What Is Radiation?

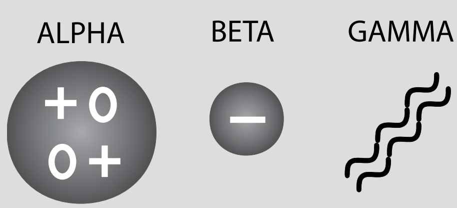
Radiation is energy released by atoms. It is very powerful and moves very fast. Not all atoms are radioactive. Some atoms—the radioactive ones—have more neutrons than protons, making them unstable. In a natural process called **radioactive decay**, these atoms give up their energy and nuclear particles and become stable.

Radiation cannot be touched, seen, or heard, but it is around us all the time. Natural sources of radiation include cosmic rays from outer space, minerals in the ground, and radon in the air. Man-made sources of radiation include the x-ray equipment used by doctors, smoke detectors, old color television sets, and luminous dial clocks. Nuclear waste is another kind of man-made radiation that usually contains higher than natural concentrations of radioactive atoms.

Atoms emit radiation in the form of tiny particles, called alpha and beta radiation, and in the form of rays, called gamma radiation. Alpha radiation is the slowest moving type of radiation and can be blocked by a sheet of paper or the outer layer of skin on your body. Beta radiation is faster and lighter than alpha radiation and can pass through about an inch of water or skin. Gamma radiation is different from alpha and beta radiation because it is an electromagnetic wave, just like radio waves, light, and x-rays. Gamma radiation has no weight and moves much faster than alpha and beta radiation. It takes several inches of lead, several feet of concrete, or a large amount of water to stop gamma rays. It can easily pass through the human body as medical x-rays do.

Alpha, beta, and gamma radiation are called ionizing radiation because they can produce electrically charged particles, called **ions**, in the things that they strike. (Visible light and radio waves are non-ionizing forms of radiation.) Ionizing radiation can be harmful to living things because it can damage or destroy cells. The used fuel from nuclear power plants is called high-level nuclear waste because of its dangerous levels of radiation.

The unit used to measure radiation is the rem and millirem (1/1000 of one rem). The average American is exposed to about 360 millirem a year from natural and man-made sources, a harmless amount. About 260 millirem of this total comes from natural (background) sources of radiation such as soil, rocks, food, and water. Another 55 millirem comes from medical x-rays and about 10 millirem from a variety of sources including mineral mining, burning fossil fuels, and consumer products such as old televisions and luminous dial clocks. Newer LCD or plasma televisions do not emit radiation. Radiation emitted from nuclear power plants accounts for only a tiny amount of exposure, only about 0.01 millirem of exposure per year.



The Department of Energy (DOE) originally looked at Yucca Mountain, Nevada, to be the site of a national spent nuclear fuel repository. In 2010, the DOE withdrew its Yucca Mountain application with the intention of pursuing new long-term storage solutions. A Blue Ribbon Commission was formed in January 2010. The commission's job is to provide recommendations for managing used nuclear fuel in the United States.

Until a final storage solution is found, nuclear power plants will continue storing used fuel at their sites in spent fuel pools or dry cask storage. In the meantime, a federal appeals court ruled in 2013 that the Department of Energy must stop collecting money for the Nuclear Waste Fund until a national repository site is chosen and construction has begun.

Nuclear Energy Use

Nuclear energy is an important source of electricity—third after natural gas and coal—providing 19.39 percent of the electricity in the U.S. today. There are 95 nuclear reactors in operation at 57 power plants in 29 states. Two new reactors are under construction.

Nuclear energy now provides about 10.2 percent of the world's electricity. The U.S., China, Russia, India, Japan, Germany, Canada, France, and Brazil are world leaders. France generates over 70 percent of its electricity with nuclear power. Japan was a former leader in worldwide nuclear production. The Fukushima incident (see page 46) prompted Japanese authorities to temporarily halt nuclear power generation, and in 2014, produced no electricity from uranium. New safety measures have led to the gradual re-opening of Japan's nuclear power plants, with five facilities becoming operational again in 2017. Japan is again among the leading generators of nuclear power.

Licensing Nuclear Power Plants

Nuclear power plants must obtain permits to start construction and licenses to begin operation. Researchers conduct many studies to find the best site for a nuclear power plant. Detailed plans and reports are submitted to the **Nuclear Regulatory Commission**, the Federal Government agency responsible for licensing nuclear power plants and overseeing their construction and operation.

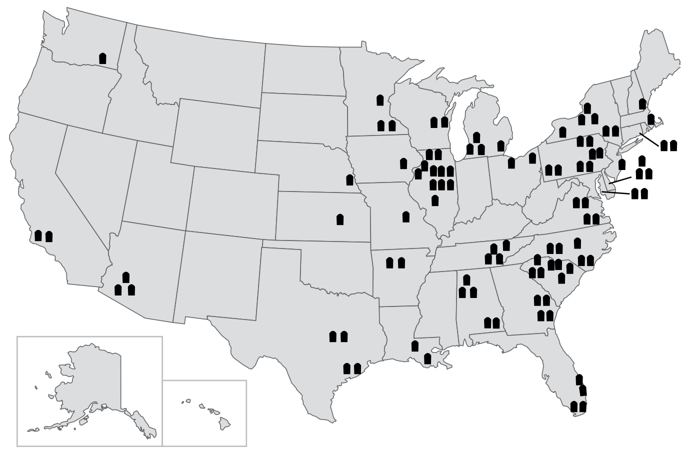
When the builders of a nuclear power plant apply for a license, local hearings are held so people can testify and air their concerns and opinions. After a plant is built, the Nuclear Regulatory Commission places inspectors at the site to assure the plant is operating properly.

Economics of Nuclear Energy

Much of the cost of producing electricity at a nuclear plant comes not from the fuel source—uranium is a very small part of the operating cost—but from the cost of building and monitoring the plant. Nuclear plants have very high up-front costs because of the licensing, construction, and inspection requirements.

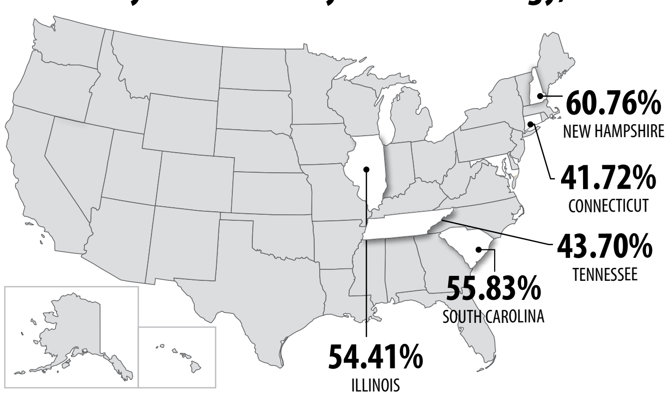
If you consider only the fuel costs and operating costs, nuclear electricity is about two and a half cents per kilowatt-hour (kWh). In comparison, the cost of producing electric power from new coal plants is approximately three and a half cents per kWh.

U.S. Nuclear Power Reactors, 2020



Data: Energy Information Administration

States with the Largest Percentage of Electricity Generated by Nuclear Energy, 2019



Data: Energy Information Administration

Uranium is an abundant natural resource that is found all over the world. Because uranium is an extremely concentrated fuel source, it requires far less mining and transportation than other fuel sources for the energy it furnishes. At current rates of use, uranium resources could last over 100 years. A process called **breeding**, which converts uranium into plutonium—an even better fuel—could extend uranium reserves for thousands of years. Breeder reactors were tested in France, but they are not planned for use in this country.

Nuclear Energy and the Environment

Nuclear power plants have very little impact on the environment. Generating electricity from nuclear power produces no air pollution because no fuel is burned. Most of the water used in the cooling process is recycled.

In the future, using nuclear energy may become an important way to reduce the amount of carbon dioxide produced by burning fossil fuels and biomass. Carbon dioxide is considered the major greenhouse gas.

People are using more and more electricity. Some experts predict that we will have to use nuclear energy to produce the amount of electricity people need at a cost they can afford.

Whether or not we should use nuclear energy to produce electricity can often be a controversial and sometimes highly emotional issue.

Nuclear Safety

The greatest potential risk from nuclear power plants is the release of high-level radiation and radioactive material. In the United States, plants are specifically designed to contain radiation and radioactive material in the unlikely case of an accident. Emergency plans are in place to alert and advise nearby residents if there is a release of radiation into the local environment. Nuclear power plants have harnessed the energy from the atom for over 50 years in the United States.

In 1979, at the Three Mile Island facility in Pennsylvania, the top half of the uranium fuel rods melted when coolant to one reactor was cut off in error. A small amount of radioactive material escaped into the immediate area before the error was discovered. Due to the safety and containment features of the plant design, multiple barriers contained almost all of the radiation and no injuries or fatalities occurred as a result of the error. In response to the incident at Three Mile Island, the U.S. nuclear industry made upgrades to plant design and equipment requirements. Operator and staff training requirements were strengthened, and the U.S. Nuclear Regulatory Commission took on a greater role in emergency preparedness and routine inspections. Lessons learned from Three Mile Island were shared with the international nuclear industry. Three Mile Island was decomissioned in 2019 for economical reasons.

In 1986, in the Ukraine (former Soviet Union) at the Chernobyl nuclear power plant, two steam explosions blew the top off of Unit 4. A lack of containment structures and other design flaws caused the release of a large amount of radioactive material into the local community. More than 200,000 people were evacuated from their homes and about 200 workers were treated for radiation sickness and burns. Several people were killed immediately or died shortly thereafter, with others suffering longer term medical ailments.

On March 11, 2011, an earthquake and resulting tsunami struck Japan, killing and injuring tens of thousands of people. Prior to that time, Japan generated a large percentage of its electricity from nuclear power. In the Fukushima prefecture (community), the Daiichi nuclear plant shut down as a result of the earthquake but suffered extraordinary damage from the tsunami. This damage included the loss of back-up power generation necessary to keep the reactor and the fuel rods contained in it cool. The release of some radioactive material required that residents within a 12 mile radius of the plant be evacuated. Residents living between 12 and 19 miles from the affected power plant were asked to evacuate voluntarily. The Japanese Nuclear and Industrial Safety Agency, the International Atomic Energy Agency, health organizations, and the nuclear energy industry continue to investigate the area as it is restored and residents return. These groups are also monitoring the impact of the radiation released from the Daiichi nuclear power plant both on the local environment and around the world.

Nuclear energy remains a major source of electricity in the United States and around the globe. The safe operation of nuclear power plants is important to quality of life and to the health and safety of individuals worldwide.

Wind

Wind at a Glance, 2018

Classification:
- renewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 2.482 Q
- 2.46%

U.S. Energy Production:
- 2.486 Q
- 2.60%

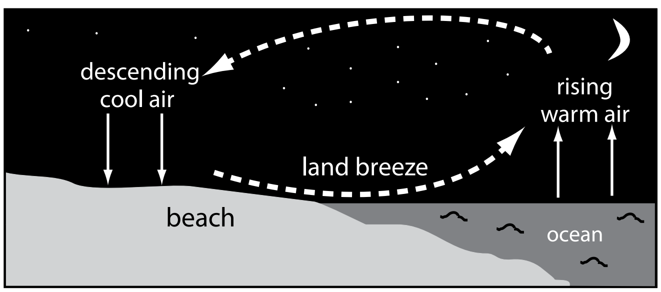
Data: Energy Information Administration

What Is Wind?

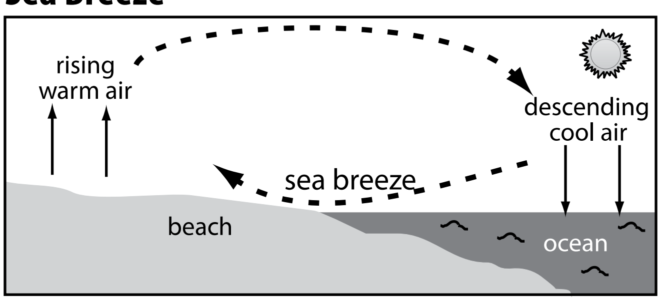
Wind is simply air in motion. It is produced by the uneven heating of the Earth's surface by energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's radiant energy at different rates. Much of this energy is converted into heat as it is absorbed by land areas, bodies of water, and the air over these formations.

On the coast, for example, the land heats up more quickly than the water. The warm air over the land expands and rises, and the heavier, cooler air over the water rushes in to take its place, creating a convection current of moving air, or wind. In the same way, the large atmospheric winds that circle the Earth are produced because the Earth's surface near the Equator receives more of the sun's energy than the surface near the North and South Poles.

Land Breeze

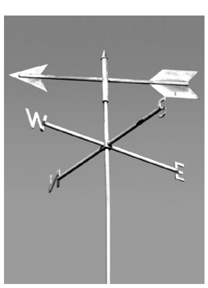


Sea Breeze



Windmill

Weather Vane



Anemometer

Wind is called a **renewable** energy source because wind will continually be produced as long as the sun shines on the Earth. Today, wind energy is mainly used to generate electricity.

The History of Wind

Throughout history, people have harnessed the wind in many ways. Over 5,000 years ago, the ancient Egyptians used wind power to sail their ships on the Nile River. Later, people built windmills to grind their grain. The earliest known windmills were in Persia (Iran). These early windmills looked like large paddle wheels.

Centuries later, the people of Holland improved the basic design of the windmill. They gave it propeller-type blades made of fabric sails and invented ways for it to change direction so that it could continually face the wind. Windmills helped Holland become one of the world's most industrialized countries by the 17th century.

American colonists used windmills to grind wheat and corn, pump water, and cut wood. As early as the 1920s, Americans used small windmills to generate electricity in rural areas without electric service. When power lines began to transport electricity to rural areas in the 1930s, local windmills were used less and less, though they can still be seen on some Western ranches.

The oil shortages of the 1970s changed the energy picture for the country and the world. It created an environment more open to alternative energy sources, paving the way for the re-entry of the windmill into the American landscape to generate electricity.

Monitoring Wind Direction

A weather vane, or wind vane, is a device used to monitor the direction of the wind. It is usually a rotating, arrow-shaped instrument mounted on a shaft high in the air. It is designed to point in the direction of the source of the wind.

Wind direction is reported as the direction from which the wind blows, not the direction toward which the wind moves. A north wind blows from the north, toward the south.

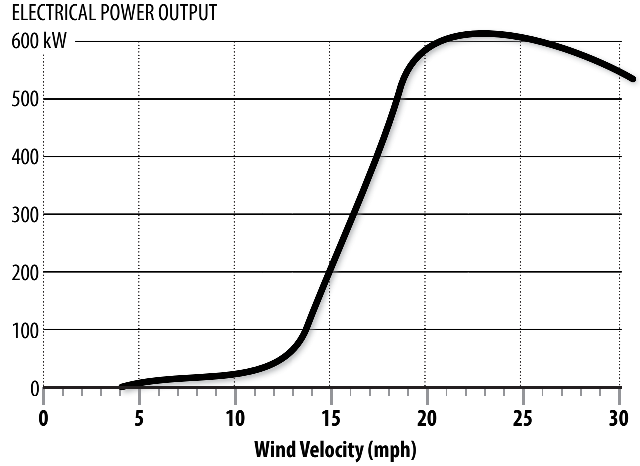
Wind

Wind Velocity

It is important to know how fast the wind is blowing. Wind speed is important because the amount of electricity that wind turbines can generate is determined in large part by wind speed, or velocity. A doubling of wind velocity from the low range to optimal range of a turbine can result in eight times the amount of power produced. This is a huge difference and helps wind companies decide where to site wind turbines.

Wind speed can be measured with wind gauges and **anemometers**. One type of anemometer is a device with three arms that spin on top of a shaft. Each arm has a cup on its end. The cups catch the wind and spin the shaft. The harder the wind blows, the faster the shaft spins. A device inside counts the number of rotations per minute and converts that figure into miles per hour (mph). A display on the anemometer shows the speed of the wind.

Sample Power Curve of a Wind Turbine



Modern Wind Machines

Today, wind is harnessed and converted into electricity using turbines called **wind turbines**. The amount of electricity that a turbine produces depends on its size and the speed of the wind. Most wind turbines have the same basic parts: blades, a tower, and a gear box. These parts work together to convert the wind's kinetic energy into motion energy that generates electricity through the following steps:

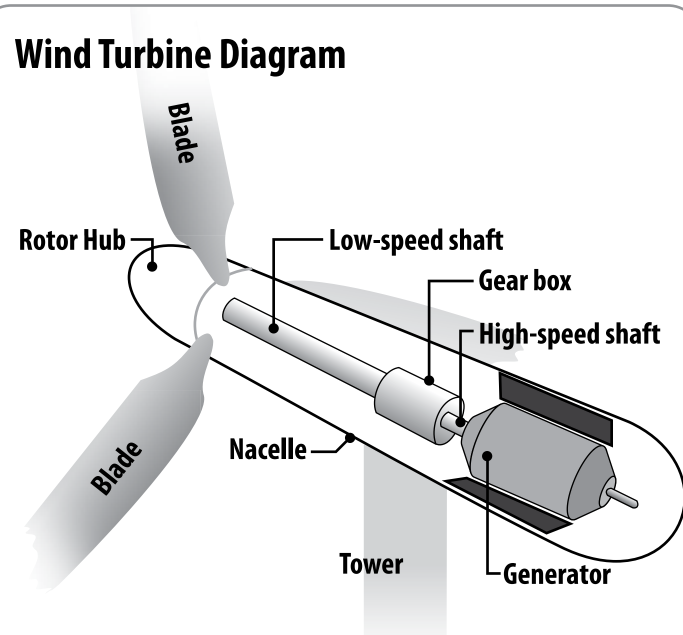
1. The moving air is caught by the blades and spins the rotor.
2. The rotor is connected to a low-speed shaft. When the rotor spins, the shaft turns.
3. The low-speed shaft is connected to a gear box. Inside the gear box, a large slow-moving gear turns a small gear quickly.
4. The small gear turns another shaft at high speed.
5. The high-speed shaft is connected to a generator. As the high-speed shaft turns the generator, it produces electricity.
6. The electric current is sent through cables down the turbine tower to a transformer that changes the voltage of the current before it is sent out on transmission lines.

Wind turbines are most efficient when they are built where winds blow consistently, at a minimum of 8-16 miles per hour (3.5-7 meters per second). Faster winds generate more electricity, but if the wind speed is too fast, generation declines. High above ground winds are stronger and steadier. Wind turbines today are typically placed on top of towers that are about 80 meters (260 feet) tall.

There are many different types of wind turbines with different tower and hub heights, as well as varying blade designs and lengths. Wind turbines can be designed to optimize output for specific ranges of wind speed. Turbines typically can generate electricity when winds are between 6 and 55 mph (3-25 m/s). They operate most efficiently, however, when wind speed falls between 18-31 mph (8-14 m/s).

Wind turbines also come in different sizes, based on the amount of electric power they can generate. Small turbines may produce only enough electricity to power a few appliances in one home. Large turbines are often referred to as 'utility-scale' because they generate enough power for utilities, or electric companies, to sell. The largest turbines in the U.S. produce 1.5 to 7.5 megawatts (MW), enough electricity to power 375 to 1,875 homes. Large turbines are grouped together into **wind farms**, which provide bulk power to the electrical grid.

Wind Turbine Diagram



Wind Power Plants

Wind power plants, or wind farms, are clusters of wind turbines grouped together to produce large amounts of electricity. Choosing the location of a wind farm is known as siting a wind farm. To build a wind farm, wind speed and direction must be studied to determine where to put the turbines. As a rule, wind speed increases with height and over open areas with no windbreaks. The site must have strong, steady winds. Scientists measure the wind in an area for several years before choosing a site.

The best sites for wind farms are on hilltops, the open plains, through mountain passes, and near the coasts of oceans or large lakes. Turbines are usually built in rows facing into the prevailing wind. Placing turbines too far from each other wastes space. If turbines are too close together they block each other's wind.

There are many factors to consider when siting a wind farm, such as:

What is the weather like? Do tornadoes, hurricanes, or ice storms affect the area? Any of these may cause expensive damage to the wind turbines.

Is the area accessible for workers? Will new roads need to be built? New roads are expensive to build.

Can the site be connected to the power grid? It is expensive to lay long-distance transmission lines to get electricity to where people live, so wind farms should be located near the areas where electricity is needed.

Will the wind farm impact wildlife in the area? Developers building a wind farm need to get permission from the local community and government before building. There are strict building regulations to follow.

Wind plants need a lot of land. Each turbine requires about 0.25 acres of land. A wind power plant can cover hundreds of acres of land, plus each tower should be five to ten turbine diameters away from each other, depending on the number of turbines. On the plus side, most of the land is still available for other uses. Ranchers, for example, can grow grain or graze cattle around the turbines once they have been installed.

Wind farms are also being constructed **offshore** in water where there is consistent wind speed much of the time. The wind blows stronger and steadier over water than land. There are no obstacles on the water to block the wind. There is a lot of wind energy available offshore. Offshore wind farms are built in the shallow waters off the coast of major lakes and oceans. While offshore turbines produce more electricity than turbines on land, they cost more to build and operate. Offshore construction is difficult and expensive. The cables that carry the electricity must be buried deep under the water.

