Electricity

Electricity at a Glance 2008

Secondary Source of Energy, Energy Carrier

Major Energy Sources Used to Generate Electricity:

- coal, uranium, natural gas, hydropower

U.S. Energy Consumption:

- 40.4 %

Net U.S. Electricity Generation:

- 4,110 BkWh

Major Uses of Electricity:

- manufacturing, heating, cooling, lighting

The Nature of Electricity

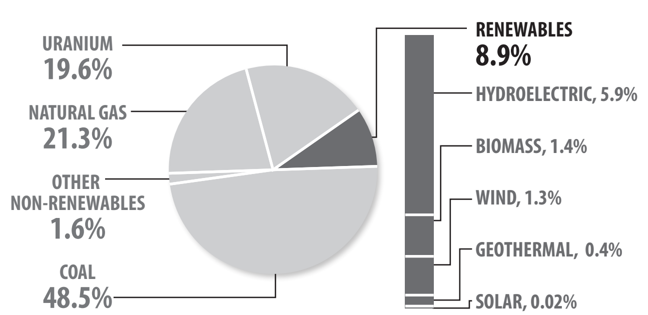
Electricity is a little different from the other sources of energy that we talk about. Unlike coal, petroleum, or solar energy, electricity is a **secondary** source of energy. That means we must use other primary sources of energy, such as coal or wind, to make electricity. It also means we can't classify 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. 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. (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.

2008 U.S. ELECTRICITY PRODUCTION



Source: 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.

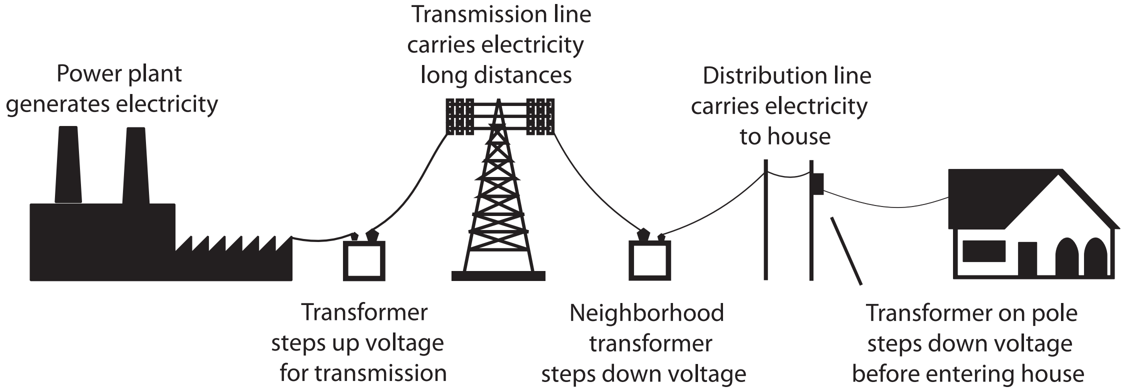
The electricity is then sent on a nationwide network of **transmission lines** made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway. The lines are interconnected, so should one line fail, another will take over the load.

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 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.

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, 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 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 (megawatt) 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.

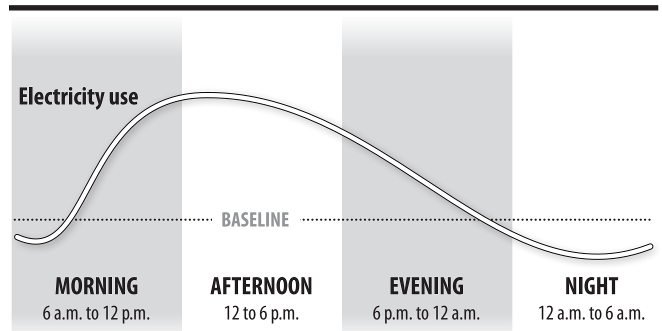
Base-load power is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Base-load power stations usually run at full or near capacity.

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 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 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. Before coming into your home, another transformer steps down the power down to 120 volts so it can operate your lights and appliances and other electrical needs. And most remarkably of all, this entire process—from generation at the power plant to the trip along the lines to its availability for use in your home—takes just a fraction of a second!

