United States and they all use energy. Refrigerators alone use the electrical output of about 25 large power plants (nearly seven percent of the energy we use in this country).

Electricity demand can be significantly reduced by using energy efficient appliances. In the last 20 years, comparing appliance efficiency has been made easier by government regulation.

Since 1980, manufacturers have put EnergyGuide labels on seven major appliances—furnaces, water heaters, refrigerators, freezers, clothes washers, dishwashers, and room air conditioners.

The bright yellow and black **EnergyGuide labels** let you compare, for instance, the cost of operating one refrigerator with another. An energy efficient refrigerator may cost more to purchase, but it could save you hundreds of dollars in electricity over its lifetime.

Efficiency Standards

In 1987, Congress passed the **National Appliance Energy Conservation Act**. The Act required certain home appliances to meet minimum energy efficiency standards. The Act set standards for seven major home appliances that were already required to have EnergyGuide labels, plus it set standards for heat pumps, central air conditioners, and kitchen ranges. Most of the standards took effect in 1990.

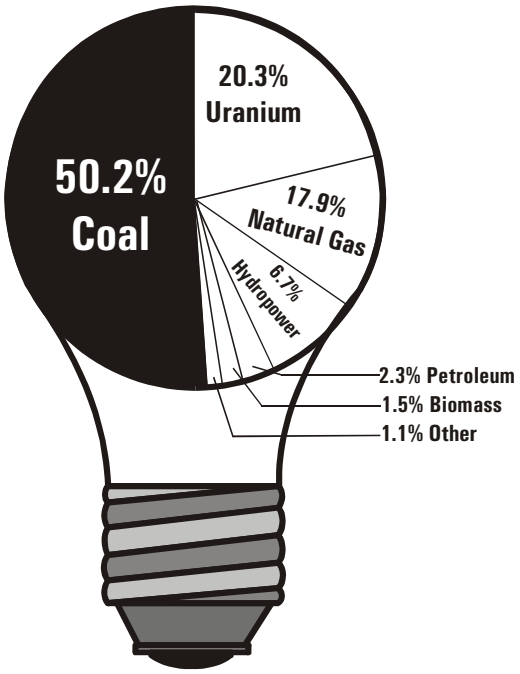
New electric appliances use less electricity but still produce the same amount of work. Appliance efficiency has improved dramatically in the last 25 years.

Today's freezers are 77 percent more efficient than those made in the early 1970s, and central air conditioners are 50 percent more efficient.

PRODUCING*electricity*

Three kinds of power plants produce most of the electricity in the United States—fossil fuel, nuclear, and hydropower.

U.S. ELECTRICITY PRODUCTION



There are also wind, geothermal, trash-to-energy, and solar power plants, but they generate only about 2.6 percent of the electricity produced in the U.S.

Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or oil. These plants use the 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 energy to make electricity. Coal is the fossil fuel of choice for most electric companies, producing 50.2 percent of the electricity. Natural gas plants produce 17.9 percent. Petroleum produces 2.3 percent of the electricity in the U. S.

Nuclear Power Plants

Nuclear plants produce 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 parts, producing heat energy. The heat energy superheats water into steam and the high pressure steam drives a turbine generator. Like fossil plants, nuclear power plants are called thermal plants because they use heat to make electricity. Nuclear energy produces 20.3 percent of the electricity in the U.S.

Hydropower Plants

Hydro (water) power plants use the 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. Hydropower is called a renewable energy source because it is renewed continuously by rainfall. Hydropower produces five to ten percent of the electricity in the United States, depending upon rainfall.

MEASURING*electricity*

ELECTRICITY

Power is the rate (time) of doing work. A watt is a measure of the electric power an appliance uses. Appliances require a certain number of watts to work correctly. All light bulbs are rated by watts, (60, 75, 100 watts) as well as appliances (such as a 1500-watt hairdryer).