OFFSHORE WIND FARM

The U.S. welcomed its first offshore wind farm in 2016. The Deepwater Wind Project, southeast of Block Island, Rhode Island, came online in August of 2016. This five-turbine, 30-megawatt farm can power 17,000 homes. Several more offshore turbines are in the works on the Atlantic coastline. Dominion Energy has recently completed construction on a 2-turbine pilot project in Federal waters off of the coast of Virginia Beach, VA. These two turbines will provide enough power for 3,000 homes. Dominion Energy also plans to build an additional 2.6 GW offshore wind project beginning in 2024.

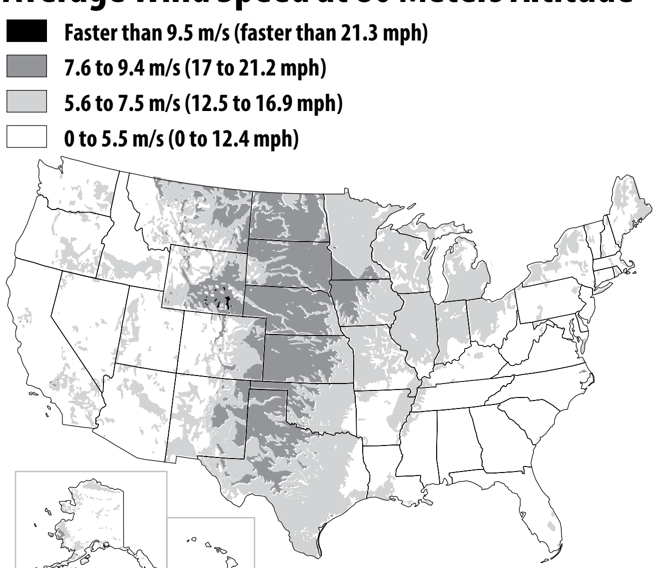
After a plant has been built, there are ongoing maintenance costs. In some states, these costs are offset by tax breaks given to power plants that use renewable energy sources.

Unlike coal or nuclear plants, many wind plants are not owned by public utilities. Instead they are owned and operated by business people who sell the electricity produced to electric utilities. These private companies are known as independent power producers (IPPs). The Public Utility Regulatory Policies Act, or PURPA, requires utility companies to purchase electricity from independent power producers at rates that are fair.

Wind Resources

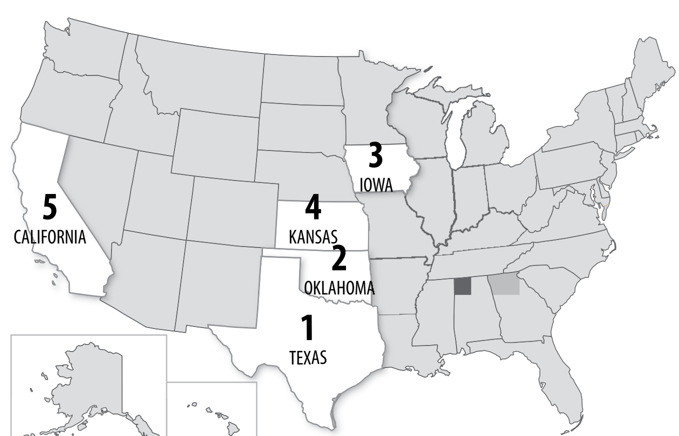
Where is the best place to build a wind plant? There are many good sites for wind farms in the United States including California, Alaska, Hawaii, the Great Plains, and mountainous regions. An average wind speed of 8-16 miles per hour (mph) is needed to convert wind energy into electricity economically. Currently, wind generates electricity in 41 states. Texas leads the nation, producing one-fourth of the wind-generated electricity in the country.

Average Wind Speed at 80 Meters Altitude



Data: National Renewable Energy Laboratory

Top Wind States (Net Electricity Generation), 2018



Data: Energy Information Administration

Wind

Wind Production

How much energy can we get from the wind? There are two terms to describe basic electricity production: efficiency and capacity factor. **Efficiency** refers to how much useful energy (electricity, in this case) we can get from an energy source. A 100 percent energy efficient machine would change all the energy put into it into useful energy. It would not waste any energy.

There is no such thing as a 100 percent energy efficient machine. Some energy is always lost or wasted when one form of energy is converted to another. The lost energy is usually in the form of heat, which dissipates into the air and cannot be used again economically.

How efficient are wind turbines? Wind turbines are just as efficient as most other plants, such as coal plants. Wind turbines convert 25 to 45 percent of the wind's kinetic energy into electricity. A coal-fired power plant converts about 35 percent of the chemical energy in coal into usable electricity.

Capacity refers to the capability of a power plant to produce electricity. A power plant with a 100 percent capacity rating would run all day, every day at full power. There would be no down time for repairs or refueling, an impossible goal for any plant. Coal plants typically have a 65 to 75 percent capacity factor since they can run day or night, during any season of the year.

Wind power plants are different from power plants that burn fuel. Wind plants depend on the availability of wind, as well as the speed of the wind. Therefore, wind turbines cannot operate 24 hours a day, 365 days a year.

A wind turbine at a typical wind farm operates 65 to 90 percent of the time, but usually at less than full capacity because the wind speed is not at optimum levels. Therefore, its capacity factor is 30 to 35 percent.

Economics also plays a large part in the capacity of wind turbines. Turbines can be built that have much higher capacity factors, but it is not economical to do so. The decision is based on electricity output per dollar of investment.

One 2.5 megawatt turbine can produce about 7.7 million kilowatt-hours (kWh) of electricity a year. That is enough electricity for almost 700 homes per year. In this country, wind turbines produce nearly 273 billion kWh of energy a year. Wind energy provides 6.55 percent of the nation's electricity, which is enough electricity to serve at least 27 million households.

Wind is the fastest growing energy technology in the world today. In the last four years, wind capacity worldwide has grown immmensely and continues to rise. In 2019 China was the largest installer of new wind capacity. The United States, Germany, India, and Spain join China as the countries with the most installed wind capacity.

Investment in wind energy is increasing because its cost has come down and the technology has improved. Wind is now one of the most competitive sources for new generation. Another hopeful sign for the wind industry is consumer demand for **green pricing**. Many utilities around the country now allow customers to voluntarily choose to pay more for electricity generated by renewable sources.

Small Wind Systems

Wind turbines are not only on wind farms or offshore, they can also be found on the property of private residences, small businesses, and schools. A typical home uses about 900 kilowatt-hours of electricity each month. Many people are choosing to install small wind turbines to lower or eliminate their electricity bills.

Siting a small wind turbine is similar to siting large turbines. Potential small wind users need to make sure that there is plenty of unobstructed wind. The tip of the turbine blade needs to be at least nine meters (30 feet) higher than the tallest wind obstacle. Sometimes this can be a challenge for installing a residential wind turbine if local zoning laws have height limitations. The turbine also requires open land between the turbine and the highest obstacle. Depending on the size of the turbine, this may require a 70 to 150 meter (250 to 500 foot) radius. Specific siting recommendations can be obtained from the turbine manufacturer.

Wind Economics

On the economic front, there is a lot of good news for wind energy. First, a wind plant is less expensive to construct than a conventional coal or nuclear plant. Wind plants can simply add wind turbines as electricity demand increases.

Second, the cost of producing electricity from the wind has dropped dramatically. Electricity generated by the wind cost 80 cents per kWh in 1980, but now can cost five cents or less per kWh. New turbines are lowering the cost even more.

Installing a wind turbine on a residential property can be expensive. Federal production and investment tax credits can help alleviate some costs. Some states and utilities offer additional incentives to residents to install renewable energy systems.

Wind Energy and the Environment

Wind energy offers a viable, economical alternative to conventional power plants in many areas of the country. Wind is a clean fuel; wind farms produce no air or water pollution because no fuel is burned.

The most serious environmental drawbacks to wind turbines may be their negative effect on wild bat populations and the visual impact on the landscape. To some, the glistening blades of windmills on the horizon are an eyesore; to others, they're a beautiful alternative to conventional power plants.

Climate Change

Earth's Atmosphere

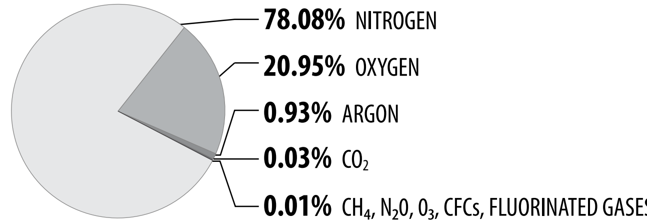
Our Earth is surrounded by layers of gases called the atmosphere. Without these gases in the atmosphere, the Earth would be so cold that almost nothing could live. It would be a frozen planet. Our atmosphere keeps us alive and warm.

The atmosphere is made up of many different gases. Most of the atmosphere (99 percent) is comprised of oxygen and nitrogen gases. Less than half of one percent is a mixture of heat-trapping gases. These heat-trapping gases are mostly water vapor mixed with carbon dioxide, methane, nitrous oxide, and F-gases. These are called **greenhouse gases (GHG)**.

- Water vapor (H_2O) is produced naturally through evaporation. It is the most abundant and important GHG. Human activities have little influence on the concentration of water vapor in the atmosphere. However, a warmer climate increases evaporation and allows the atmosphere to hold higher concentrations of water vapor.
- **Carbon dioxide** (CO_2) is produced naturally through plant, animal, and human respiration and volcanic eruptions. Carbon dioxide is mostly produced through human activities such as **combustion** of fossil fuels and biomass, industrial processes, and deforestation.
- **Methane** (CH_4) is produced naturally when organic matter decays during wildfires, and from animals. Human activities are responsible for methane emissions from the production and transport of fossil fuels, managing livestock waste, and landfill decay.
- Nitrous oxide (N_2O) comes from the bacterial breakdown of nitrogen in soil and the oceans. Human activities contribute to nitrous oxide emissions through agricultural and industrial activities, the combustion of fossil fuels, and sewage treatment.
- Tropospheric, or ground-level, **ozone** (O_3) is produced in the atmosphere when chemicals from human activities interact with sunlight. These emissions are from automobiles, power plants, and other industrial sources.

GREENHOUSE

Major Gases in the Atmosphere (Dry)



Note: These percentages represent atmospheric composition for a completely dry atmosphere. Water vapor is nearly always present, but concentration varies based on location. Atmospheric composition changes with the addition of water vapor.

Data: NASA

- **F-gases** are synthetically sourced substances, also known as fluorinated gases. This group of chemicals is made of bonded halogen and carbon atoms and depending on the combination, can have a variety of uses, including insecticides, coolants, solvents, propellants, and electricity production. The presence of F-gases in the atmosphere is due to human activities. Certain types of F-gases (CFCs and HCFCs) have been or will be phased out internationally, due to their long atmospheric lifetimes and their role in ozone depletion in the stratosphere.

Sunlight and the Atmosphere

Rays of sunlight (radiant energy) shine down on the Earth every day. Some of these rays bounce off of molecules in the atmosphere and are reflected back into space. Some rays are absorbed by molecules in the atmosphere and are turned into thermal energy.

About half of the radiant energy passes through the atmosphere and reaches the Earth. When the sunlight hits the Earth, most of it is converted into heat. The Earth absorbs some of this heat; the rest flows back out toward the atmosphere. This outward flow of heat keeps the Earth from getting too warm.

When this out-flowing heat reaches the atmosphere, most of it is absorbed. It can't pass through the atmosphere as readily as sunlight. Most of the heat becomes trapped and flows back toward the Earth again. Most people think it is sunlight that heats the Earth, but actually it is this contained heat that provides most of the warmth.

The Greenhouse Effect

We call the trapping of **thermal energy** by the atmosphere the **greenhouse effect**. A greenhouse is a building made of clear glass or plastic in which we can grow plants in cold weather. The glass allows the sunlight to pass through, and it turns into heat when it hits objects inside. The heat becomes trapped. The **radiant energy** can pass through the glass; the thermal energy cannot.

What is in the atmosphere that allows radiant energy to pass through but traps thermal energy? It is the presence of greenhouse gases—mostly carbon dioxide and methane. These gases are very good at absorbing heat in the atmosphere, where it can flow back toward Earth.

According to studies conducted by NASA, the National Aeronautics and Space Administration, and many other researchers around the world, the concentration of carbon dioxide has increased over 47 percent since the Industrial Revolution in the late 18th century. Climate change experts have concluded that this increase is due primarily to the expanding use of fossil fuels.

In addition to the increase in the level of carbon dioxide, there has also been a substantial rise in the amount of methane in the atmosphere. While there is much less methane in the atmosphere than carbon dioxide, it is 21 times more effective than carbon dioxide at trapping heat. However, it does not remain intact as long in the atmosphere, only about 12 years.

Fluorinated gases are the best GHGs at trapping heat. While their concentrations are very low, they are 140 to 23,900 times more effective at absorbing heat than carbon dioxide. Fluorinated gases have extremely long atmospheric lifetimes, up to 50,000 years. In addition, scientists expect concentrations of fluorinated gases to increase faster than other GHGs.

Global Climate Change

Increased levels of greenhouse gases are trapping more heat in the atmosphere. This phenomenon is called global **climate change** or **global warming**. According to NASA, the average temperature of the Earth has risen by about 0.95°C (1.71°F) since 1880. This increase in average temperature has been the major cause of a 17 centimeter rise in sea level over that time period, as well as an increase in extreme precipitation events. Sea levels are rising because sea water expands as it warms and land-based ice is melting in the Arctic, Antarctic, and in glaciers. Regions such as the Gulf Coast of the United States and several Pacific islands have already experienced losses to their coastlines. Recent research has also linked the increased severity of hurricanes and typhoons to global warming.

Climate scientists use sophisticated computer models to make predictions about the future effects of climate change. Because of the increased level of carbon dioxide and other GHGs already in the atmosphere, the Intergovernmental Panel on Climate Change (IPCC) forecasts at least another 2.5 degree Fahrenheit temperature increase over the next century. The climate models predict more floods in some places and droughts in others, along with more extreme weather, such as powerful storms and hurricanes. They predict an additional rise in sea level of up to two feet in some areas, which would lead to the loss of low-lying coastal areas.

These predictions have led many scientists to call for all countries to act now to lower the amount of carbon dioxide they emit into the atmosphere. Countries around the world are working to determine ways to lower the levels of carbon dioxide in the atmosphere, while minimizing negative impacts on the global economy.

The Greenhouse Effect

Radiant energy (light rays) shines on the Earth. Some radiant energy reaches the atmosphere and is reflected back into space. Some radiant energy is absorbed by the atmosphere and is transformed into thermal energy (dark arrows).

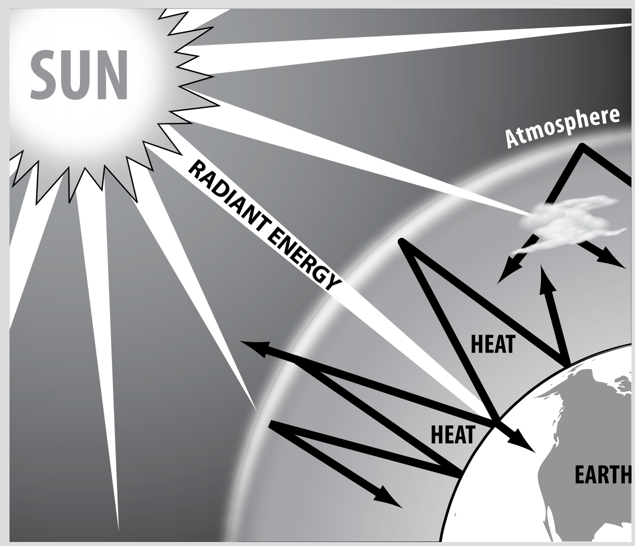
Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into thermal energy.

The Earth absorbs some of this thermal energy.

Most of the thermal energy flows back into the air. The atmosphere traps the thermal energy.

Very little of the thermal energy escapes back into space.

The trapped thermal energy flows back toward the Earth.



International Awareness

Climate change is impacting every person around the globe, so climate change is an international issue. There has been a history of the international community coming together to try and make plans to combat rising levels of greenhouse gases. In 1997, the Kyoto Protocol was the first step in coming to an international agreement on greenhouse gas levels. The United States did not ratify the Kyoto Protocol because it did not include targets or timetables outlined for developing nations as well as industrialized nations.

This agreement expired in 2012 and, in an attempt to continue international efforts, world leaders are meeting periodically. One of the main roadblocks is regulating GHG emissions from developing countries. These nations argue that since current climate change was primarily caused by emissions from the developed, industrialized countries, those countries should bear the responsibility of lowering emissions. They see limits on GHGs as a limit to their development and their efforts to bring millions of their citizens out of poverty. While the developed nations accept that they need to curb their emissions, they feel that developing nations will have an unfair economic advantage if they are not regulated. An international conference in Copenhagen, Denmark in 2009 ended without a strong agreement on how to regulate emissions globally. Many, but not all, countries made commitments to specific GHG targets, but there is no international system to monitor or regulate their efforts. Meetings are continuing in hopes of crafting a strong international treaty. In 2015 the UN and EU hosted climate talks in Paris. The Paris Agreement sets out a global plan of action to limit warming to below 2°C. The agreement has been ratified by 179 of the 197 Parties to the Convention. Set to begin enforcement in 2020, the United States withdrew its support from the agreement.

Hydrogen

What Is Hydrogen?

Hydrogen is the simplest element known to exist. An atom of hydrogen has one proton and one electron. Hydrogen has the highest energy content of any common fuel by weight, but the lowest energy content by volume. It is the lightest element and a gas at normal temperature and pressure.

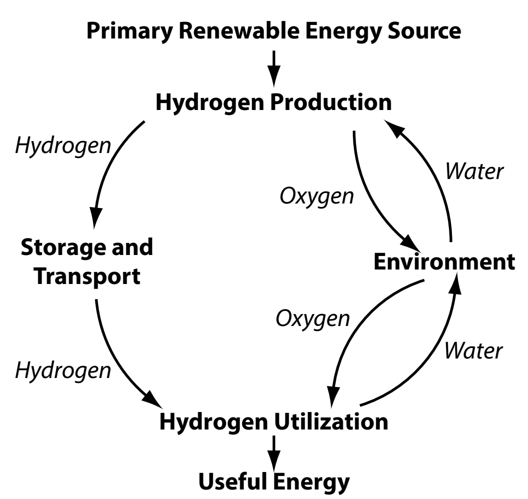
Hydrogen is also the most abundant gas in the universe, and the source of all the energy we receive from the sun. The sun is basically a giant ball of hydrogen and helium gases. In a process called **fusion**, hydrogen nuclei combine to form one helium atom, releasing energy as radiation.

This radiant energy is our most abundant energy source. It gives us light and heat and makes plants grow. It causes the wind to blow and the rain to fall. It is stored as chemical energy in fossil fuels. Most of the energy we use originally came from the sun.

Hydrogen as a gas (H_2), however, doesn't exist naturally on Earth. It is found only in compound form. Combined with oxygen, it is water (H_2O). Combined with carbon, it forms organic compounds such as methane (CH_4), coal, and petroleum. It is found in all growing things—biomass. Hydrogen is also one of the most abundant elements in the Earth's crust.

Most of the energy we use today comes from fossil fuels. Only about nine percent comes from **renewable** energy sources. Usually renewable sources are cleaner, and can be replenished in a short period of time. Hydrogen can come from either renewable or **nonrenewable** resources.

Hydrogen Life Cycle



Every day we use more fuels like coal and natural gas, to produce electricity. Electricity is a secondary source of energy. Secondary sources of energy—energy carriers—are used to store, move, and deliver energy in an easily usable form. We convert energy to electricity because it is easier for us to transport and use. Try splitting an atom, building a dam, or burning coal to run your television. Energy carriers make life easier.

Hydrogen is one of the most promising energy carriers. It is a high efficiency, low polluting fuel that can be used for transportation, heating, and power generation in places where it is difficult to use electricity.

How Is Hydrogen Made?

Since hydrogen gas is not found on Earth, it must be manufactured. There are several ways to do this. Industry produces the hydrogen it needs by a process called **steam reforming**. High-temperature steam separates hydrogen from the carbon atoms in methane. The hydrogen produced by this method isn't used as a fuel, but for industrial processes. This is the most cost-effective way to produce hydrogen today, but it uses fossil fuels both in the manufacturing process and as the heat source.

Another way to make hydrogen is by **electrolysis**—splitting water into its basic elements—hydrogen and oxygen. Electrolysis involves passing an electric current through water to separate the atoms ($2H_2O$ + electricity = $2H_2 + O_2$). Hydrogen collects at the cathode and oxygen at the anode.

Hydrogen produced by electrolysis is extremely pure, and electricity from renewable sources can power the process, but it is very expensive at this time. Today, hydrogen from electrolysis can be more than 10 times more costly than natural gas and 1.5 times more costly than gasoline per Btu.