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 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're using. Of course, there are many more parts to this process, ranging from substations and wires for different phases of current to safety devices

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 3.3 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 48.5 percent of total U. S. electricity. Natural gas plants produce 21.3 percent. Petroleum produces 1.1 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 plants, nuclear power plants are called thermal plants because they use heat to generate electricity. Nuclear energy produces 19.6 percent of the electricity in the U. S.

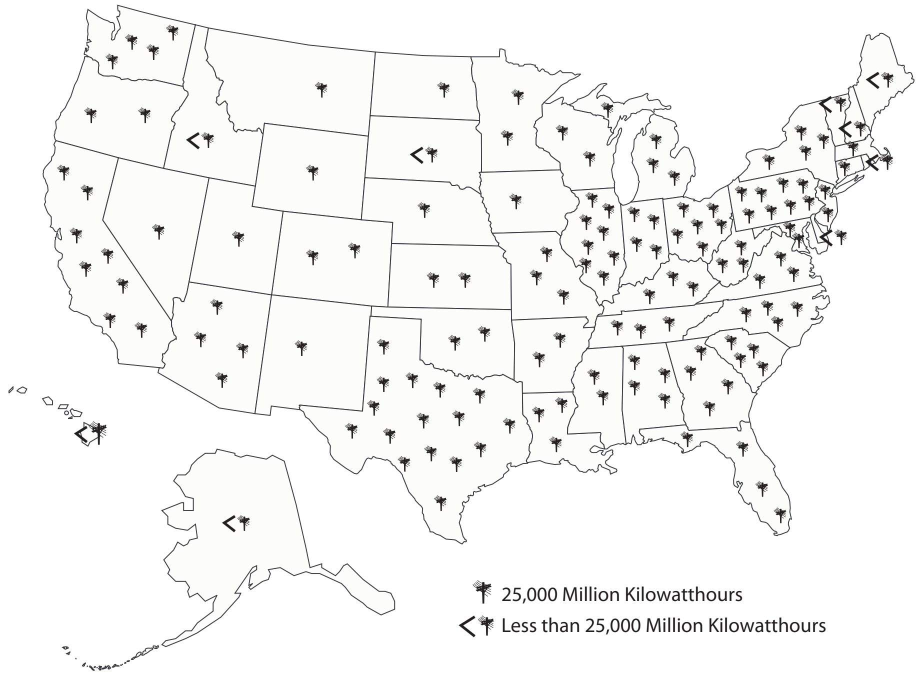
Hydropower Plants: Hydropower plants use the gravitational force of falling water to generate electricity. Hydropower is the cheapest way to produce electricity in this country, but there are few places where new dams can be built economically. There are many existing dams that could be retrofitted with 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 2008, hydropower generated 6.0 percent of U.S. electricity.

TRANSMISSION LINES

Transmission lines carry electricity at high voltages over long distances.

U.S. ELECTRIC POWER GENERATION

Kilowatt hours of electricity generated by state.



Source: Energy Information Administration

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."

But 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 40 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.

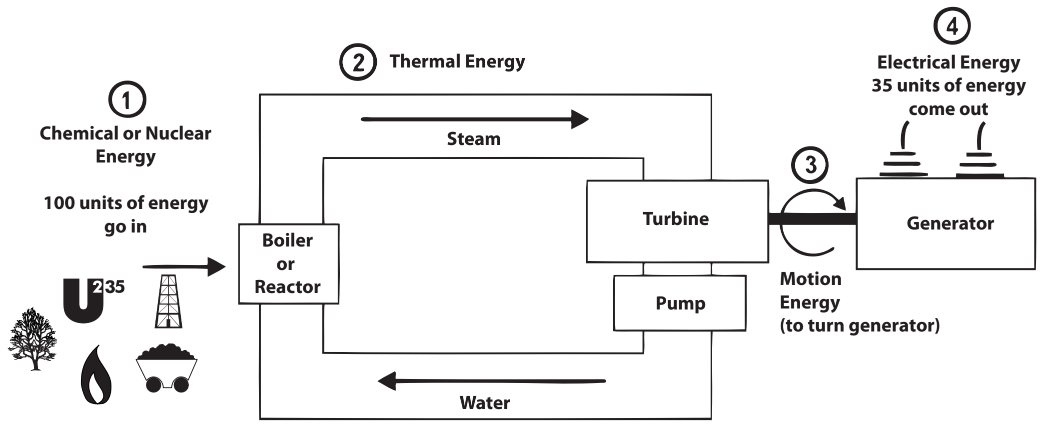
For many years, America's electric grid has been a shining example of our technology and ability, and a major part of the country's prosperity, comfort and security. To meet the country's growing electricity needs today and in the future, changes are needed in how the grid operates and the equipment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

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (50 percent), the cost of transmission (20 percent) and local distribution (30 percent). The average cost of electricity is eleven 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.