A kilowatt is 1,000 watts. A kilowatt-hour (kWh) is the amount of electricity used in one hour at a rate of 1,000 watts. Think of adding water to a pool. In this analogy, a kilowatt is the rate, or how fast water is added to the pool; and a kilowatt-hour is the amount, or how much water is added to the pool.

Just as we buy gasoline in gallons or wood in cords, we buy electricity in kilowatt-hours. Utility companies charge us for the kilowatt-hours we use during a month. If an average family of four uses 750 kilowatt-hours in one month, and a utility company charges 10 cents per kilowatt-hour, the family will receive a bill for $75. (750 x $0.10 = $75.00)

Electric utilities use megawatts and gigawatts to measure large amounts of electricity. Power plant capacity is usually measured in megawatts. One megawatt (MW) is equal to one million watts or one thousand kilowatts. Gigawatts are often used to measure the electricity produced in an entire state or in the United States. One gigawatt is equal to one billion watts, one million kilowatts, or one thousand megawatts.

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (50%), the cost of transmission (20%) and local distribution (30%). The average cost of electricity is 8.0 cents per kWh for residential customers and 4.5 cents for industrial customers. A major key to cost is the fuel used to generate electricity. For example, electricity produced from natural gas costs more than electricity produced from coal or nuclear power.

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.

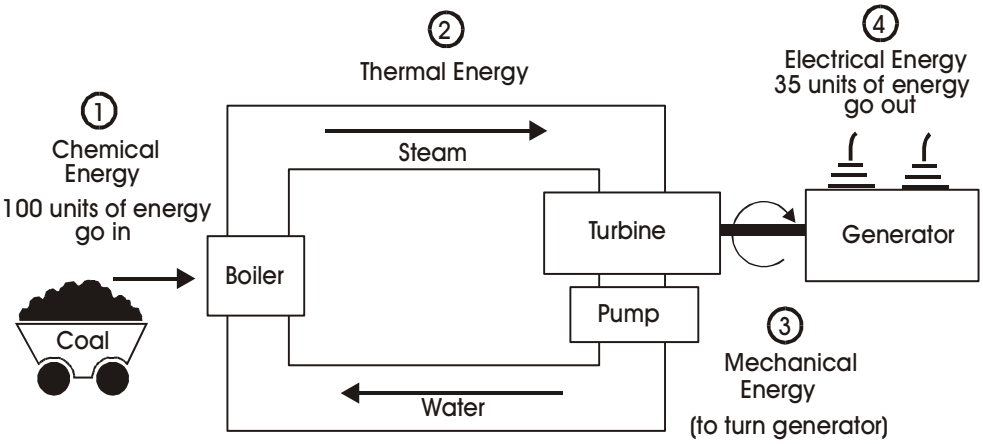
In 1900, electric power plants were only four percent efficient. That means they wasted 96 percent of the fuel used to generate electricity. Today's power plants are over eight times more efficient with efficiency ratings around 35 percent. Still, this means 65 percent of the initial heat energy used to make electricity is lost. (You can see this waste heat in the great 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 heat energy in coal is converted into electrical energy.

But that's not all. About two percent of the electricity generated at a power plant must be used to run equipment. And then, even after the electricity is sent over electrical lines, another 10 percent of the electrical energy is lost in transmission. Of course, consumers pay for all the electricity generated whether "lost" or not.

The cost of electricity is affected by what time of day it is used. During a hot summer afternoon from noon to 6 p.m., there is a peak of usage when air-conditioners are working harder to keep buildings cool. Electric companies charge their industrial and commercial customers more for electricity during these peak load periods because they must turn to more expensive ways to generate power.

EFFICIENCY OF POWER PLANTS

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.



Deregulation

Since the 1930s, most electric utilities in the U.S. have operated under state and federal regulations in a defined geographical area. Only one utility provides service to any one area. People and businesses can not choose their electricity provider. In return, the utilities have to provide service to every consumer, regardless of profitability.