On the other hand, water is abundant and renewable, and technological advances in renewable electricity could make electrolysis a more attractive way to produce hydrogen in the future.

There are also several experimental methods of producing hydrogen. Photoelectrolysis uses sunlight to split water molecules into its components. A **semiconductor** absorbs the energy from the sun and acts as an electrode to separate the water molecules.

In biomass gasification, wood chips and agricultural wastes are super-heated until they turn into hydrogen and other gases. Biomass can also be used to provide the heat.

Scientists have also discovered that some algae and bacteria produce hydrogen under certain conditions, using sunlight as their energy source. Experiments are underway to find ways to induce these microbes to produce hydrogen efficiently.

Nearly every region of the country (and the world) has one or more resources that can be used to produce hydrogen. It can be produced at large central facilities or at small distributed facilities for local use. One of its main advantages is its flexibility.

Hydrogen Uses

The U.S. hydrogen industry currently produces several million cubic feet of hydrogen every day. Most of this hydrogen is used for industrial applications such as refining, treating metals, and food processing.

Liquid hydrogen is the fuel that once propelled the space shuttle and other rockets. Hydrogen fuel cells powered the shuttle's electrical systems, producing pure water, which was used by the crew as drinking water.

In the future, however, hydrogen will join electricity as an important energy carrier, since it can be made safely from renewable energy sources and is virtually non-polluting. It can also be used as a fuel for zero-emissions vehicles, to heat homes and offices, to produce electricity, and to fuel aircraft. Cost is the major obstacle.

The first widespread use of hydrogen will probably be as an additive to transportation fuels. Hydrogen can be combined with compressed natural gas (CNG) to increase performance and reduce pollution. Adding 20 percent hydrogen to CNG can reduce **nitrogen oxide (NO_X)** emissions by 50 percent in today's engines. An engine converted to burn pure hydrogen produces only water and minor amounts of NO_X as exhaust.

A few hydrogen-powered vehicles are on the road today, but it will be some time before you can walk into your local car dealer and drive away in one. Today 61 hydrogen fuel stations are operating in 12 states and the District of Columbia. Not all of these stations are open to the public. With 40 stations (32 open to the public), California has 66 percent of the nation's hydrogen fuel stations.

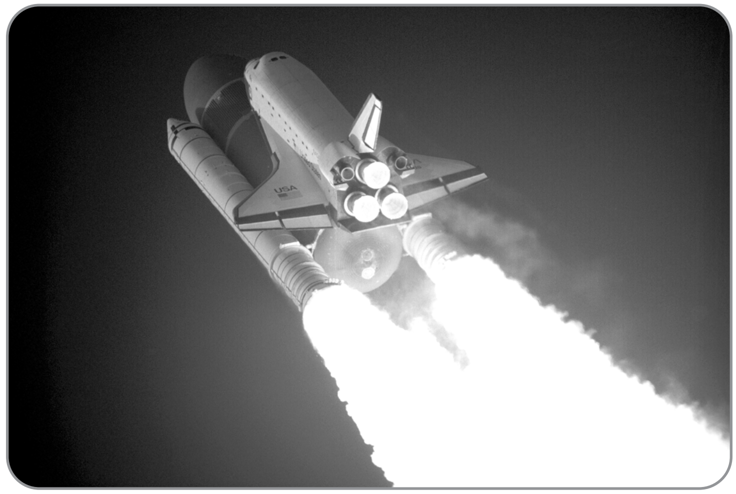
Can you imagine how huge the task would be to quickly change the gasoline-powered transportation system we have today? Just think of the thousands of filling stations across the country and the production and distribution systems that serve them. Change will come slowly to this industry, but hydrogen is a versatile fuel; it can be used in many ways.

Fuel cells (batteries) provide another use option, just as they were utilized by NASA. Fuel cells basically reverse electrolysis—hydrogen and oxygen are combined to produce electricity. Hydrogen fuel cells are very efficient and produce only water as a by-product, but they are expensive to build.

With technological advances, small fuel cells could someday power electric vehicles and larger fuel cells could provide electricity in remote areas. Because of the cost, hydrogen will not produce electricity on a wide scale in the near future. It may, though, be added to natural gas to reduce emissions from existing power plants.

As the production of electricity from renewables increases, so will the need for energy storage and transportation. Many of these sources—especially solar and wind—are located far from population centers and produce electricity only part of the time. Hydrogen may be the perfect carrier for this energy. It can store the energy and distribute it to wherever it is needed.

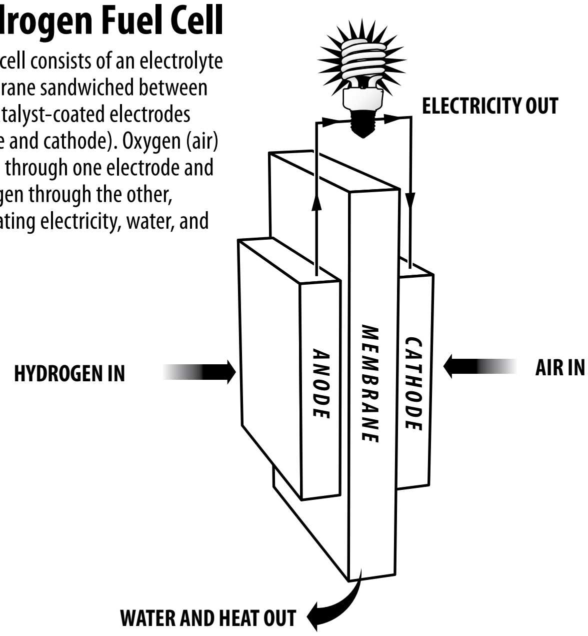
SPACE SHUTTLE



NASA once used hydrogen to fuel the space shuttle. Hydrogen batteries—called *fuel cells*—powered the shuttle's electrical systems.

Hydrogen Fuel Cell

A fuel cell consists of an electrolyte membrane sandwiched between two catalyst-coated electrodes (anode and cathode). Oxygen (air) passes through one electrode and hydrogen through the other, generating electricity, water, and heat.



Future of Hydrogen

Before hydrogen can make a significant contribution to the U.S. energy picture, many new systems must be designed and built. There must be large production and storage facilities and a distribution system. Consumers must have the technology to use it.

The use of hydrogen raises concerns about safety. Hydrogen is a volatile gas with high energy content. Early skeptics had similar concerns about natural gas and gasoline—even about electricity. People were once afraid to let their children too near the first light bulbs. As hydrogen technologies develop, safety issues will be addressed. Hydrogen can be produced, stored, and used as safely as other fuels.

As a domestically produced fuel, hydrogen has the potential to reduce our dependence on foreign oil and provide clean, renewable energy for the future.

Electricity

Electricity at a Glance, 2018

Secondary Source of Energy, Energy Carrier

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

U.S. Energy Consumption:
- 37.78%

Net U.S. Electricity Generation:
- 4,161.424 billion kWh

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

Data: Energy Information Administration

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.

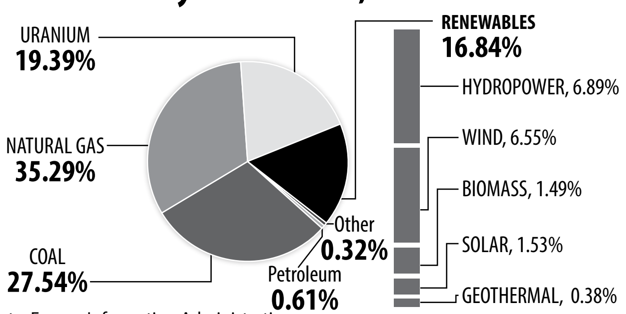
Making Electricity

Almost all electricity made in the United States is generated by large, central power plants. There are about 9,719 power plants in the U.S. Most power plants use natural gas, coal, nuclear fission, 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 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 now 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.

U.S. Electricity Production, 2018



Data: Energy Information Administration
*Total does not equal 100% due to independent rounding

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 connected by tall power towers. The lines are interconnected, so should one line fail, another will take over the load.

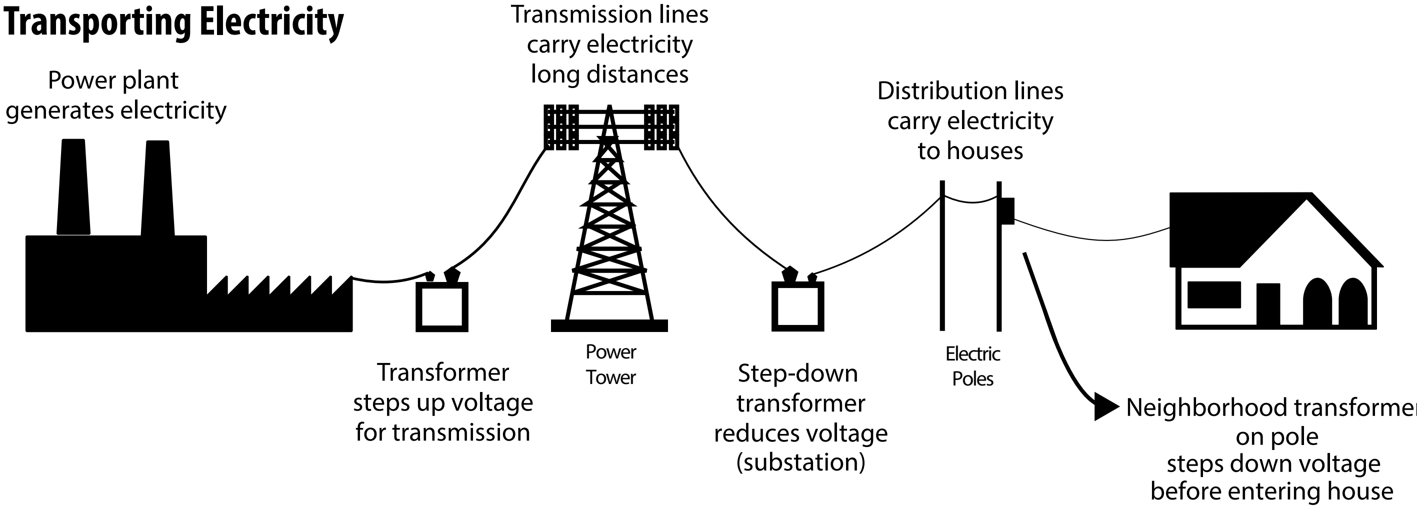
Step-down transformers located at substations along the lines reduce the voltage to 12,000 volts. Substations are small buildings in fenced-in areas that contain the switches, transformers, and other electrical equipment. Electricity is then carried over distribution lines that bring electricity to your 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 neighborhood transformer reduces the electricity to 240 and 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.

Electricity

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, baseload, 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 demand is 12,000 megawatts (MW) 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.

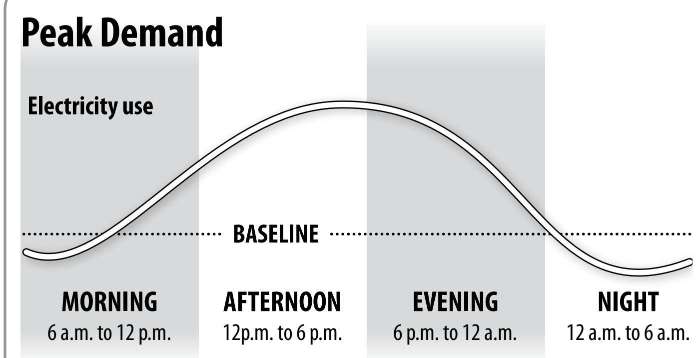
Baseload power is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Baseload power stations usually run at full or near capacity.

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 peaking generators run on natural gas, diesel, or hydropower and can be put into operation in minutes because they require little start-up time. 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 eight 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 98 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 demand, also called 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 peak load periods. Through energy efficiency and load management, electric utilities can save over 1,000 billion kilowatt-hours annually.

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 hot 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.

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 3,300 electric distribution utilities all over America that produce and distribute electricity to homes, businesses, and other energy users.

To get electricity to its users, there are more than 450,000 miles of high-voltage electric transmission lines across the U.S. and more than 2.5 million miles of feeder lines. 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.

These transmission and distribution 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, your family, and the other homes and businesses in your community that use electricity.

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, waste-to-energy, and solar power plants, but together they generate about 9.95 percent of the electricity produced in the United States.

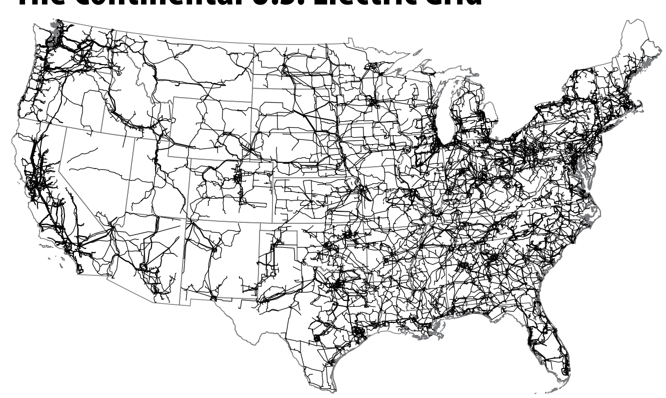
Fossil Fuel Power Plants: Fossil fuel plants burn coal, natural gas, or petroleum. These plants use the chemical energy in fossil fuels to superheat water into steam, which drives a **steam generator**. Fossil fuel plants are sometimes called thermal power plants because they use heat to generate electricity. Coal and natural gas are the fossil fuels of choice for most electric companies, producing 27.54 percent and 35.29 percent of total U.S. electricity respectively. Petroleum produces 0.61 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 a **reactor** and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller elements, producing a great amount of 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 thermal plants because they use heat to generate electricity. Nuclear energy produces 19.39 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 2018, hydropower generated 6.89 percent of U.S. electricity.

TRANSMISSION LINES

The Continental U.S. Electric Grid



Data: Energy Information Administration

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 an analog 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 TVs, DVRs, speakers, computers, gaming consoles, 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.

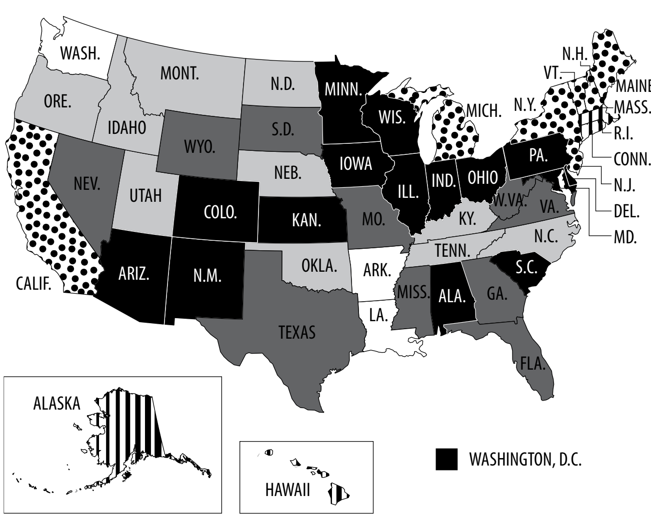
The surge in demand for electricity has far exceeded the creation of new transmission facilities and equipment over the years. Compounding the problem is the fact that about two-thirds of the electricity produced in our power plants never reaches potential users because of losses in energy conversion 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.

Average Residential Price for Electricity, 2018

PRICE PER KILOWATT-HOUR

< 10¢ / kWh — 10 to 11¢ / kWh — 11 - 12¢ / kWh

12 to 15¢ / kWh — 15 to 19¢ / kWh — > 20.00¢ / kWh



Data: Energy Information Administration

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 98 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 can cost consumers billions to even hundreds of billions of dollars each year, depending on the type of outage. Outages can be due to weather, 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 need to be made to the grid and the equipment it uses.

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (58 percent), the cost of transmission (13 percent), and local distribution (29 percent). The average cost of electricity is about 13 cents per kWh (13.04¢) for residential customers, almost eleven cents (10.66¢) for commercial customers, and a little less than seven cents (6.83¢) 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 uranium or hydropower. Location plays a part in electricity costs. Hawaii and Connecticut residents can pay as much as 32 cents and 21 cents per kWh, respectively, while residents of Washington State pay only 9.8 cents per kWh.

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 thermal energy. 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 thermal power plants are over eight times more efficient with efficiency ratings around 35 percent. Still, this means 65 percent of the initial thermal 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 4,500 tons of coal each day, and about two-thirds of the energy in 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 percent efficient at converting the kinetic energy of moving water into electricity.

But that's not all. Between three and eight 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 seven 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 and 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 was 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 embargos**, 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.

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. Light bulbs, for example, are rated by watts (13, 32, 60, 75, 100 watts), as are appliances, such as a 1500-watt hairdryer.

A **kilowatt** is 1,000 watts. A **kilowatt-hour** 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.

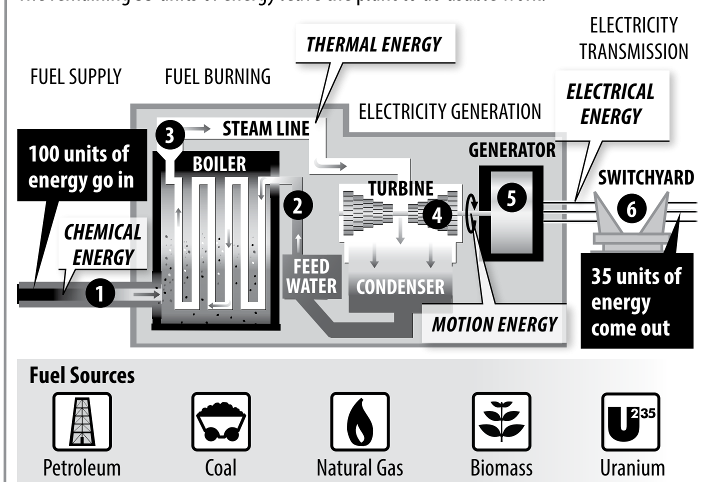
Just as we buy gasoline in gallons or wood in cords, we buy electricity in kilowatt-hours. Utility companies charge us for the kilowatt-hours we use during a month. If an average family of four uses 914 kilowatt-hours in one month, and the utility company charges 13 cents per kilowatt-hour, the family will receive a bill for $118.82 (914 x $0.13 = $118.82).

Electric utilities use **megawatts** and **gigawatts** to measure large amounts of electricity. Power plant capacity is usually measured in megawatts. One megawatt 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.

Efficiency of a Thermal Power Plant

Most thermal power plants are about 35 percent efficient. Of the 100 units of energy that go into a plant, 65 units are lost as one form of energy is converted to other forms. The remaining 35 units of energy leave the plant to do usable work.



How a Thermal Power Plant Works

1. Fuel is fed into a boiler, where it is burned to release thermal energy. Nuclear plants are thermal plants but the fuel is not burned, however, and undergoes a nuclear fission reaction to heat water.
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 a ring of magnets inside coils of copper wire. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage,

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 and maintain the infrastructure.

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

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 over 1 million megawatts by one-fifth in the next 20 years. Demand for electricity is projected to increase in the future despite technological energy efficiency improvements in electric devices and appliances.

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 natural gas, coal, 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 their backyard, but everyone wants the benefits of electricity.

Right now, most new power generation comes from natural gas, wind, and solar. 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 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 consumers. During peak demand when power generation is reaching its limit, the utility company can contact

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 crisis 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, 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 to 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 40.39 percent of the nation's electricity.

A special independent power producer is a **cogenerator** (combined heat and power, CHP)—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 3.43 percent of the electricity produced in the U.S. is cogenerated.

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.

Energy Storage

Scientists have recently been working hard to develop a wide range of energy storage methods and technologies that can allow electricity to be stored temporarily. Electric power producers use these energy storage technologies to quickly supply energy when it is needed, and to consume energy when there is a surplus – helping to balance supply and demand instantaneously. Energy storage is continually at work, improving the way electricity is generated, delivered, and consumed in America, making our electricity grid more reliable and efficient. Ultimately, energy storage helps power producers save money, which results in consumers saving money, too. Energy storage systems work with both nonrenewable and renewable sources of energy. Some examples of energy storage in use in small or large-scale include: pumped storage, batteries, capacitors, flywheels, thermal storage, and compressed air. While some of these technologies have been used for many years, others are more recent. Scientists continue to experiment and develop new storage methods that can help consumers on a smaller scale, and utilities on the largest of scales.

Monitoring Electricity Use

Homes and apartment buildings are equipped with meters so that utilities can determine how much electricity and natural gas each residence consumes. Most homes, apartment buildings, and commercial buildings in the U.S. have digital electric meters. However, some places may still have analog meters. These meters contain an aluminum disk. As electricity enters the house it passes through a pair of loops that creates a magnetic field. This creates an eddy current in the disk and causes the disk to rotate. The speed the disk rotates is proportional to the amount of power being consumed. As the disk spins, hands on dials move to record how much electricity has been consumed. Regardless of the type of meter, once a month the utility reads the meter and charges the customer for their electricity usage.