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.

Measuring ELECTRICITY

Power is the rate (time) of doing work. A watt is a measure of the electric power an electrical device uses. Most electrical devices require a certain number of watts to work correctly. All light bulbs, for example, are rated by watts (60, 75, 100 watts), as are 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. Visualize adding water to a pool. In this analogy, a kilowatt is the rate at which water is added to the pool; a kilowatt-hour is the amount of water added to the pool in a period of time.

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 the 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.

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 90-95 percent efficient at converting the kinetic energy of moving water into electricity.

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, 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.

Deregulation & Competition

Beginning in the 1930s, most electric utilities in the U.S. operated under state and federal regulations in a defined geographical area. Only one utility provided service to any one area. Consumers could not choose their electricity provider. In return, the utilities had to provide service to every consumer, regardless of profitability.

Under this model, utilities generated the power, transmitted it to the point of use, metered it, billed the customer, and provided 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 varied widely among the states and utilities, from a high of 16 cents to a low of four cents. The price for large industrial users varied, too. The types of generating plants, the cost of fuel, taxes, and environmental regulations were 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 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 now have competition in the electric power industry. 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 have the option of choosing their electric utility, much like people can choose their telephone carrier or internet service provider. Their local utility would distribute the power to the consumer.

This competition created new markets and new companies when a utility would separate its operation, transmission and retail operations into different companies.

Independent Power 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 many different energy sources.

Independent power producers (IPPs) 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 the **Public Utility Regulatory Policies Act** or PURPA. This law changed the relationship between electric utilities and smaller IPPs. Under the law, a public utility company cannot ignore a nearby IPP. A utility must purchase power from an IPP if the utility has a need for the electricity, and if the IPP can make electricity for less than what it would cost the utility to make it.

The relationship between IPPs and utilities varies from state to state. Some utilities welcome the IPPs 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 IPPs 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 IPPs 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, IPPs are subject to the most stringent environmental controls. In any case, most experts predict that IPPs will produce more and more electricity. Today, IPPs generate nearly 40 percent of the nation's electricity.

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's plant 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.

Electricity

Future Demand

Home computers, microwave ovens, and video games have invaded our homes and they are demanding electricity! Electronic devices are part of the reason why Americans use more electricity every year.

The U. S. Department of Energy predicts the nation will need to increase its current generating capacity of 995,000 megawatts by a third in the next 20 years.

Some parts of the nation, especially California, have begun experiencing power shortages. Utilities can resort to rolling blackouts—planned power outages to one neighborhood or area at a time—because of the limited power. Utilities often warn that there will be increasing outages nationwide during the summer months even if consumers implement energy conservation techniques. However, well planned and managed energy efficiency and conservation programs can help avoid these electricity shortages.

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 about 172 thousand more megawatts of generating capacity by the year 2030. 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 300 coal plants by the year 2030 to meet that demand.

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

Smart Grids

Another way to meet future demand is to update the electric grid and create a "smart grid." The "grid" refers to the electrical distribution system which transmits electricity from the power plants to the individual locations where it is needed. The existing electric grid has worked well for many years, but developing a new, more efficient grid will help meet growing electricity demand. Updating the current grid and transmission lines would not only improve current operations, but would also open new markets for electricity generated by renewable energy sources.

The smart grid system will include two-way interaction between the utility company and utilities. During peak demand when power generation is reaching its limit, the utility company can contact consumers to alert them of the need to reduce energy until the demand decreases. The smart grid would alert the power producer to an outage or power interruption long before the homeowner has to call the producer to let them know the power is out.

Developing the smart grid would offer a variety of technologies that will help consumers lower their power usage during peak periods, allow power producers to expand their use of photovoltaics, wind and other renewable energy technologies, provide system back-up to eliminate power outages during peak times, and save money while reducing carbon dioxide emissions.

Research and 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. One promising technology is superconductivity.

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.