Under this model, utilities generate the power, transmit it to the point of use, meter it, bill the customer, and provide information on efficiency and safety. The price is regulated by the state.

As a result, the price of a kilowatt-hour of electricity to residential customers varies widely among the states and utilities, from a high of 16 cents to a low of four cents. The price for large industrial users varies, too. The types of generating plants, the cost of fuel, taxes, and environmental regulations are some of the factors contributing to the price variations.

In the 1970s, the energy business changed dramatically in the aftermath of the Arab Oil Embargo, the advent of nuclear power, and stricter environmental regulations. **Independent power producers** and **cogenerators** began making a major impact on the industry. Large consumers began demanding more choice in providers.

In 1992, Congress passed the **Energy Policy Act** to encourage the development of a competitive electric market with open access to transmission facilities. It also reduced the requirements for new non-utility generators and independent power producers.

The Federal Energy Regulatory Commission (FERC) began changing their rules to encourage competition at the wholesale level. Utilities and private producers could, for the first time, market electricity across state lines to other utilities.

Some state regulators are encouraging broker systems to provide a clearinghouse for low-cost electricity from under-utilized facilities. This power is sold to other utilities that need it, resulting in lower costs to both the buyer and seller. This wholesale marketing has already brought prices down in some areas.

Many states are now considering whether competition in the electric power industry is a good thing for their consumers. This competition can take many forms, including allowing large consumers to choose their provider and allowing smaller consumers to join together to buy power.

In some states, individual consumers now have the option of choosing their electric utility, much like people can now choose their long-distance telephone carrier.

INDEPENDENT *producers*

The business of generating electricity once was handled solely by electric utility companies, but today many others are generating—and selling—electricity. Independent power producers (sometimes called private power producers, or non-utility generators) generate electricity using coal or gas-fired boilers, or such renewable energy sources as hydropower, solar, geothermal, wind, and biomass.

Independent power producers came on strong after the oil crises of the 1970s. At that time, Congress wanted to encourage greater efficiency in energy use and the development of new forms of energy. In 1978, Congress passed a set of energy laws including the Public Utility Regulatory Policies Act or PURPA. This new law changed the relationship between electric utilities and smaller, independent power producers.

Under the law, a public utility company cannot ignore a nearby independent power producer. A utility must purchase power from an independent power producer if the utility has a need for the electricity, and if the independent power producer can make electricity for less than what it would cost the utility to make it.

The relationship between independent power producers and utilities varies from state to state. Some utilities welcome the independent power producers because they help them meet the growing demand for electricity in their areas without having to build new—and expensive—power plants.

Other utilities worry that power from independent producers will make their systems less reliable and increase their costs. They fear that this may cause industries to think twice before locating in their areas.

For different reasons, some environmentalists also worry that independent producers may not be subject to the same pollution control laws as public utilities. In reality, the opposite is true. Because they are generally the newest plants, independent power producers are subject to the most stringent environmental controls.

In any case, most experts predict that independent power producers will produce more and more electricity. Today, independent power producers generate about 25.1 percent of the nation's electricity. In the last five years, more than half of all new electric generation in the U.S. has come from independent power producers.

Cogenerators

A special independent power producer is a cogenerator—a plant that produces electricity and uses the waste heat to manufacture products. Industrial plants, paper mills, and fast-food chains can all be cogenerators.

These types of plants are not new. Thomas Edison was a cogenerator. Plants generate their own electricity to save money and ensure they have a reliable source of energy that they can control.

Now, some cogenerators are selling the electricity they do not use to utilities. The electric utilities supply that energy to their customers. So, even though your family's electric bill comes from a utility company, your electricity may have been made by a local factory. Today, about seven percent of the electricity produced in the U.S. is cogenerated.

Their local utility would distribute the power to the consumer. Some experts say this could lower electric bills, but don't expect to see this happening on a large scale in the next few years.

It will take the industry and the states several years to decide if residential competition is a good thing and figure out how to implement the changes.