With once a month meter readings it is difficult for the consumer to monitor their electricity usage. Consumers can adjust their electricity usage after they receive their bills, but it’s too late to change their behaviors to affect their current bill. When electricity is generated it has to be used. If it is not used, that electricity is lost. Monitoring electricity usage once a month doesn’t help the utilities either. In order to better gauge how much electricity is needed at a given time, engineers have designed new meters that more accurately measure energy usage. This technology will allow utilities to generate enough electricity to meet their customers’ needs. In the future it will also allow utilities to more effectively employ renewable energy resources. These meters are called **smart meters.**

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 was discovered in the laboratory about 100 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 -419ºF. That temperature could only be maintained by using costly liquid helium. But new ceramic-like materials are superconducting at temperatures as high as -211ºF. These new materials can maintain their superconducting state using liquid nitrogen. The economics of superconductivity is becoming practical. As helium reserves continue to diminish, costs of helium continue to rise. Its many high-tech uses will need to find substitutes. For superconductivity, liquid nitrogen may be a better bet than helium. 100 cubic feet of liquid nitrogen could cost researchers or companies 30 cents to $2.00 per 100 cubic feet, whereas helium could cost 8 cents to $1.50 per cubic foot.

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.

Smart meters measure electricity usage much like the analog or digital meters. What makes these meters “smart” is the addition of two-way wireless communication between the meter and the utility. Rather than sending a meter reader to read meters once a month, the smart meter sends data to the utility every hour. Consumers can log on to secure websites to monitor their energy usage on an hourly basis as well. Seeing near real-time data allows consumers to make changes to their energy usage, which will have a direct impact on their energy bill. Many utilities implementing smart meters offer services that will e-mail or text consumers when their electricity usage is nearing a price bracket, allowing consumers to adjust their electricity usage accordingly.

Smart meters allow customers to more closely monitor their energy usage and make changes to conserve energy. In 2018, more than 52 percent of all U.S. electric customers had smart meters.

History of Electricity

Starting with Ben

Many people think Benjamin Franklin discovered electricity with his famous kite-flying experiments in 1752. Franklin is famous for tying a key to a kite string during a thunderstorm, proving that static electricity and lightning were indeed, the same thing. However, that isn't the whole story of electricity. Electricity was not "discovered" all at once.

Electricity is an action—not really a thing—so different forms of electricity had been known in nature for a long time. Lightning and static electricity were two forms.

In the early years, electricity became associated with light. After all, electricity lights up the sky during a thunderstorm. Likewise, static electricity creates tiny, fiery sparks. People wanted a cheap and safe way to light their homes, and scientists thought electricity could do it.

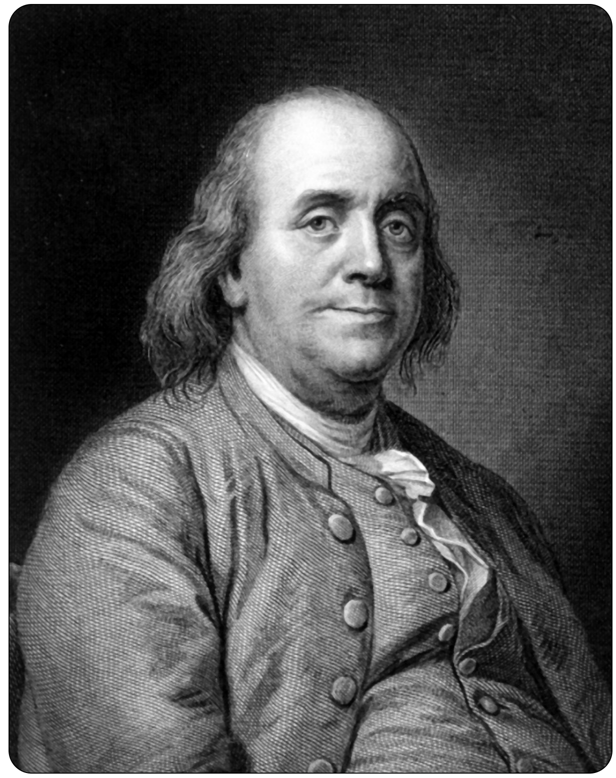


Image courtesy of NOAA Photo Library

Benjamin Franklin

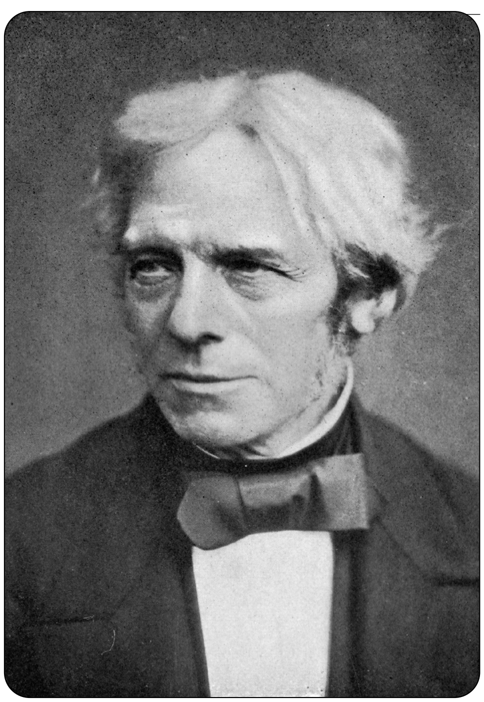
A Different Kind of Power: The Battery

The road to developing a practical use of electricity was a long one. Until 1800, there was no dependable source of electricity for experiments. It was in this year that an Italian scientist named Alessandro Volta soaked some paper in salt water, placed zinc and copper on alternate sides of the paper, and watched the chemical reaction produce an electric current. Volta had created the first electric cell.

By connecting many of these cells together, Volta was able to "string a current" and create a **battery**. (It is in honor of Volta that we rate batteries in **volts**.) Finally, a safe and dependable source of electricity was available, making it easy for scientists to study electricity. The electric age was just around the corner!

A Current Began

English scientist Michael Faraday was the first to realize that an electric current could be produced by passing a magnet through copper wiring. Both the electric generator and the electric motor are based on this principle. A generator converts motion energy into electricity. A motor converts electrical energy into motion.



Michael Faraday

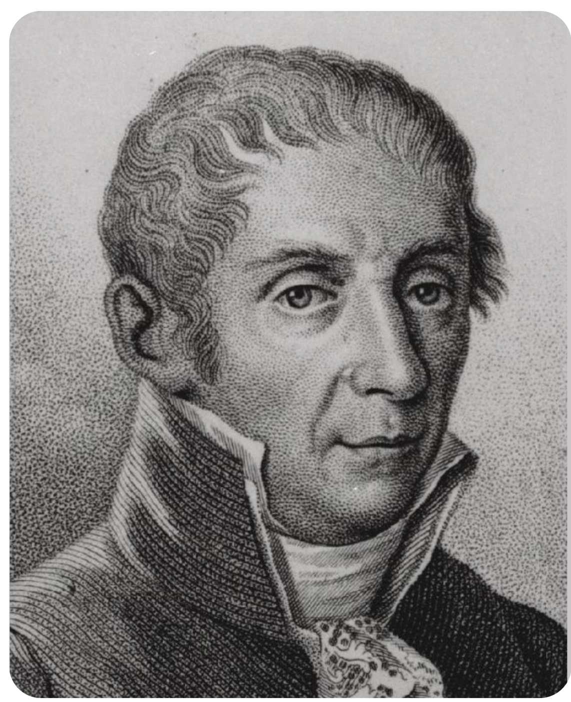


Image courtesy of Teylers Museum

Alessandro Volta

Mr. Edison and His Light

In 1879, Thomas Edison focused on inventing a practical light bulb, one that would last a long time before burning out. The challenge was finding a strong material to be used as the **filament**, the small wire inside the bulb that conducts the electricity.

Finally, Edison used ordinary cotton thread that had been soaked in carbon. The filament did not burn—instead, it became **incandescent**; that is, it glowed. These new lights were battery-powered, though, and expensive.

The next obstacle was developing an electrical system that could provide people with a practical, inexpensive source of energy. Edison went about looking for ways to make electricity both practical and inexpensive. He engineered the first electric power plant that was able to carry electricity to people's homes.

Edison's Pearl Street Power Station started up its generator on September 4, 1882, in New York City. About 85 customers in lower Manhattan received enough power to light 5,000 lamps. His customers paid a lot for their electricity. In today's dollars, the electricity cost $5 per kilowatt-hour! Today's electricity costs about 13.0 cents per kilowatt-hour.

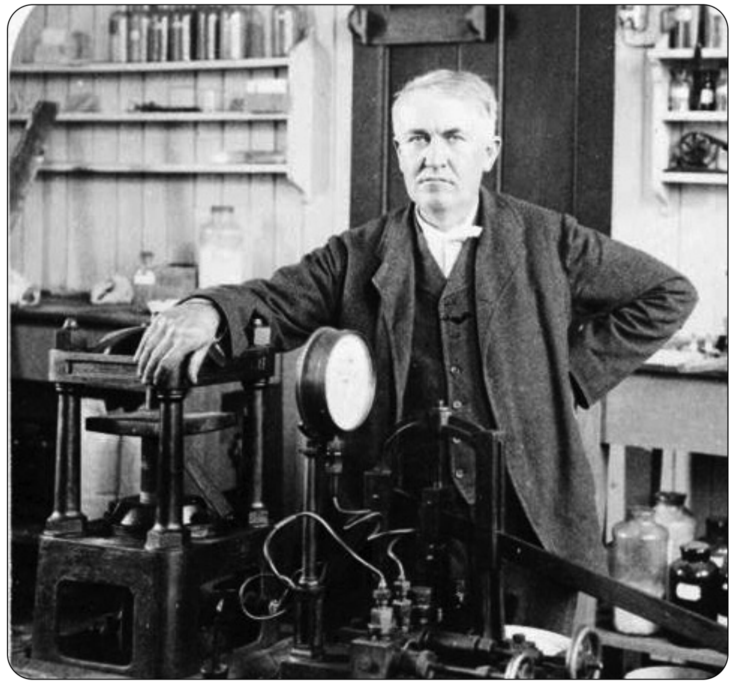


Image courtesy of U.S. Library of Congress

Thomas Edison in his lab in 1901.

The Question: AC or DC?

The turning point of the electric age came a few years later with the development of **AC (alternating current)** power systems. Croatian-born scientist, Nikola Tesla came to the United States to work with Thomas Edison. After a falling out, Tesla discovered the rotating magnetic field and created the alternating current electrical system that is used very widely today. Tesla teamed up with engineer and business man George Westinghouse to patent the AC system and provide the nation with power that could travel long distances – a direct competition with Thomas Edison's DC system. Tesla later went on to form the Tesla Electric Company, invent the Tesla Coil, which is still used in science labs and in radio technology today, and design the system used to generate electricity at Niagara Falls.

Now using AC, power plants could transport electricity much farther than before. While Edison's **DC (direct current)** plant could only transport electricity within one square mile of his Pearl Street Power Station, the Niagara Falls plant was able to transport electricity over 200 miles!

Electricity didn't have an easy beginning. While many people were thrilled with all the new inventions, some people were afraid of electricity and wary of bringing it into their homes. They were afraid to let their children near this strange new power source. Many social critics of the day saw electricity as an end to a simpler, less hectic way of life. Poets commented that electric lights were less romantic than gaslights. Perhaps they were right, but the new electric age could not be dimmed.

In 1920, about two percent of U.S. energy was used to make electricity. In 2018, with the increasing use of technologies powered by electricity, it was 38 percent.

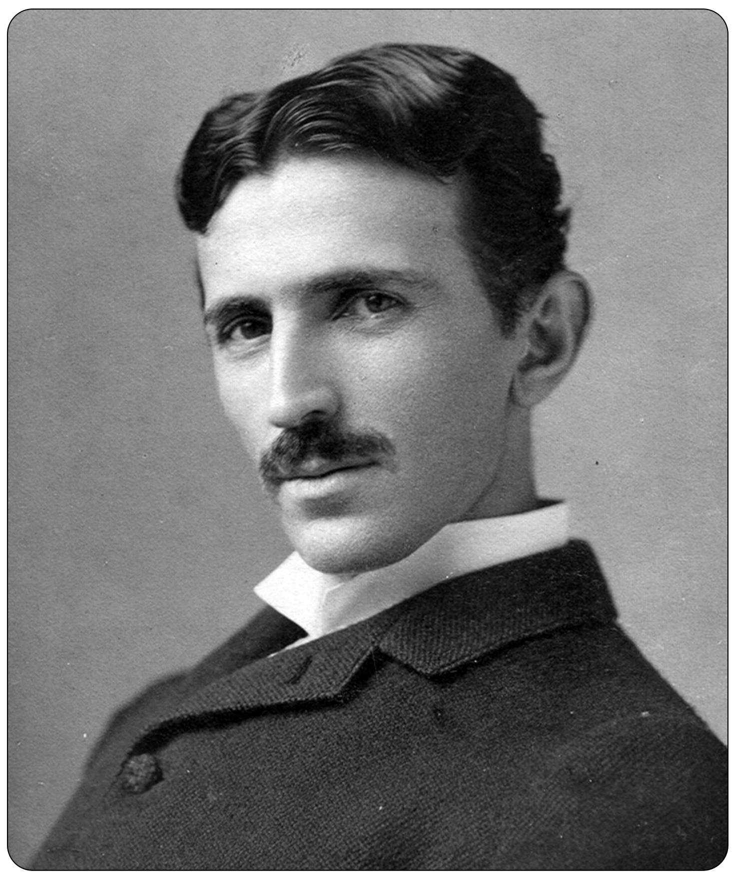


Photo by Napoleon Sarony

Nikola Tesla

Measuring Electricity

Electricity makes our lives easier, but it can seem like a mysterious force. Measuring electricity is confusing because we cannot see it. We are familiar with terms such as watt, volt, and amp, but we do not have a clear understanding of these terms. We buy a 100-watt light bulb, a tool that requires 120 volts, or an appliance that uses 8.8 amps, but we don't think about what those units mean.

Using the flow of water as an analogy can make electricity easier to understand. The flow of electrons in a **circuit** is similar to water flowing through a hose. If you could look into a hose at a given point, you would see a certain amount of water passing that point each second. The amount of water depends on how much pressure is being applied—how hard the water is being pushed. It also depends on the diameter of the hose. The harder the pressure and the larger the diameter of the hose, the more water passes each second. The flow of electrons through a wire depends on the electrical pressure pushing the electrons and on the cross-sectional area of the wire.

Voltage

The pressure that pushes electrons in a circuit is called voltage. Using the water analogy, if a tank of water were suspended one meter above the ground with a 1-centimeter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you.

Voltage (V) is a measure of the pressure applied to electrons to make them move. It is a measure of the strength of the current in a circuit and is measured in **volts (V)**. Just as the 10-meter tank applies greater pressure than the 1-meter tank, a 10-volt power supply (such as a battery) would apply greater pressure than a 1-volt power supply.

AA batteries are 1.5 volts; they apply a small amount of voltage for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a dangerous voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous voltage.

Current

The flow of electrons can be compared to the flow of water. The water current is the number of molecules of water flowing past a fixed point; electric current is the number of electrons flowing past a fixed point.

Electric current (I) is defined as electrons flowing between two points having a difference in voltage. Current is measured in **amperes** or **amps (A)**. One ampere is 6.25×10^{18} electrons per second passing through a circuit.

With water, as the diameter of the pipe increases, so does the amount of water that can flow through it. With electricity, conducting wires take the place of the pipe. As the cross-sectional area of the wire increases, so does the amount of electric current (number of electrons) that can flow through it.

Resistance

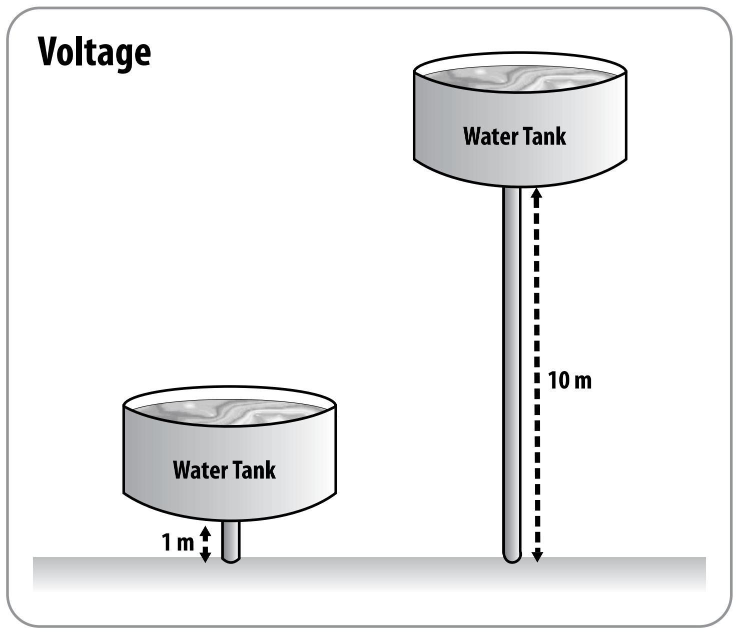
Resistance (R) is a property that slows the flow of electrons. Using the water analogy, resistance is anything that slows water flow, such as a smaller pipe or fins on the inside of a pipe.

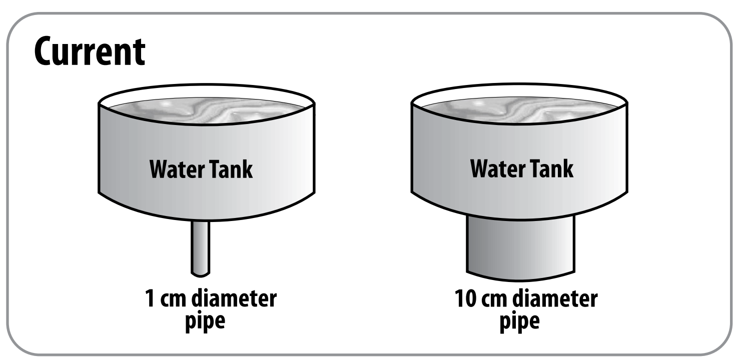
In electrical terms, the resistance of a conducting wire depends on the properties of the metal used to make the wire and the wire's diameter. Copper, aluminum, and silver—metals used in conducting wires—have different resistance.

Resistance is measured in units called **ohms (Ω)**. There are devices called resistors, with set resistances, that can be placed in circuits to reduce or control the current flow. Any device placed in a circuit to do work is called a **load**. The light bulb in a flashlight is a load. A television plugged into a wall outlet is also a load. Every load has resistance.

Ohm's Law

George Ohm, a German physicist, discovered that in many materials, especially metals, the current that flows through a material is proportional to the voltage. He found that if he doubled the voltage, the current also doubled. If he reduced the voltage by half, the current dropped by half. The resistance of the material remained the same.





This relationship is called **Ohm's Law** and can be described using a simple formula. If you know any two of the measurements, you can calculate the third using the following formula:

voltage = current x resistance

$$V = I \times R \quad \text{or} \quad V = A \times \Omega$$

Electric Power

Power (P) is a measure of the rate of doing work, or the rate at which energy is converted. Electric power is the rate at which electricity is produced or consumed. Using the water analogy, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work.

A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater force (voltage) than at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from 10 meters.

Electric power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electric power is measured in **watts (W)**. The formula is:

power = voltage x current

$$P = V \times I \quad \text{or} \quad W = V \times A$$

Electrical Energy

Electrical energy introduces the concept of time to electric power. In the water analogy, it would be the amount of water falling through the pipe over a period of time, such as an hour. When we talk about using power over time, we are talking about using energy. Using our water example, we could look at how much work could be done by the water in the time that it takes for the tank to empty.

The electrical energy that an appliance or device consumes can be determined only if you know how long (time) it consumes electric power at a specific rate (power). To find the amount of energy consumed, you multiply the rate of energy consumption (measured in watts) by the amount of time (measured in hours) that it is being consumed. Electrical energy is measured in watt-hours (Wh).

energy = power x time

$$E = P \times t \quad \text{or} \quad E = W \times h = Wh$$

Another way to think about power and energy is with an analogy to traveling. If a person travels in a car at a rate of 40 miles per hour (mph), to find the total distance traveled, you would multiply the rate of travel by the amount of time you traveled at that rate.

If a car travels for 1 hour at 40 miles per hour, it would travel 40 miles.

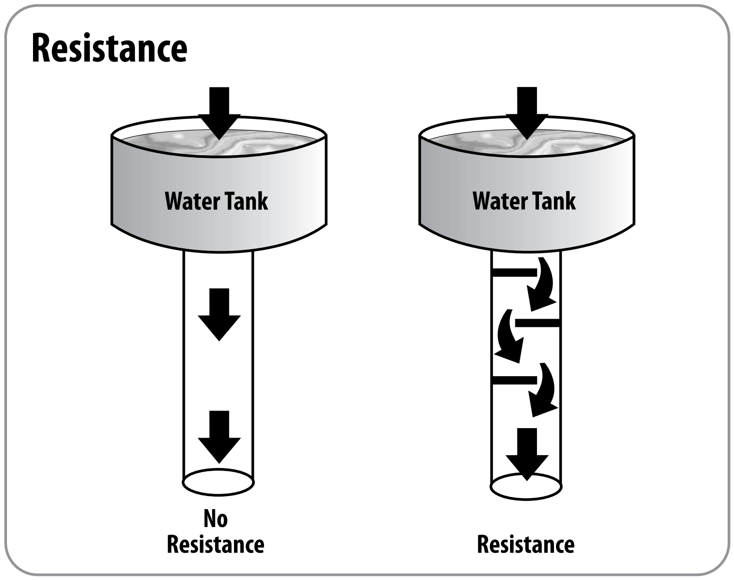
distance = 40 mph x 1 hour = 40 miles

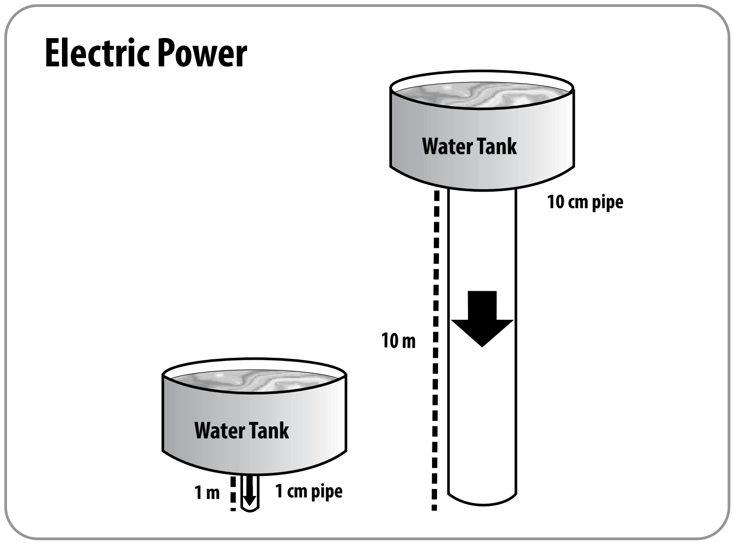
If a car travels for 3 hours at 40 miles per hour, it would travel 120 miles.

distance = 40 mph x 3 hours = 120 miles

The distance traveled represents the work done by the car. When we look at power, we are talking about the rate that electrical energy is being produced or consumed. Energy is analogous to the distance traveled or the work done by the car.

A person wouldn't say he took a 40-mile per hour trip because that is the rate. The person would say he took a 40-mile trip or a 120-mile trip. We would describe the trip in terms of distance traveled, not rate traveled. The distance represents the amount of work done.





The same applies with electric power. You would not say you used 100 watts of light energy to read your book, because a watt represents the rate you use energy, not the total energy used. The amount of energy used would be calculated by multiplying the rate by the amount of time you read.

If you read for five hours with a 100-W light bulb, for example, you would use the formula as follows:

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

energy = 100 W x 5 hour = 500 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). A kilowatt-hour is the unit that utilities use when billing most customers. The average cost of a kilowatt-hour of electricity for residential customers is about $0.13.

To calculate the cost of reading with a 100-W light bulb for five 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:

$$500\,\text{Wh} \times \frac{1\,\text{kW}}{1{,}000\,\text{W}} = 0.5\,\text{kWh}$$

$$0.5\,\text{kWh} \times \$0.13/\text{kWh} = \$0.065$$

Therefore, it would cost a little more than six cents to read for five hours with a 100-W light bulb.

Energy Consumption

The U.S. Department of Energy divides the way we use energy into categories—residential, commercial, industrial, electric power, and transportation. These are called sectors of the economy.

Residential and Commercial Sector

The residential and commercial sector—homes and buildings—consumes 11.58 percent of the energy used in the United States today. We use energy to heat and cool our homes and buildings, to light them, and to operate appliances and office machines. In the last 40 years, Americans have significantly reduced the amount of energy we use to perform these tasks, mostly through technological improvements in the systems we use, as well as in the manufacturing processes to make those systems.

Heating and Cooling

The ability to maintain desired temperatures is one of the most important accomplishments of modern technology. Our ovens, freezers, and homes can be kept at any temperature we choose, a luxury that wasn't possible 100 years ago.

Keeping our living and working spaces at comfortable temperatures provides a healthier environment, but uses a lot of energy. Forty-eight percent of the average home's energy consumption is for heating and cooling rooms.

The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, about half of the nation's homes are heated by natural gas, a trend that will continue, at least in the near future. **Natural gas** is a clean-burning fuel. Most natural gas furnaces used in the 1970s and 1980s were about 60 percent efficient—they converted 60 percent of the energy in the natural gas into usable heat. Some of these furnaces might still be in use today. Depending on maintenance and homeowner use, these furnaces could last for over 20 years.

New furnaces manufactured today can reach efficiency ratings of 98 percent, since they are designed to capture heat that used to be lost up the chimney. These furnaces are more complex and costly, but they save significant amounts of energy.

The payback period for a new high-efficiency furnace is between four and five years, resulting in considerable savings over the life of the furnace. **Payback period** is the amount of time a consumer must use a system before beginning to benefit from the energy savings because of the higher initial investment cost.

Electricity is the second leading source of energy for home heating and provides almost all of the energy used for air conditioning. The efficiency of air conditioners and heat pumps has increased 50 percent in the last 35 years.

In the 1970s, air conditioners and heat pumps had an average **Seasonal Energy Efficiency Ratio**, or **SEER**, of 7.0. Today, the new units must have a SEER of 13, and high-efficiency units are available with SEER ratings as high as 18. These highly-rated units are more expensive to buy, but their payback period is only three to five years.

Heating oil is the third leading fuel for home heating and is widely used in northeastern states. In 1973, the average home used 1,294 gallons of oil a year. Today, that figure is more like 485 gallons, over a 62 percent decrease.

This decrease in consumption is a result of improvements in oil furnaces. Not only do today's burners operate more efficiently, they also burn more cleanly. According to the Environmental Protection Agency, new oil furnaces operate as cleanly as natural gas and propane burners. A new technology under development would use PV cells to convert the bright, white oil burner flame into electricity.

Saving Energy on Heating and Cooling

The four most important things a consumer can do to reduce heating and cooling costs are:

- **Maintenance**

Maintaining equipment in good working order is essential to reducing energy costs. A certified technician should service systems annually, and filters should be cleaned or replaced on a regular schedule by the homeowner.

- **Programmable Thermostats**

Programmable **thermostats** regulate indoor air temperature automatically, adjusting for time of day and season. They can be used with both heating and cooling systems and can lower energy usage appreciably.

- **Insulation**

Most heat enters and escapes from homes through the ceilings and walls. Adequate **insulation** is very important to reduce heat loss and air infiltration. The amount of insulation required varies with the climate of the region in which the house is located.

- **Caulking and Weather Stripping**

Preventing the exchange of inside air with outside air is very important. Weather stripping and caulking around doors and windows can significantly reduce air leakage. Keeping windows and doors closed when systems are operating is also a necessity.

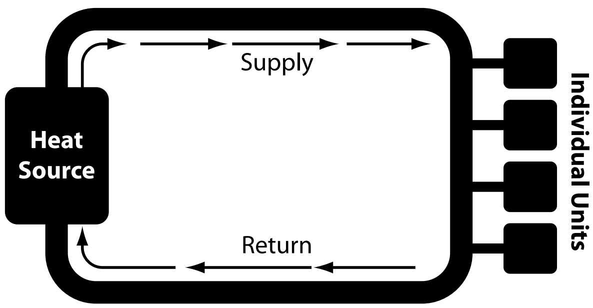
District Energy Systems

Where there are many buildings close together, like on a college campus, it is sometimes more efficient to have a central heating and cooling facility, which is called a **district energy system**. A district system can reduce equipment and maintenance costs, as well as produce energy savings.

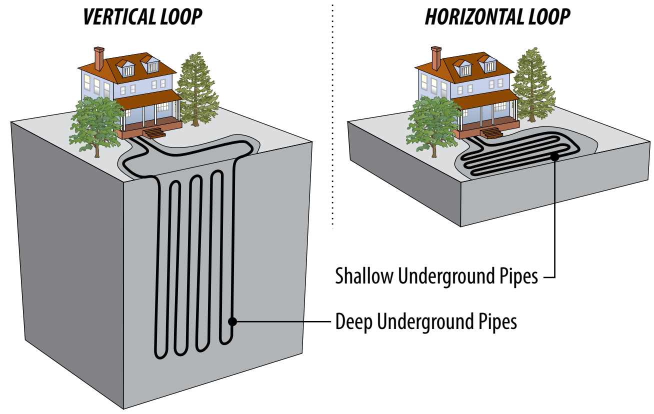
If the system relies on a fossil fuel cogeneration plant for heat, the overall efficiency of the plant can increase from 35 to 80 percent. **Cogeneration** can also reduce emissions per unit of energy produced by 50 percent.

If the district energy system uses a renewable energy source, such as geothermal energy or waste heat, emission levels can be reduced even more. A major benefit of district heating is its ability to use materials as fuel that would otherwise be waste products. These fuels may include biomass, such as waste from the forest product industry, straw, garbage, industrial waste heat, and treated sewage.

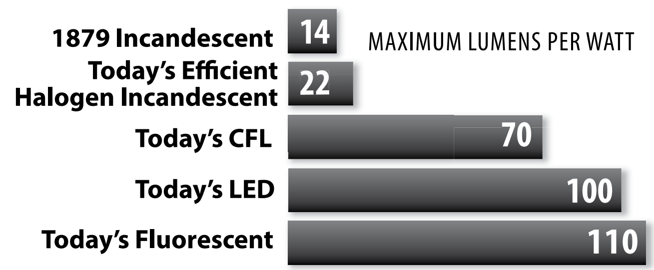
District Heating System



Residential Geoexchange Units



Lighting Efficiency



Data: Madison Gas and Electric

Geoexchange Systems

There are only a few areas in the country that have high temperature geothermal reservoirs, but low temperature geothermal resources are everywhere. Geothermal heat pumps, or **geoexchange units** as they are often called, can use low temperature geothermal energy to heat and cool buildings.

Geothermal systems cost more to install than conventional systems, but over the life of the system, they can save a significant amount of money and energy. They can reduce heating costs by 30-70 percent and cooling costs by 20-50 percent. Today, there are more than one million geothermal systems in homes and buildings.

Building Design

The placement, design, and construction materials used can affect the energy efficiency of homes and buildings. Making optimum use of the light and heat from the sun is becoming more prevalent, especially in commercial buildings.

Many new buildings are situated with maximum exposure to the sun, incorporating large, south-facing windows to capture the energy in winter, and overhangs to shade the windows from the sun in summer. Windows are also strategically placed around the buildings to make use of natural light, reducing the need for artificial lighting during the day. Using materials that can absorb and store heat can also contribute to the energy efficiency of buildings.

The Department of Energy's National Renewable Energy Lab developed computer programs to design energy efficient buildings for any area of the country, taking into account the local climate and availability of building materials.

For existing houses and buildings, there are many ways to increase efficiency. Adding insulation and replacing windows and doors with high efficiency models can significantly reduce energy costs. Adding insulated draperies and blinds, and using them wisely, can also result in savings. Even planting trees that provide shade in the summer and allow light in during the winter can make a big difference.

Lighting

Lighting is essential to a modern society. Lights have revolutionized the way we live, work, and play. Lighting accounts for about five percent of the average home's total energy bills, but for stores, schools, and businesses, the figure is slightly higher. On average, the commercial sector uses about 10 percent of its energy for lighting.

Some homes still use the traditional **incandescent light bulbs** invented by Thomas Edison. These bulbs convert only 10 percent of the electricity they use to produce light; the other 90 percent is converted into heat. With new technologies, such as better filament designs and gas mixtures, these bulbs are more efficient than they used to be. In 1879, the average bulb produced 14 **lumens** per watt, compared to up to 17 lumens per watt today. By adding halogen gases, this efficiency can be increased to 22 lumens per watt. Energy-wasting, traditional incandescents have been phased out, beginning in 2012 with the 100-watt and 75-watt bulbs. 60-watt and 40-watt incandescent bulbs followed and were phased out in 2014. Halogen and energy efficient varieties of incandescents are still available for consumers.

Compact fluorescent light bulbs (CFL) are more common in homes now. They last up to ten times longer than incandescents and use much less energy, producing significant savings over the life of the bulb. New fluorescent bulb technology has made more dramatic advances in lighting efficiency. Some of the new fluorescent systems have increased the efficiency of these bulbs to as high as 70 lumens per watt.

Most commercial buildings have converted to linear fluorescent lighting, which costs more to install, but uses much less energy to produce the same amount of light. Buildings with fluorescent lighting already installed can lower lighting costs by updating to more efficient fluorescent systems.

Light emitting diodes (LED) are readily becoming the most common efficient lighting choice. Even more efficient and cheaper than CFLs, these bulbs last two and a half times longer than CFLs and have many tech-friendly applications.

Most light bulbs are used in some kind of fixture. The design of fixtures can have a major impact on the amount of light required in buildings. Good fixture designs that capture all of the light produced and direct it to where it is needed can reduce energy costs significantly.

Energy Consumption

Outdoor lighting consumes a lot of energy, too. Most of our major highways and residential streets have streetlights, as well as many parking lots. In the 1970s, most streetlights were inefficient incandescent and mercury vapor lights. It was at this time that the Federal Government began replacing these lights with high-pressure sodium lights, which produce about three times as much light per watt. Automatic sensors were also installed to reduce energy use.

Consumers should make use of fluorescent bulbs wherever feasible and use only the amount of light they need for the task at hand. Automatic turn-off and dimmer switches can also contribute to energy savings. Keeping light bulbs free of dust is an energy-saver, too. Some of the most important actions consumers can take is to turn off lights they aren't using, buy lamps that are suited to their needs in different rooms, and make energy conservation a priority in their daily lives. After CFLs have completed their lifespan, they should be recycled.

Appliances

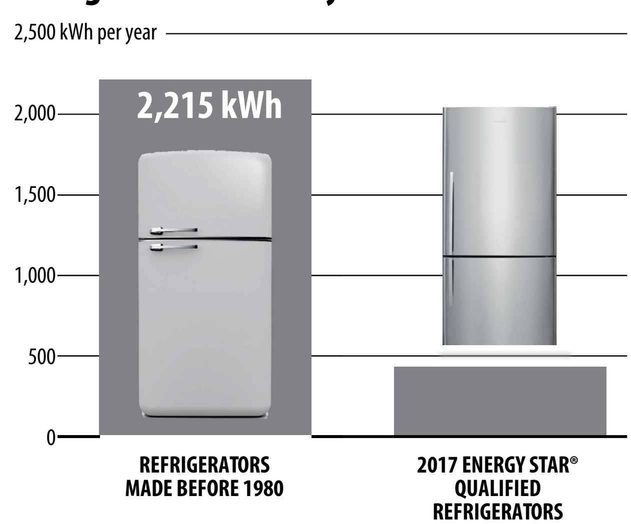
In the last 100 years, appliances have revolutionized the way we spend our time at home. Tasks that used to take hours are now accomplished in minutes, using electricity most of the time instead of human energy. In 1990, Congress passed the National Appliance Energy Conservation Act, which requires appliances to meet strict energy efficiency standards.

▪ Water Heating

Heating water uses more energy than any other task, except for home heating and cooling. Most water heaters use natural gas or electricity as fuel. New water heaters are much more energy efficient than earlier models. Many now have timers that can be set to the times when hot water is needed, so that energy is not being used 24 hours a day. New systems on the market combine high efficiency water heaters and furnaces into one unit to share heating responsibilities. Combination systems can produce a 90 percent efficiency rating.

In the future, expect to see water heaters that utilize heat that is usually pumped outside as waste heat. Systems will collect the waste heat and direct it into the water heater, resulting in efficiency ratings three times those of conventional water heaters.

Refrigerator Efficiency



Data: ENERGY STAR®

Most consumers set the temperature on their water heaters much too high. Lowering the temperature setting can result in significant energy savings. Limiting the amount of hot water usage with low-flow showerheads and conservation behaviors also contributes to lower energy bills.

▪ Refrigerators

Refrigerators have changed the way we live and have brought health benefits to our lives. With these appliances, we can safely store foods for long periods of time. Since refrigerators involve heat exchange, they also consume a significant amount of electricity each year.

New refrigerators are many times more efficient than early models. Manufacturers have improved the insulation and the seals, or **gaskets**, to hold in the cold air better. The industry has also made technological advances in defrost systems, as well as in more energy efficient motors and compressors.

The appliance industry has worked with the chemical industry to develop refrigerants that are not harmful to the ozone layer, as the early CFCs were. As with all appliances, the most efficient models are more expensive to purchase but produce energy savings over the life of the refrigerator.

▪ Washers and Dryers

Before washers and dryers, doing the laundry meant hard physical work all day, no matter what the weather. Today, the most difficult thing about laundry is deciding which cycle to use. Today's machines have many innovations that save energy. Dryers with automatic sensors can tell when clothes are dry.

High-efficiency washing machines are being designed with either a horizontal axis or the traditional top-load design. These machines use 35 percent less water and 20 percent less energy than a regular washer. They also have higher capacity; they can wash large items such as comforters and sleeping bags.

▪ Appliance Efficiency Ratings

We use many other appliances every day. Some use less than 10 cents worth of electricity a year, while others use much more. Have you noticed that those appliances that produce or remove heat require the most energy?

When purchasing any appliance, consumers should define their needs and pay attention to the **Energy Efficiency Ratio (EER)** included on the yellow label of every appliance. The EER allows consumers to compare not just purchase price, but operating cost as well, to determine which appliance is the best investment.

Usually, more energy efficient appliances cost more to buy, but result in significant energy savings over the life of the appliance. Buying the cheapest appliance is rarely a bargain in the long run.

In the next few years, consumers will have the choice of many smart appliances that incorporate computer chip technology to operate more efficiently, accurately, and effectively.

Industrial Sector

The United States is a highly industrialized society. We use a lot of energy. Industry consumed 22.73 percent of the energy in 2018, but U.S. industry produces about 20 percent of the world's manufacturing output. Advanced technologies have allowed industry to do more with less. Industry has also been a leader in developing cogeneration technology. Cogenerators produce electricity and use the waste heat for manufacturing, increasing overall energy efficiency by 35 percent.

Every industry uses energy, but there are six energy-intensive industries that use the majority of the energy consumed by the industrial sector.

Petroleum Refining

Refineries need energy to convert crude oil into transportation fuels, heating fuels, chemicals, and other products. Enormous amounts of heat are required to separate crude oil into its components, such as gasoline, diesel, aviation fuel, and important gases. Heat is also needed to crack, or break, big hydrogen and carbon molecules into lighter, more valuable petroleum products.

Refineries use a mixture of fuels to operate, including by-product gases made during the refining process. On a per barrel basis, today's refineries use about 30 percent less energy than they did in the 1970s.

Steel Manufacturing

The steel industry consumes about two percent of total U.S. energy demand. The energy is used to convert iron ore and scrap metal into hundreds of products we use daily. The cost of energy represents 15 percent of the manufacturing cost of steel. Most of this energy comes directly from the heating of coal, and natural gas, and also from electricity generated by coal or natural gas plants.

Since 1990, the steel industry has reduced its energy consumption by 30 percent per ton of steel. This increase in efficiency has been accomplished through advanced technologies, the closing of older plants, and the increased use of recycled steel.

The increased use of recycled steel also saves energy. It requires 75 percent less energy to recycle steel than to make it from iron ore. Today, steel is one of the nation's leading recycled products, with two-thirds of new steel being manufactured from recycled scrap.

Aluminum Manufacturing

It takes huge amounts of electricity to make aluminum from **bauxite**, or aluminum ore. It requires six to seven kilowatt-hours of electricity to convert bauxite into one pound of aluminum. The cost of electricity accounts for one-third of the total manufacturing cost.

It requires 20 percent less energy to produce a pound of aluminum than it did 20 years ago, mostly because of the growth of recycling. Aluminum recycling has grown substantially over the last 4 decades. Using recycled aluminum requires 95 percent less energy than converting bauxite into aluminum.

Paper Manufacturing

The U.S. uses enormous amounts of paper every day and energy is required in every step of the papermaking process. Energy is used to chip, grind, and cook the wood into pulp, and more is needed to roll and dry the pulp into paper. Paper and paper products manufacturing is the third largest energy consumer in the industrial sector.

PETROLEUM REFINERY

Photo courtesy of BP

The pulp and paper industry has reduced its fossil fuel consumption per ton of paper by about 30 percent in the last 20 years, mostly through the use of better technology and cogeneration systems. Over 63 percent of the fuel the industry uses to power the cogeneration equipment comes from wood waste, a renewable energy source.

Chemical Manufacturing

Chemicals are essential to our way of life. We use chemicals in our medicines, cleaning products, fertilizers, and plastics, as well as in many of our foods. The chemical industry uses natural gas, coal, and oil to power the equipment they use to manufacture chemicals. Chemical manufacturing also needs a **hydrocarbon** source of raw materials, or **feedstock**, to process into chemical products. Petroleum, propane, and natural gas are the major feedstocks.