Future Demand

Home computers, answering machines, FAX machines, microwave ovens, and video games have invaded our homes and they are demanding electricity!

New electronic devices are part of the reason why Americans are using more electricity every year.

The U. S. Department of Energy predicts the nation will need to increase its current generating capacity of 780,000 megawatts by a third in the next 20 years.

Some parts of the nation, especially California, have begun experiencing power shortages. Utilities are resorting to rolling blackouts—planned power outages to one neighborhood or area at a time—because of the limited power. Utilities are warning that there will be increasing outages nationwide during the summer months even if consumers implement energy conservation techniques.

Conserving electricity and using it more efficiently will help, but everyone agrees we need more power plants now. That's where the challenge begins. Should we use coal, natural gas, or nuclear power to generate electricity?

Can we produce more electricity from renewable energy sources such as wind or solar? And where should we build new power plants? No one wants a power plant in his backyard, but everyone wants the benefits of electricity. Experts predict we will need 200 thousand more megawatts of generating capacity by the year 2010.

Demand for electricity will only increase in the future. We must also make machines and appliances much more energy efficient or we will have to build the equivalent of 350 coal plants by the year 2010 to meet that demand.

Right now, most new power generation comes from natural gas. Natural gas is a relatively clean fuel and is abundant in the United States.

New natural gas combined-cycle turbines use the waste heat they generate to turn a second turbine. Using this waste heat increases efficiency to 50 or 60 percent, instead of the 35 percent efficiency of conventional power plants.

The present shortage is also bringing about a renewed interest in nuclear power plants, especially with the increasing concern over global climate change.

RESEARCH&*development*

Electricity research didn't end with Edison and Westinghouse. Scientists are still studying ways to make electricity work better. The dream is to come up with ways to use electricity more efficiently and generate an endless supply of electricity. Two promising technologies are superconductivity and nuclear fusion.

Superconductivity

Superconductivity was discovered in the laboratory about 75 years ago, long before there was any adequate theory to explain it. Superconductivity is the loss of virtually all resistance to the passage of electricity through some materials. Scientists found that as some conducting materials are cooled, the frictional forces that cause resistance to electric flow suddenly drop to almost nothing at a particular temperature. In other words, electricity remains flowing without noticeable energy loss even after the voltage is removed.

Until just a few years ago, scientists thought that superconductivity was only possible at temperatures below -419° F. That temperature could only be maintained by using costly liquid helium. But new ceramic-like materials are superconducting at temperatures as high as -270°F. These new materials can maintain their superconducting state using liquid nitrogen. The economics of superconductivity is becoming practical. The cost of liquid helium is $11 per gallon, but the cost of liquid nitrogen is just 22¢ per gallon.

Some obstacles remain in the way of incorporating this new technology into commercial products, however.

First, researchers have conducted most experiments using only very small samples of the new ceramic materials, which tend to be very brittle and difficult to shape.

Second, researchers are still not sure the ceramic materials can carry large electric currents without losing their superconductivity.

Still, the development of the new superconductors has the potential to dramatically change, perhaps even revolutionize, the electronics, electric power, and transportation industries.

Fusion Energy

Nuclear energy is energy that comes from the nucleus (core) of an atom. Nuclear energy can be released from an atom by one of two processes: nuclear fission or nuclear fusion. In nuclear fission, energy is released when the nuclei of atoms are split apart. In nuclear fusion, energy is released when the nuclei of atoms are combined or fused together. This is the way the sun generates energy. Today's nuclear power plants can only use nuclear fission to generate electricity.

But scientists are working on ways to make fusion energy possible. The problem is that fusing atoms together requires incredibly high temperatures—around 270 million degrees Fahrenheit! To date, fusion machines have managed to obtain the required fusion temperatures, but for less than one second. This means that much more electricity is used to create the high temperature than is released from the very brief fusion reaction. It probably won't be a practical energy source for producing electricity until well into this century.