Improved technology has made the chemical industry about 50 percent more energy efficient today than it was 30-40 years ago. Technology has allowed the industry to use less energy, as well as produce more product from an equivalent amount of feedstock.

Cement Manufacturing

Some people think the United States is becoming a nation of concrete. New roads and buildings are being built everywhere, every day. Concrete is made from cement, water, and crushed stone. Making cement is an energy-intensive industry because of the extremely high temperatures required—up to 3,400 degrees Fahrenheit (more than 2,000°C).

Thirty years ago, cement plants all burned fossil fuels to produce this heat. Today, the industry has reduced its energy consumption by more than one-third using innovative waste-to-energy programs.

Nearly 70 percent of the cement plants in the U.S. now use some type of waste by-product for fuel, including used printing inks, dry cleaning fluids, and used tires—all of which have high energy content. One pound of used tires, for example, has more energy than one pound of coal.

Today, a modern cement plant can meet between 20 and 70 percent of its energy needs by burning waste materials that otherwise would not be used for their energy value.

Transportation Sector

America is a nation on the move. 28.14 percent of the energy we use every day goes to transporting people and goods from one place to another.

The Automobile

The people in the United States have always had a love affair with the automobile. Until the **oil embargoes** of the 1970s, Americans drove without thought of fuel economy or environmental impacts.

In 1973, there were 125 million vehicles on the road, driving an average of 10,000 miles a year. Today, there are over 270 million vehicles, driving over 11,000 miles a year. Even with the scares of oil embargoes, political unrest in oil-producing areas, and damaging storms in the Gulf of Mexico, we are driving more cars, more miles. It's a good thing we're doing it more efficiently and cleanly.

Although the oil crises didn't alter Americans' driving habits much, they did bring about changes in vehicle design. Automakers downsized many large and mid-sized models and significantly reduced vehicle weight. Aerodynamic designs were incorporated and engine size reduced. More important, engines were improved to increase fuel efficiency with fuel injectors and electronic transmissions. All of these improvements have resulted in almost doubling the fuel efficiency for vehicles since the 1970s.

▪ Mileage Requirements

Most of the improvements in automobile efficiency have been the result of mandates by the Federal Government such as CAFE standards. First enacted by Congress in 1965, the purpose of Corporate Average Fuel Economy (CAFE) standards is to reduce energy consumption by increasing the fuel economy of cars and light trucks. The National Highway Traffic Safety Administration (NHTSA) sets fuel economy standards for cars and light trucks sold in the U.S., while the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each manufacturer. Today, new passenger cars are required to achieve a combined city and highway mileage of about 40 **miles per gallon (mpg)**.

When gas prices were low, consumers made no great effort to buy fuel-efficient vehicles. In 2004, for example, sales of the ten most efficient cars and ten most efficient trucks totaled less than one percent of total sales. On the other hand, sport utility vehicles (SUVs) and light trucks made up half of total passenger vehicle sales. Today is not much different, with nearly 70% of the vehicles sold in 2018 being SUVs and light trucks.

Many car manufacturers are producing hybrid vehicles powered by a combination of gasoline and electricity. These vehicles are much more fuel efficient than their gasoline-only counterparts because they are designed to run on only electricity during periods of low power demand. In many states, commuters driving hybrid vehicles are allowed in limited access lanes and are given tax deductions.

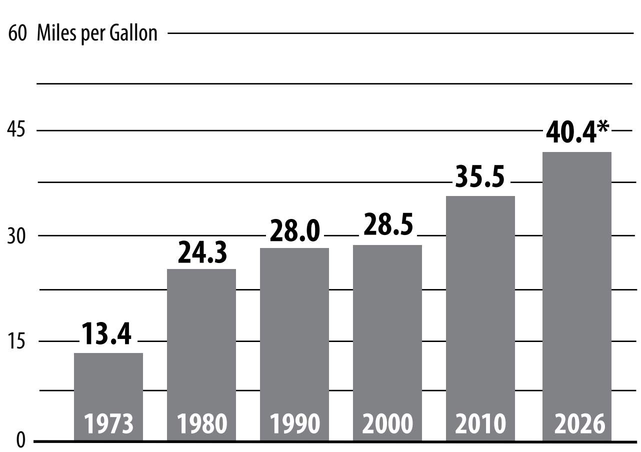
In 2012, the NHTSA had proposed CAFE standards for model year 2021-2026 for all passenger vehicles (including light trucks, subcompact cars, large sedans, station wagons, crossover utility vehicles, SUVs, minivans, and pickup trucks) of an average of 40.1 mpg in 2021 and 46.7 mpg in 2026. In 2017, the proposed rules were revoked and placed under further review. In early 2020 the Safer Affordable Fuel-Efficient Vehicles Rule (SAFE) re-established CAFE standards for model years 2021-2026. Automobile manufacturers must now meet or exceed an average of 40.4 mpg by model year 2026.

As the nation's automakers re-invent themselves, energy efficiency is a major consideration of future auto makes and models. Auto makers are expanding their options for electric powered vehicles and alternative fuels.

▪ Alternative Fuels

There is also a push to develop vehicles that run on fuels other than petroleum products or on blended fuels. Today, there are vehicles that run on electricity, natural gas, propane, biodiesel, ethanol, and hydrogen. In the 1970s, there were only a few vehicles that ran on alternative fuels. Today, there are several million alternative fuel vehicles in the United States. That number will continue to increase as barriers to acceptance across the nation are overcome. These include:

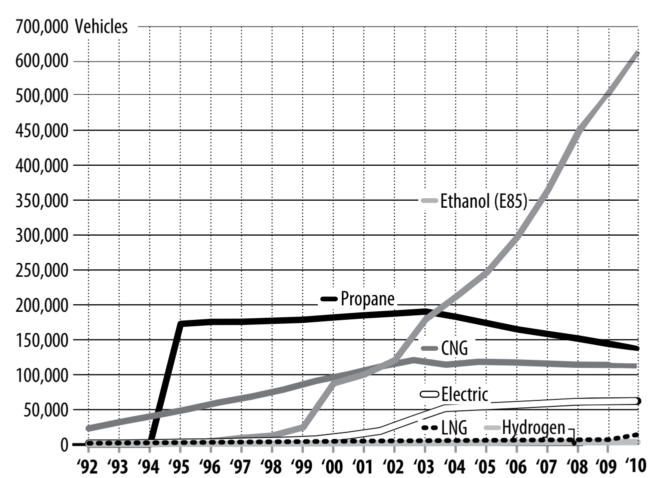
Average Fuel Economy of New Passenger Cars



*By 2026, new CAFE standards will require cars and light trucks to meet a 40.4 mpg fuel economy standard.

Data: U.S. Department of Energy

Alternative Fuel Fleet Vehicles in Use Since 1992



Data: Energy Information Administration

Refueling Infrastructure: Manufacturers are now capable of producing a large volume of alternative fuel vehicles, but there needs to be a convenient infrastructure for obtaining the fuels. Not many people are willing to drive 15 miles or more to refuel.

Consumer Education: Most Americans know very little about **alternative fuel vehicles**. Consumers must be educated about environmental and other benefits of these vehicles before they will consider them a choice.

If these barriers can be removed, alternative fuel vehicles can develop a strong niche market in the U.S. New technologies are being developed to make these vehicles more practical and convenient for consumers.

Commercial Transportation

The United States is a large country. We use a lot of energy moving goods and groups of people from one place to another. Passenger vehicles consume about 60% of the transportation fuel and commercial vehicles and transport modes consume the remaining 40%. The fuel efficiency of trains, trucks, buses, and planes has increased significantly in the last 40 years, as well as the number of miles traveled.

▪ Trucks

Trucks use more transportation fuel than any other commercial vehicle. Almost all products are at some point transported by truck. In the early 1970s, the average tractor-trailer traveled 5.5 miles on a gallon of fuel. New trucks manufactured today can travel about seven miles on a gallon of fuel. This increase in fuel efficiency is due mainly to improvements in engine design and computerized electronic controls.

New diesel engines can convert about 45 percent of the energy in the fuel into vehicle movement, while gasoline engines can convert only about 30 percent. Federal research is aimed at improving diesel efficiency to 55 percent, by redesigning engines, redesigning braking systems to use air flow to help slow down vehicles, and engineering tires to roll more easily.

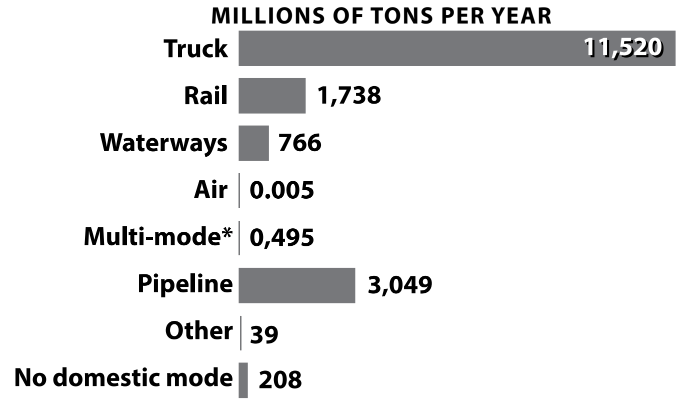
▪ Planes

Since 1980, the number of passengers on planes has more than doubled. Planes all use petroleum products for fuel, which is the largest cost item for air transport after labor. The airline industry has been a leader in efficiency.

Since the 1970s, airlines have increased their fuel efficiency 70 percent. Many factors have led to better efficiency—newer engines, better flight routing, single engine taxiing, and design modifications. Boeing's newest plane, the 787 Dreamliner, is touted to be 20 percent more efficient than comparable sized planes by using new engines, lighter weight materials, improvements in aerodynamics, and other engineering advances. The International Air Transport Association has set a goal of improving fuel efficiency another 25 percent by 2020.

Airlines are also using alternative fuels for airplanes. Airbus flew an A380 with one engine powered by a gas-to-liquid fuel in 2008. The same year Virgin Atlantic flew a Boeing 747-400 with one engine operating on a 20 percent biofuel blend. In 2009, Continental Airlines conducted a successful Boeing 737 test flight using jet fuel blended with algae oil and **jatropha**. Other airlines have been running similar tests, mixing biofuels with jet fuel. In 2010, the U.S. Navy flew an F/A-18 fighter jet on a 50/50 jet fuel/biofuel blend. These tests have demonstrated that biofuels can be blended with existing fuels and not impact an airplane's performance. United Airlines began flights using biojet fuel in 2016.

U.S. Freight, by Mode of Transportation, 2017



*Multi-mode includes any combination of truck, rail, air, waterway, and mail.
Data: Bureau of Transportation Statistics

▪ Railroads

Since the 1970s, the fuel efficiency of freight trains has increased by more than half. This reduction in energy use was accomplished by using longer trains with less handling and fewer changes and stops. The equipment is stronger and lighter to handle more cargo. There have also been major improvements in rail technology that have contributed to ease of movement.

The trucking and marine shipping industries work with the railroad industry to move cargo efficiently. More freight is being transported on trains directly in truck trailers and uniform containers so that there is less handling. Today, containers often travel by ship, rail, and truck in one shipment called multi-mode or intermodal transportation.

In the future, there will be an increase in the use of AC motors on diesel electric engines on locomotives. With AC motors, there are fewer moving parts, so less heat is generated, resulting in more efficient use of fuel. A train that today requires six locomotives might require only four with this new technology.

▪ Mass Transit: Public Transportation

Mass transit is the system of public transportation for moving people on buses, trains, light rail, and subways. In 1970, nine percent of workers who traveled to work used public transit systems, two-thirds on buses. Today, less than ten percent of commuters use public transportation, half on buses. Why this decrease? Americans love cars. Most families own more than one. As more people have moved from cities into suburbs, public transportation has not been economically feasible for many dispersed locations.

The average American spends more than 40 hours each year delayed by traffic congestion. Building more roads isn't the only answer, especially with environmental concerns over vehicle emissions and the higher cost of transportation fuels.

Efficiency and Conservation

Selected Countries and Energy Consumption, 2018

Country	Population (millions)	Total 2017 Primary Energy Consumption (Qbtu)	2017 Energy per capita (MBtu/ person)
World	7,594.3	582.46	77.74
China	1,384.69	139.44	100.7
India	1,296.83	30.48	23.5
United States	327.17	97.8	296.73
Indonesia	262.79	7.16	27.24
Brazil	208.85	12.59	60.3
Pakistan	207.86	3.18	15.32
Nigeria	203.45	1.54	7.57
Russia	142.12	32.83	231.01
Japan	126.17	19.6	155.38
Mexico	125.96	7.91	62.8
Germany	80.46	14.01	174.15
Iran	83.02	11.6	139.7
Thailand	68.62	5.52	80.44
France	67.36	10.32	153.23
United Kingdom	65.11	8.23	126.38
South Africa	55.38	5.68	102.48
South Korea	51.42	12.36	240.36
Canada	35.88	15.05	419.55
Saudi Arabia	33.09	11	332.32
Australia	23.47	6.08	259.21
Netherlands	17.15	0.2	11.39
Chile	17.93	1.51	84.32
Honduras	9.18	0.17	18.63
Haiti	10.79	0.05	4.5
Libya	6.75	0.57	84.68
Iraq	40.19	1.87	46.42
Dominican Republic	10.30	0.34	33.1
Kuwait	2.92	1.59	545.6
Angola	30.36	0.36	11.95
Zimbabwe	14.03	0.16	11.35
Mauritius	1.36	0.08	66.66

*2018 Global Energy Data not yet available for all nations.
Data: Energy Information Administration, The World Bank

Introduction

The United States uses a lot of energy— over 2.1 million dollars worth of energy each minute, 24 hours a day, every day of the year. With less than five percent of the world's population, we consume a little less than one-fifth (17.35 percent) of the world's energy. We are not alone among industrialized nations; average-world energy use per person continues to grow in many countries, while population also continues to increase.

The average American consumes 4.02 times the world average per capita consumption of energy. Every time we fill up our vehicles or open our utility bills, we are reminded of the economic impacts of energy.

Energy Efficiency and Conservation

Energy is more than numbers on a utility bill; it is the foundation of everything we do. All of us use energy every day—for transportation, cooking, heating and cooling rooms, manufacturing, lighting, water-use, and entertainment. We rely on energy to make our lives comfortable, productive, and enjoyable. Sustaining this quality of life requires that we use our energy resources wisely. The careful management of resources includes reducing total energy use and using energy more efficiently.

The choices we make about how we use energy—turning machines off when not in use or choosing to buy energy efficient appliances—will have increasing impacts on the quality of our environment and lives. There are many things we can do to use less energy and use it more wisely. These things involve energy conservation and energy efficiency. Many people use these terms interchangeably; however, they have different meanings.

Energy conservation includes any behavior that results in the use of less energy. **Energy efficiency** involves the use of technology that requires less energy to perform the same function. A compact fluorescent light bulb that uses less energy to produce the same amount of light as an incandescent light bulb is an example of energy efficiency. The decision to replace an incandescent light bulb with a compact fluorescent is an example of energy conservation.

As individuals, our energy choices and actions can result in a significant reduction in the amount of energy used in each sector of the economy.

Residential/Commercial

Households use about one-fifth of the total energy consumed in the United States each year. The typical U.S. family spends about $1,850 a year on utility bills. At least 55 percent is in the form of electricity, the remainder is mostly natural gas and oil, depending on the systems in the home.

Much of this energy is not put to use. Heat, for example, pours out of homes through doors and windows and under-insulated attics, walls, floors, and basements. Some idle appliances use energy 24 hours a day. The amount of energy lost through poorly insulated windows and doors equals the amount of energy flowing through the Alaskan oil pipeline each year.

Energy efficient improvements cannot only make a home more comfortable, they can yield long-term financial rewards. Many utility companies and energy efficiency organizations provide energy audits to identify areas where homes are poorly insulated or energy inefficient. This service may be free or at low cost.

The residential and commercial sectors generate more than 10 percent of greenhouse gas emissions that contribute to global climate change. The three main sources of greenhouse gas emissions from homes are electricity use, space heating, and waste. Using a few inexpensive, energy efficient measures can reduce your energy bill and, at the same time, reduce air pollution.

▪ Heating and Cooling

Heating and cooling systems use more energy than any other systems in American homes. Natural gas and electricity are used to heat most American homes, electricity to cool almost all. Typically, about half of the average family's utility bills goes to keeping homes at a comfortable temperature.

With all heating, ventilation, and air-conditioning systems, you can save money and increase comfort by installing proper insulation, maintaining and upgrading equipment, and practicing energy efficient behaviors. By combining proper maintenance, upgrades, insulation, weatherization, and thermostat management, you can reduce energy bills and emissions by half.

A seven to ten degree adjustment to your **thermostat** setting for eight hours a day can lower heating bills by ten percent. Programmable thermostats can automatically control temperature for time of day and season for maximum efficiency.

▪ Insulation and Weatherization

Warm air leaking into your home in cooling seasons and out of your home in heating seasons can waste a substantial amount of energy. You can increase home comfort and reduce heating and cooling needs by up to 20 percent by investing a few hundred dollars in proper **insulation** and weatherization products. Insulation is rated using an R-value that indicates the resistance of the material to heat flow. You need a minimum **R-value** of 26, or more than three inches of insulation, in ceilings and walls. In very cold climates, a higher R-value is recommended.

Insulation wraps your house in a nice warm blanket, but air can still leak in or out through small cracks. Often the effect of the many small leaks in a home is equivalent to a wide open door. One of the easiest money-saving measures you can perform is to caulk, seal, and weather strip all seams, cracks, and openings to the outside. You can save 10 percent or more on your energy bill by reducing the air leaks in your home.

▪ Doors and Windows

About one-quarter of a typical home's heat loss occurs around and through the doors and windows. Energy efficient doors are insulated and seal tightly to prevent air from leaking through or around them. If your doors are in good shape and you don't want to replace them, make sure they seal tightly and have door sweeps at the bottom to prevent air leaks. Installing insulated storm doors provides an additional barrier to leaking air.

Window Ratings

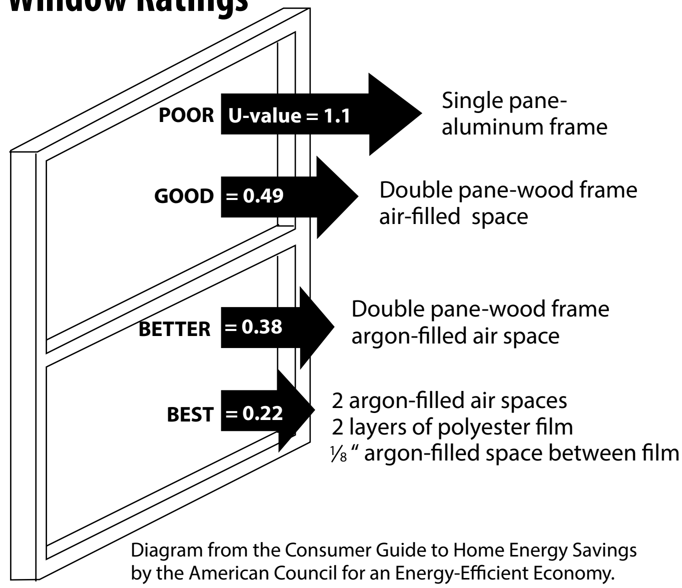
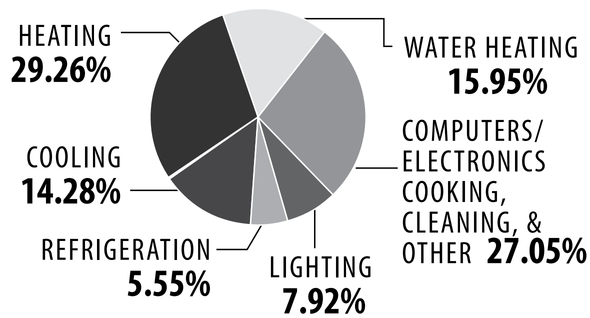


Diagram from the Consumer Guide to Home Energy Savings by the American Council for an Energy-Efficient Economy.

Home Energy Expenditures



Data: EIA 2015 RECS

Most homes have more windows than doors. Replacing older windows with energy efficient ones can significantly reduce air leaks and utility bills. The best windows shut tightly and are constructed of two or more pieces of glass separated by a gas that does not conduct heat well. The National Fenestration Rating Council has developed a rating factor for windows, called the **U-factor**, that indicates the insulating value of windows. The lower the U-factor, the better the window is at preventing heat flow through the window.

Windows, doors, and skylights are part of the government-backed **ENERGY STAR®** program that certifies energy efficient products. To meet ENERGY STAR® requirements, windows, doors, and skylights must meet requirements tailored for the country's three broad climate regions. Windows in the northern states must have a U-factor of 0.30 or less; in the central climate, a U-factor of 0.35 or less; and in the southern climate, a U-factor of 0.60 or less. They must also meet other criteria that measure the amount of solar energy that can pass through them.

Efficiency and Conservation

Appliance Energy Consumption

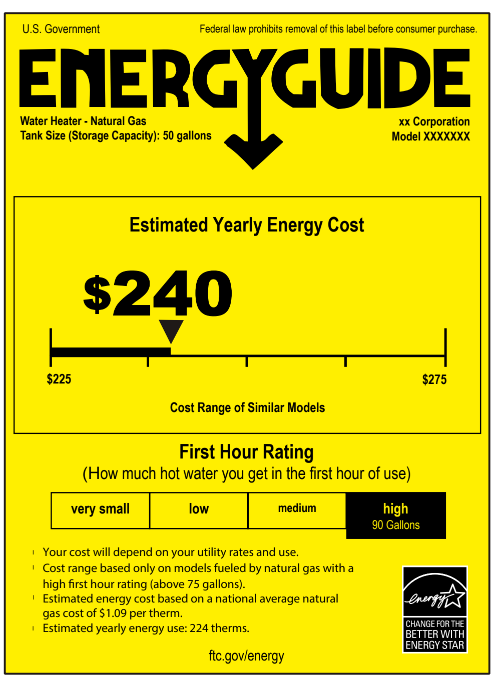
Appliance	Average annual expenditure	kWh/yr
Electric stove, oven or range	$31	241
Ceiling fan	$36	285
Clothes dryer	$98	776
Clothes washer	$8	59
Dishwasher	$15	113
Microwaves	$17	123
Refrigerator	$103	756
Second freezer	$69	537
TV and related components	$103	760

Data: EIA 2015 RECS
*Average yearly consumption data accounts for devices used in different modes, i.e. idle, charging, etc.

ENERGY STAR® Logo

Energy efficient products are labeled with the ENERGY STAR® logo. Appliances include the EnergyGuide label allowing for easy energy comparisons between products.

EnergyGuide Label


U.S. Government
Federal law prohibits removal of this label before consumer purchase.
ENERGYGUIDE
Water Heater - Natural Gas
Tank Size (Storage Capacity): 50 gallons
xx Corporation
Model XXXXXXX

Estimated Yearly Energy Cost
$240
$225 $275
Cost Range of Similar Models

First Hour Rating
(How much hot water you get in the first hour of use)

very small	low	medium	high 90 Gallons

- Your cost will depend on your utility rates and use.
- Cost range based only on models fueled by natural gas with a high first hour rating (above 75 gallons).
- Estimated energy cost based on a national average natural gas cost of $1.09 per therm.
- Estimated yearly energy use: 224 therms.

CHANGE FOR THE BETTER WITH ENERGY STAR
ftc.gov/energy

If you cannot replace older windows, there are several things you can do to make them more efficient. First, caulk any cracks around the windows and make sure they seal tightly. Add storm windows or sheets of clear plastic to create additional air barriers. You can also hang insulated drapes. During heating seasons, open them on sunny days and close them at night. During cooling seasons, close them during the day to keep out the sun.

▪ Landscaping

Although it isn't possible to control the weather, certain landscape practices can modify its impact on home environments. By strategically placing trees, shrubs, and other landscape structures to block the wind and provide shade, residents can reduce the energy needed to keep their homes comfortable during heating and cooling seasons. If the landscaping is well done, residents receive the additional benefits of beauty and increased real estate values. A well-planned landscape is one of the best investments a homeowner can make.

▪ Appliances

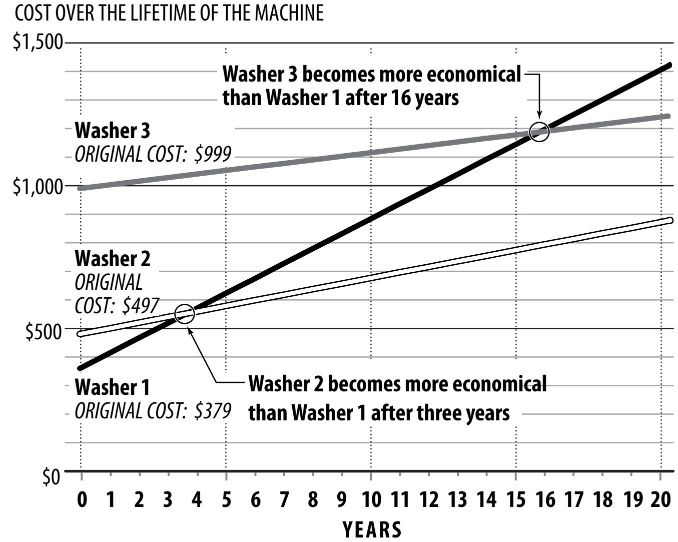
In 1987, Congress passed the National Appliance Energy Conservation Act. The Act required certain home **appliances** to meet minimum

Washing Machine Payback Period

Spending a little bit more money on an energy efficient appliance could save you several hundred dollars over the lifetime of the product. The payback period could be shorter than you think!

	WASHER 1	WASHER 2	WASHER 3
Original Cost	$379	$497	$999
Estimated Annual Electricity Use	427 kWh	160 kWh	102 kWh
Price of Electricity (per kWh)	$0.13	$0.13	$0.13
Operating Cost per Year	$55.51	$20.80	$13.26

COST OVER THE LIFETIME OF THE MACHINE



Data: NEED analysis of washing machine EnergyGuide labels 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. Appliances that contribute significantly to a typical household's energy consumption, are refrigerators, laundry machines, and cooking appliances.

When you shop for new appliances, you should think of two price tags. The first one covers the purchase price—consider it a down payment. The second price tag is the cost of operating the appliance during its lifetime. You'll be paying that second price tag on your utility bill every month for the next 10 to 20 years, depending on the appliance. Many energy efficient appliances have higher initial purchase costs, but they save significant amounts of money in lower energy costs. Over the life of an appliance, an energy efficient model is always a better deal.

When you shop for a new appliance, look for the ENERGY STAR® logo—your assurance that the product saves energy. ENERGY STAR® appliances have been identified by the Environmental Protection Agency and U.S. Department of Energy as the most energy efficient products in their classes. These appliances incorporate advanced technologies that use 10-50 percent less energy and water than standard models. A list of these appliances can be found on the ENERGY STAR® website at www.energystar.gov.

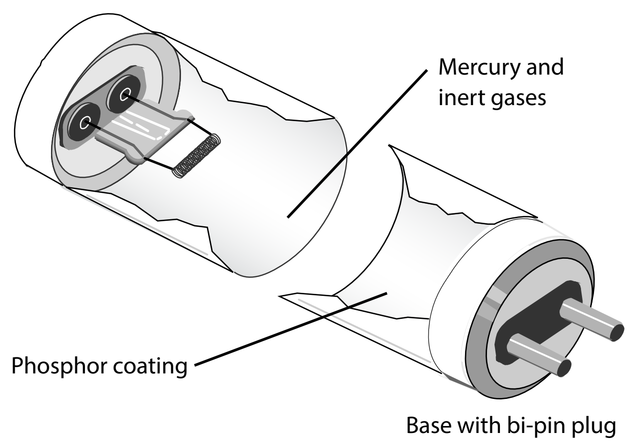
Another way to determine which appliance is more energy efficient is to compare energy usage using **EnergyGuide labels**. The Federal Government requires most appliances to display bright yellow and black EnergyGuide labels. Although these labels do not tell you which appliance is the most efficient, they will tell you the annual energy consumption and average operating cost of each appliance so you can compare them.

Refrigerators, for example, account for about five percent of household energy use. Replacing an older refrigerator with a new energy efficient model can save significantly on energy bills, as well as emissions. With older models, a large amount of electricity can be saved by setting the refrigerator temperature at 37 degrees, the freezer temperature at five degrees, and making sure that the energy saver switch is operational and in use.

Refrigerators should also be airtight. Make sure the gaskets around the doors are clean and seal tightly. Close the door on a piece of paper—if you can easily pull out the paper when the door is closed, you need to replace the gaskets.

LEDs offer better light quality than incandescent bulbs and halogens, last 25 times as long, and use even less energy than CFLs. LEDs now have a wide array of uses because technology has improved and costs have decreased.

Fluorescent Tube Lamp



In fluorescent tubes, a very small amount of mercury mixes with inert gases to conduct the electric current. This allows the phosphor coating on the glass tube to emit light.

▪ Lighting

In the typical home, lighting accounts for almost eight percent of the total energy bill. Much of this expense is unnecessary, caused by using inefficient incandescent light bulbs. Only 10 percent of the energy consumed by an incandescent bulb produces light; the remainder is given off as heat.

To help combat this waste, the Energy Independence and Security Act of 2007 changed the standards for the efficiency of light bulbs used most often. As of 2014, most general use bulbs needed to be 30 percent more efficient than traditional, inefficient incandescent bulbs.

What do the new standards mean for consumers? The purpose of the new efficiency standards is to give people the same amount of light using less energy. There are several lighting choices on the market that already meet the new efficiency standards.

Energy-saving incandescent, or halogen bulbs, are different than traditional, inefficient incandescent bulbs because they have a capsule around the filament (the wire inside the bulb) filled with halogen gas. This allows the bulbs to last three times longer and use 25 percent less energy.

Compact fluorescent light bulbs (CFLs) provide an equivalent amount of light as incandescents, but use up to 75 percent less energy and last ten times longer.

Light emitting diodes (LEDs) use even less energy than a CFL and last 25 times longer than traditional incandescent bulbs. This means life cycle emissions for an LED will be far fewer than any other type of bulb. LEDs have become the more affordable, efficient option for homes and businesses and are more durable than other bulb options. LEDs have many uses in the home and can be utilized in mainly technical applications.

Efficiency and Conservation

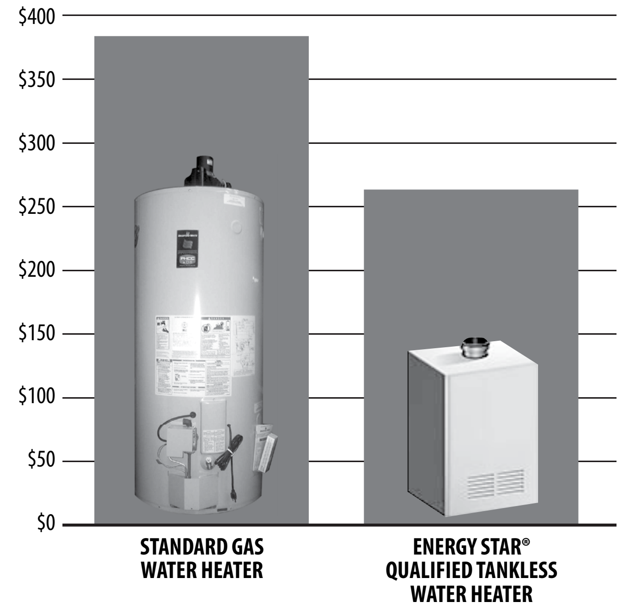
▪ Water Heating

Water heating is one of the largest energy expenses in your home after space heating and cooling appliances. It typically accounts for about 16 percent of your utility bill. Heated water is used for showers, baths, laundry, dishwashing, and general cleaning. There are four ways to cut your water heating bills—use less hot water, turn down the thermostat on your water heater, insulate your water heater and pipes, and buy a new, more efficient water heater.

One of the easiest and most practical ways to cut the cost of heating water is to simply reduce the amount of hot water used. In most cases, this can be done with little or no initial cost and only minor changes in lifestyle. A family of four uses roughly 260 gallons of water per day. You can lessen that amount simply by using low-flow, aerating showerheads and faucets. Other ways to conserve hot water include taking showers instead of baths, taking shorter showers, fixing leaks in faucets and pipes, and using the lowest temperature wash and rinse settings on clothes washers.

Most water heater thermostats are set much higher than necessary. Lowering the temperature setting on your water heater can save energy. A new, energy efficient tankless water heater can save $100 or more annually in water-heating costs. A solar water-heating system can save up to $250 a year.

Water Heater Comparison



Data: ENERGY STAR®

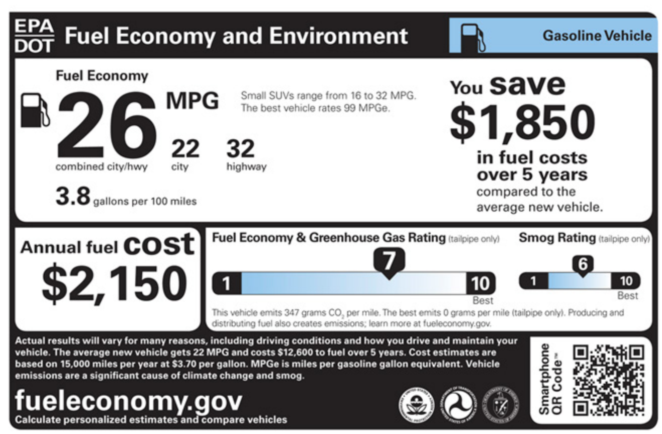
Transportation

Americans own about 15 percent of the world's automobiles. The transportation sector of the U.S. economy accounts for 28.13 percent of total energy consumption and 70.58 percent of petroleum consumption each year. America is a country on the move. We love the freedom provided by our vehicles. The average price of gasoline in 2018 was $2.71 per gallon and at the time of print was $2.16. If the average vehicle is driven 11,200 miles each year, with an average fuel efficiency of 27.3 miles per gallon, the average driver spent more than $900 per year per vehicle on gasoline. A person driving a small, fuel-efficient car will have spent as little as $800 per year, while a person driving a larger vehicle that is less efficient could spend $4,000 or more each year on fuel.

Most people must use a personal vehicle. The key is to use it wisely. When you are on the road, you can achieve 10 percent fuel savings by improving your driving habits and keeping your car properly maintained.

Improvements in the average fuel economy of new cars and light trucks from the mid-1970s through the mid-1980s were significant. The average fuel economy of cars almost doubled in that time period and for trucks it increased by more than 50 percent. These improvements were due mainly to the Corporate Average Fuel Economy (CAFE) standards enacted in 1975. The standards were met largely through cost-effective technologies such as engine efficiency improvements and weight reduction, not downsizing. The safety and environmental performance of new vehicles improved along with fuel efficiency during this period.

Fuel Economy Label



Label source: www.fueleconomy.gov

Today CAFE standards for brand new cars are set at over 40 miles per gallon. Standards for light trucks are slightly lower. Many manufacturers are meeting or exceeding these standards, but not all cars meet these standards. Manufacturers must pay a fine for each model that does not meet CAFE standards. The U.S. imports about 44 percent of the oil we use. Our dependence on foreign oil for gasoline will be greatly lessened by these standards.

When buying a vehicle, significant savings can be achieved by selecting a fuel-efficient model. All new cars must display a mileage performance label, or Fuel Economy Label, that lists estimated miles per gallon for both city and highway driving. Compare the fuel economy ratings of the vehicles you are considering and make efficiency a priority. Over the life of the vehicle, you can save thousands of dollars and improve air quality.

Industry

Manufacturing the goods we use every day consumes an enormous amount of energy. The industrial sector of the U.S. economy consumes a little less than one-third of the nation's total energy demand.

In the industrial sector, energy efficiency and conservation measures are not driven so much by consumers as by the market. Manufacturers know that they must keep their costs as low as possible to compete in the global economy.

Since energy is one of the biggest costs in many industries, manufacturers must use energy efficient technologies and conservation measures to be successful. Their demand for energy efficient equipment has driven much of the research and development of new technologies in the last decades as energy prices have fluctuated.

Individual consumers can, however, have an effect on industrial energy consumption through the product choices we make and what we do with the packaging and the products we no longer use.

A Consumer Society

Not only is America a consumer society, it is also a 'throw away' society. In 2017, the U.S. produced about 268 million tons of solid waste. The average citizen generates over 1,640 pounds of trash each year.

The most effective way for consumers to help reduce the amount of energy consumed by the industrial sector is to decrease the amount of unnecessary products produced and to reuse or repair items in their original form whenever possible. Purchasing only those items that are necessary, as well as reusing and recycling products wherever possible, can significantly reduce energy use in the industrial sector.

The four "Rs" of an energy-wise consumer are easy to put into practice. Reducing waste saves money, energy, and natural resources, and it helps protect the environment.

▪ Reduce

Buy only what you need. Purchasing fewer goods means less to throw away. It also results in fewer goods being produced and less energy being used in the manufacturing process. Buying goods with minimal packaging also reduces the amount of waste generated and the amount of energy used.

Fuel Economy

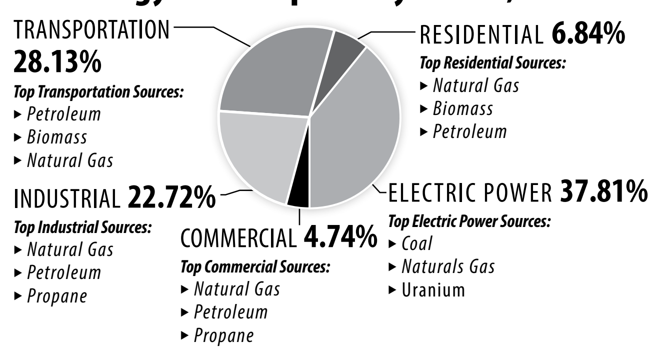
Follow these tips to increase fuel economy:

- Combine errands into one trip.
- Turn the engine off rather than letting it idle for more than a minute.
- Have your car serviced as described in the maintenance manual.
- Keep tires inflated to recommended pressures.
- Anticipate traffic stops.

These behaviors lower fuel economy:

- Quick acceleration.
- Traveling at high speeds. Traveling at more than 60 mph lowers fuel economy.
- Carrying unnecessary weight in the vehicle.
- Revving the engine.
- Operating the vehicle with the suspension out of alignment or with the wheels and tires out of balance.
- Using electrical accessories that require high amperage when they are not needed.

U.S. Energy Consumption by Sector, 2018

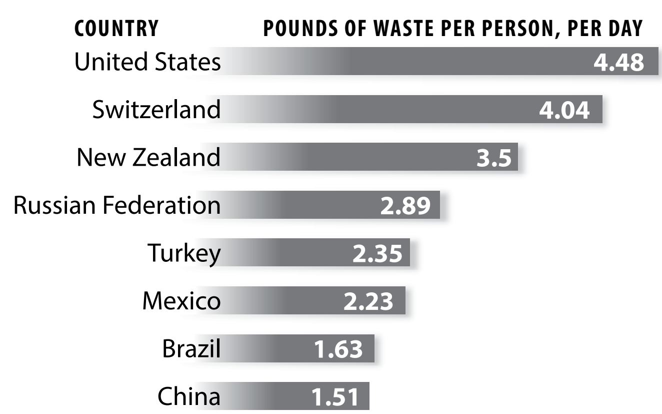


The residential, commercial, and industrial sectors use electricity. This graph depicts their energy source consumption outside of electricity.

Data: Energy Information Administration

*Total does not equal 100% due to independent rounding.

Waste Generation Around the World



Data: Organisation for Economic Co-operation and Development

Efficiency and Conservation

▪ Reuse

Buy products that can be used repeatedly. If you buy things that can be reused rather than disposable items that are used once and thrown away, you will save natural resources. You'll also save the energy used to make them, and reduce the amount of landfill space needed to contain the waste.

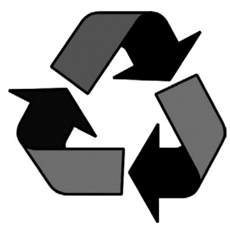
Savings also result when you buy things that are durable. They may cost more initially, but they last a long time and don't need to be replaced often, saving money and energy.

▪ Repair

Many people throw away products when they break and buy new ones. Many of these products could be easily and cheaply repaired. Always consider repairing a product before throwing it away. It saves energy, money, and natural resources.

▪ Recycle

Make it a priority to **recycle** all materials that you can. Using recycled material as the feedstock for manufacturing almost always consumes less energy than using virgin (raw) materials. Reprocessing used materials reduces energy needs for mining, refining, and many other manufacturing processes.



Recycling a pound of steel can save 1.25 pounds of iron ore. Recycling aluminum cans saves 95 percent of the energy required to produce aluminum from bauxite. Recycling paper cuts energy usage by 60 percent.

Energy Sustainability

Efficiency and conservation are key components of energy **sustainability**—the concept that every generation should meet its energy needs without compromising the needs of future generations.

Sustainability focuses on long-term energy strategies and policies that ensure adequate energy to meet today's needs as well as tomorrow's. Sustainability also includes investing in research and development of advanced technologies for producing conventional energy sources, promoting the use of new and renewable energy sources, and encouraging sound environmental policies and practices.

Energy sustainability focuses on long-term energy strategies and policies that ensure adequate energy to meet today's needs, as well as tomorrow's.

Glossary

a	**acid rain**	precipitation with a low pH; usually caused by man-made emissions that react with water molecules in the atmosphere
	active solar heating system	a solar water or space-heating system that moves heated air or water using pumps or fans
	alternating current (AC)	an electric current that reverses its direction at regular intervals or cycles; in the U.S. the standard is 120 reversals or 60 cycles per second; typically abbreviated as AC
	alternative fuel	a popular term for "non-conventional" transportation fuels made from natural gas (propane, compressed natural gas, methanol, etc.) or biomass materials (ethanol, methanol)
	alternative fuel vehicle (AFV)	a vehicle designed to operate on an alternative fuel (e.g., compressed natural gas, methane blend, electricity); the vehicle could be either a vehicle designed to operate exclusively on alternative fuel or a vehicle designed to operate on an alternative fuel and a traditional fuel
	ampere (A)	a unit of measure for an electric current; the amount of current that flows in a circuit at an electromotive force of one volt and at a resistance of one ohm; abbreviated as amp
	anemometer	a device used to measure wind speed
	appliance	a piece of equipment, commonly powered by electricity, used to perform a particular energy-driven function; examples of common appliances are refrigerators, clothes washers and dishwashers, conventional ranges/ovens and microwave ovens, humidifiers and dehumidifiers, toasters, radios, and televisions
	atom	a tiny unit of matter made up of protons and neutrons in a small dense core, or nucleus, with a cloud of electrons surrounding the core
b	**barrage**	a man-made dam or channel to capture and direct tidal waters
	baseload power	the minimum amount of electricity a utility must have available to its customers round-the-clock, using the most inexpensive sources
	battery	a device that stores chemical energy that can later be transformed into electrical energy
	bauxite	the ore that provides the principle source of aluminum
	biodiesel	an alternative fuel that can be made from any fat, grease, or vegetable oil; can be used in any diesel engine with few or no modifications; although biodiesel does not contain petroleum, it can be blended with diesel at any level or used in its pure form
	biofuels	liquid fuels and blending components produced from biomass (plant) feedstock, used primarily for transportation
	biogas	a gas produced by the breakdown of organic matter
	biogas digester	containers or pits to deposit biogenic waste that ferments and produces a methane-rich gas, which can then be harvested for electricity production
	binary cycle plant	type of power plant that transfers thermal energy from one reservoir to another to produce electricity
	biomass	any organic (plant or animal) material that is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants
	breeding	a process used at a specific reactor creating extra fissile material
	British thermal unit (Btu)	the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories; abbreviated as Btu
	bulk plant	a filling station for propane dealers
c	**capacity**	the amount of electric power a power plant can produce
	carbohydrate	an energy rich organic compound made of carbon, hydrogen, and oxygen
	carbon dioxide	a colorless, odorless, noncombustible gas with the formula CO_2 that is present in the atmosphere; it is formed by combustion and by respiration
	cellulose	an organic compound, typically the main component of plant cell walls, that is a long chain of sugar molecules

chain reaction	a self-sustaining nuclear reaction that takes place during fission; uranium absorbs a neutron and divides, releasing additional neutrons that are absorbed by other fissionable nuclei, releasing still more neutrons
chemical energy	energy stored in the chemical bonds of a substance and released during a chemical reaction such as burning wood, coal, or oil
circuit(s)	a conductor or a system of conductors through which electric current flows
climate change	a term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another
coal	a fossil fuel formed by the breakdown of plant material millions to hundreds of millions of years ago; four types exist, but energy production focuses on subbituminous and bituminous because of available amounts
cogeneration	the production of electrical energy and another form of useful energy (such as thermal energy) through the sequential use of energy
coke	residue from coal that can be used to create other metals
combustion	chemical oxidation accompanied by the generation of light and heat
commercial sector (of the economy)	the part of the economy having to do with the buying and selling of goods and services; the commercial sector is made up of merchants, businesses, etc.
compact fluorescent light bulb	a light bulb consisting of a gas-filled tube and an electronic ballast; electricity flows from the ballast through the gas, causing it to give off ultraviolet light; the ultraviolet light causes a white phosphor coating inside of the tube to emit visible light; a compact fluorescent light bulb uses less energy and transforms a smaller fraction of that energy into thermal energy than a comparable incandescent bulb
compressor	a machine used to increase the pressure of a gas
concentrated solar power	technologies that focus the energy from the sun onto one smaller area creating high temperatures that can produce electricity
conservation	reducing energy consumption
control rod	rods contained in the fuel assembly of a nuclear reactor that absorb neutrons and slow the reaction within the core
cooling tower	structure used at thermal power plants to remove heat from the plant and extract it into the surrounding atmosphere
core	the innermost layer of the Earth composed of both solid and liquid contents under extreme heat and pressure
crude oil	see *petroleum*
crust	the upper-most, brittle, thin layer of the Earth that is divided into moving plates

d

derrick	a frame tower that supports the drill equipment used to find oil and natural gas in the earth
developmental well	a well drilled in an area proven to produce oil and natural gas resources
diesel fuel	a fuel composed of distillates obtained in petroleum refining operation or blends of such distillates with residual oil used in motor vehicles; the boiling point and specific gravity are higher for diesel fuels than for gasoline
direct current (DC)	an electric current that flows in only one direction through a circuit, as from a battery; typically abbreviated as DC
dish/engine systems	a form of concentrated solar power that relies on solar dishes and an engine to generate power
distillation	process by which heat is added to a liquid to reach its boiling point and separate materials or impurities
distribution terminal	facility used by propane companies to store propane before shipping it to retailers
district energy system	a centralized system, usually for heating and cooling multiple buildings in close proximity
dopant	an element that is inserted into a substance to alter the conductivity or electrical properties
drilling rig	equipment used for drilling and producing oil from an on-shore well
dry steam plant	power plant that relies on steam produced from a geothermal reservoir, but uses very little water in liquid form

e	**EPA**	United States Environmental Protection Agency; a government agency tasked with regulating and protecting the environment
	efficiency	the ratio of useful energy delivered compared to energy supplied
	elastic energy	energy stored through the application of a force to stretch or compress an item
	electric current	the flow of charged particles like electrons through a circuit, usually measured in amperes
	electric power	see *power*; the part of the economy related to generation of electricity
	electrical energy	the energy associated with electric charges and their movements
	electricity	a form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change; electricity is electrons in motion
	electrolysis	the process of splitting a water molecule into its basic elements
	electromagnetic	having to do with magnetism produced by an electric current
	electron	a subatomic particle with a negative electric charge; electrons form part of an atom and move around its nucleus
	emission	a discharge or something that is given off; generally used in regard to discharges into the air or releases of gases into the atmosphere from some type of human activity (cooking, driving a car, etc.); in the context of global climate change, emissions consist of greenhouse gases (e.g., the release of carbon dioxide during fuel combustion)
	energy	the ability to do work, produce change, or move an object; electrical energy is usually measured in kilowatt-hours (kWh), while heat energy is usually measured in British thermal units (Btu)
	energy consumption	the use of energy as a source of heat or power or as a raw material input to a manufacturing process
	energy efficiency	the ratio of energy input to output; energy transformations have varying levels of efficiency, depending on the forms of energy involved; efficiency can be increased with the incorporation or substitution of equipment
	Energy Efficiency Ratio (EER)	rating used to help determine efficiency of appliances; see also *SEER*
	ENERGY STAR®	a program that tests and certifies products based on efficiency and features; labels help consumers save money
	EnergyGuide label	a label on an appliance that shows how much energy the appliance uses in comparison to similar appliances
	ethanol	a colorless liquid that burns to produce water and carbon dioxide; the vapor forms an explosive mixture with air and can be used as a fuel in internal combustion engines, usually blended with gasoline
	exploratory well	a well drilled by energy companies in an effort to locate a source of fuel, or geothermal activity
f	**F-gases**	synthetically sourced gases composed of bonded halogen and carbon atoms; these gases, also known as fluorinated gases, have a multitude of uses but can be harmful to the atmosphere
	Federal Energy Regulatory Commission (FERC)	the Federal Government agency that regulates and oversees energy industries in the economic, environmental, and safety interests of the American public
	feedstock	a raw material that can be used as a fuel or processed into a different fuel or product
	fermentation	the changing of a sugar into an acid, gas, or alcohol with the presence of bacteria or yeast
	filament	the fine metal wire in a light bulb that glows when heated by an electric current
	fish ladder	installations at dams that allow fish to travel upstream, over the dam, to spawn
	fission	the splitting of atomic nuclei; this splitting releases large amounts of energy and one or more neutrons; nuclear power plants split the nuclei of uranium atoms
	flash steam plants	electrical generation facilities where water explosively boils into steam to turn the turbine generator; usually these plants must have water under high pressure
	flow	in hydropower, the amount of water moving through the dam or system
	fossil fuels	fuels (coal, oil, natural gas, etc.) that result from the compression of ancient plant and animal life formed over hundreds of millions of years
	free electrons	electrons that are not held tightly to an atom and are likely to be donated
	fuel cell	a device used to generate electricity using hydrogen and oxygen, an electrolyte membrane, and catalysts

	fuel rods	sealed metal tubes consisting of ceramic fuel pellets, which are bundled into assemblies for use in nuclear reactors
	fumarole	an opening in the Earth's crust that emits steam and other gases; often near a volcano
	fusion	when the nuclei of atoms are combined or "fused" together; the sun combines the nuclei of hydrogen atoms into helium atoms in a process called fusion; energy from the nuclei of atoms, called "nuclear energy", is released from fusion
g	**gaseous diffusion plant**	plant used to produce enriched uranium; uranium hexafluoride is forced (as a gas) through membranes to separate and increase percentages of U-235
	gasket	a material used to make a joint or seal air or water tight
	gasoline	a complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines
	generator	a device that turns mechanical or motion energy into electrical energy; the motion energy is sometimes provided by an engine or turbine
	geoexchange unit	see *heat exchanger*
	geothermal energy	the heat energy that is produced by natural processes inside the Earth; it can be taken from hot springs, reservoirs of hot water deep below the ground, or by breaking open the rock itself
	gigawatt	unit of power used to measure large quantities of power; 10^9 watts
	global warming	an increase in the near surface temperature of the Earth; global warming has occurred in the distant past as the result of natural influences, but the term is most often used today to refer to the warming some scientists predict will occur as a result of increased man-made emissions of greenhouse gases
	gravitational potential energy	energy of position or place
	green pricing	consumers can voluntarily choose to pay a higher cost for electricity generated by renewable energy sources
	greenhouse effect	the trapping of heat from the sun by the atmosphere, due to the presence of certain gases; the atmosphere acts like a greenhouse
	greenhouse gases	gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect; the two major greenhouse gases are water vapor and carbon dioxide; lesser greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrogen oxides
	grid	the layout of an electrical distribution system
	gross domestic product (GDP)	the market value of goods and services produced by a country
h	**head**	the distance water drops from the top of the dam
	heat exchanger	any device that transfers heat from one fluid (liquid or gas) to another or to the environment
	heating value	gross heat content, or number of British thermal units (Btu) produced by the combustion of a volume of gas
	hybrid solar systems	a combination of passive and active solar systems
	hydrocarbon	an organic compound made entirely of hydrogen and carbon; hydrocarbons are found in crude oil, natural gas, and other fossil fuels
	hydrocarbon gas liquids (HGL)	mixtures of hydrogen and carbon molecules found within natural gas and petroleum; can be extracted from other hydrocarbons as a gas or, if pressurized, can be turned into a liquid
	hydroelectric power plant	a power plant that uses moving water to power a turbine generator to produce electricity
	hydrogen	a colorless, odorless, highly flammable gaseous element; it is the lightest of all gases and the most abundant element in the universe, occurring chiefly in combination with oxygen in water and also in acids, bases, alcohols, petroleum, and other hydrocarbons
	hydropower	energy that comes from moving water
i	**in situ leaching**	a mining process for uranium where the uranium has been dissolved in solution and is separated as a precipitate
	incandescent light bulb	a type of electric light in which light is produced by a filament heated by electric current
	industrial sector (of the economy)	the part of the economy having to do with the production of goods; the industrial sector is made up of factories, power plants, etc.

	insulation	a material or substance used to separate surfaces to prevent the transfer of electricity, thermal energy, or sound
	ions	atoms that have developed a positive or negative charge due to an imbalance in the number of protons and electrons
	isotope	an atom of an element with a differing number of neutrons and atomic mass, but similar chemical behavior
j	**jatropha**	genus of flowering plants, shrubs, and succulents
	jobbers	companies that handle wholesale distribution of oil and refined products to merchants, industries, and utilities
k	**kerosene**	a thick oil obtained from petroleum and used as a fuel and solvent
	kilowatt	a unit of power, usually used for electric power or energy consumption (use); a kilowatt equals 1,000 watts
	kilowatt-hour (kWh)	a measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour; one kWh is equivalent to 3,412 Btu
	kinetic energy	the energy of a body which results from its motion
l	**Law of Conservation of Energy**	the law governing energy transformations and thermodynamics; energy may not be created or destroyed, it simply changes form, and thus the sum of all energies in the system remains constant
	light emitting diode (LED)	energy saving light bulb that generates light through the use of a semiconductor
	liquefied natural gas (LNG)	natural gas that has been converted to a liquid by cooling it to temperatures below -260°C; when cooled to become LNG, natural gas' volume is reduced 600 times
	liquefied petroleum gas (LPG)	a group of hydrocarbon-based gases derived from crude oil refining or natural gas fractionation, including: ethane, ethylene, propane, propylene, butane, butylene, and others; for convenience of transportation, these gases are liquefied through pressurization
	load	the power and energy requirements of users on the electric power system in a certain area or the amount of power delivered to a certain point; the amount of power drawn by a device
	longwall mining	an automated form of underground coal mining with high recovery and extraction rates, possible only in relatively flat-lying, thick, and uniform coal beds; a high-powered cutting machine is passed across the exposed face of coal, shearing away broken coal, which is continuously hauled away by a floor-level conveyor system
	lumen	a unit of luminous flux used, for example, to measure the total amount of visible light emitted from a light bulb
m	**magma**	hot, liquid rock below the Earth's surface
	magnet	any piece of iron, steel, etc., that has the property of attracting iron or steel
	mantle	the largest, middle layer of the Earth, composed of rock and magma
	megawatt	a unit of electric power equal to 1,000 kilowatts or one million watts
	mercaptan	an organic chemical compound that has a sulfur-like odor that is added to natural gas and propane before distribution to the consumer, to give it a distinct, unpleasant odor (smells like rotten eggs); this serves as a safety device by allowing it to be detected in the atmosphere, in cases where leaks occur
	methane	a colorless, flammable, odorless hydrocarbon gas (CH_4), which is the major component of natural gas; it is also an important source of hydrogen in various industrial processes; methane is a greenhouse gas
	methane hydrates	layers of ocean sediment containing methane gas that has dissolved and been locked within water molecules that, due to pressure, have become crystalized
	miles per gallon (mpg)	a measure of vehicle fuel efficiency; mpg is computed as the ratio of the total number of miles traveled by a vehicle to the total number of gallons consumed
	molecule	a particle that normally consists of two or more atoms joined together; an example is a water molecule that is made up of two hydrogen atoms and one oxygen atom
	motion energy	the displacement of objects and substances from one place to another
n	**n-type silicon**	layer of silicon in a solar cell that has been doped with phosphorus to have a negative character and repel electrons

	natural gas	an odorless, colorless, tasteless, non-toxic, clean-burning fossil fuel; usually found in fossil fuel deposits and used as a fuel
	Newton's Laws of Motion	three physical laws that govern the force and motion interaction of all bodies, for example, the Law of Inertia
	nitrogen oxide (NO_X)	a greenhouse gas and pollutant produced during combustion
	nonrenewable	fuels that cannot be easily made or replenished; we can use up nonrenewable fuels; oil, natural gas, and coal are examples of nonrenewable fuels
	nuclear energy	energy stored in the nucleus of an atom that is released by the joining or splitting of the nuclei
	Nuclear Regulatory Commission (NRC)	a federal agency responsible for monitoring and licensing the construction and operation of nuclear generation facilities
	nucleus	the positively charged core of an atom; contains protons and neutrons
o	**offshore**	the geographic area that lies seaward of the coastline; in general, the coastline is the line of ordinary low water along with that portion of the coast that is in direct contact with the open sea or the line marking the seaward limit of inland water
	ohm (Ω)	the unit of resistance to the flow of an electric current
	Ohm's Law	a mathematical relationship between voltage (V), current (I), and resistance (R) in a circuit; Ohm's Law states the voltage across a load is equal to the current flowing through the load times the resistance of the load ($V = I \times R$)
	oil	a black, liquid fossil fuel found deep in the Earth; the raw material that petroleum products are made from; gasoline and most plastics are made from oil
	oil embargo	often referred to as a crisis, where members of an oil exporting country or group of countries halt commerce or trade of oil with another country or group of countries; embargoes result in high prices and shortages in the nations affected; the U.S. has been affected by embargoes and crises in the 1960s and 1970s
	OPEC	the Organization of Petroleum Exporting Countries organized for the purpose of negotiating with oil companies on matters of oil production, prices, and future concession rights
	OTEC	Ocean Thermal Energy Conversion, produces electricity using the temperature differential of ocean water at the surface and at greater depths
	outer continental shelf	offshore federal domain where deposits of oil and natural gas can be found
	overburden	soil, rock, and earth materials that are removed in order to mine for materials at the surface of the Earth
	ozone	also known as trioxygen, this unstable gas is created when chemicals from human activities in the atmosphere react with sunlight; an ozone layer, however, in the atmosphere protects plants and animals from ultraviolet light (UV) exposure
p	**p-n junction**	point of contact where wafers of doped silicon meet and form a barrier preventing electron movement in a solar cell
	p-type silicon	layer of silicon in a solar cell that has been doped with boron to have a positive character and attract electrons
	parabolic trough	a type of solar concentrator collector that has a linear parabolic shaped reflector that focuses the sun's radiation on a receiver at the focus of the reflector
	passive solar heating system	a means of capturing, storing, and using heat from the sun, without using specialized equipment
	payback period	the length of time a person must use a more expensive, energy efficient appliance before it begins to save money in excess of the initial cost difference
	peak demand	a period when many consumers want electricity at the same time; peak demand often takes place during the day, and may require additional generation by utilities to satisfy demand
	penstock	a large pipe that carries moving water from the reservoir to a turbine generator in a hydropower plant
	petroleum	generally refers to crude oil or the refined products obtained from the processing of crude oil (gasoline, diesel fuel, heating oil, etc.); petroleum also includes lease condensate, unfinished oils, and natural gas plant liquids
	photon	a particle of light that acts as an individual unit of energy

	photosynthesis	the process by which green plants make food (carbohydrates) from water and carbon dioxide, using the energy in sunlight
	photovoltaic cell	a device, usually made from silicon, which converts some of the energy from light (radiant energy) into electrical energy; another name for a solar cell
	pipeline	a series of pipes that convey petroleum and natural gas from a refinery to their end consumer
	porous	having tiny openings or spaces in a material that can hold fluid
	potential energy	the energy stored within a body, due to place or position
	power	the rate at which energy is transferred; electrical energy is usually measured in watts; also used for a measurement of capacity
	power plant	a facility where power is generated
	power pool	a group of electric utilities able to share power as needed
	propane	a normally gaseous, straight-chain hydrocarbon; it is a colorless paraffinic gas that boils at a temperature of -43.67 degrees Fahrenheit; it is extracted from natural gas or refinery gas streams
	pump stations	stations located along pipelines that monitor and control the movement of petroleum and natural gas products
	pumped storage system	a method of storing and producing electricity to supply high peak demands by moving water between reservoirs at different elevations
q	**quadrillion Btu (Q)**	one quadrillion (10^{15}) British thermal units (Btu), often referred to as a quad
r	**R-value**	a measure of a material's resistance to heat flow in units of Fahrenheit degrees x hours x square feet per Btu; the higher the R-value of a material, the greater its insulating capability
	radiant energy	any form of energy radiating from a source in electromagnetic waves
	radiation	any high-speed transmission of energy in the form of particles or electromagnetic waves
	radioactive decay	a natural process where atoms give up energy and particles become stable; radioactive waste from a power plant has not yet become stable and, thus, can be harmful
	reactor	part of a nuclear power station
	recycling	the process of converting materials that are no longer useful as designed or intended into a new product
	refinery	an industrial plant that heats crude oil (petroleum) so that it separates into chemical components, which are then made into more useful substances
	reliability	the ability of a utility provider to provide electricity to customers without disruption
	renewable	fuels that can be easily made or replenished; we can never use up renewable fuels; types of renewable fuels are hydropower (water), solar, wind, geothermal, and biomass
	repository	a site for storage
	reserves	natural resources that are technically and economically recoverable
	reservoir	natural or artificial storage facility
	residential sector (of the economy)	the part of the economy having to do with the places people stay or live; the residential sector is made up of homes, apartments, condominiums, etc.
	resistance (R)	a measure of the amount of energy per charge needed to move a charge through an electric circuit, usually measured in ohms
	Ring of Fire	a region of high geothermal activity in the Pacific Ocean, located along several plate boundaries
	rock-catcher	implement used to separate steam and rocks from a geothermal reservoir
	room-and-pillar mining	method of coal mining where coal is left behind in column formations to prevent the mine from collapsing
s	**scrubber**	air pollution control device that power plants use to remove particulate matter and gases from their emissions
	Seasonal Energy Efficiency Ratio (SEER)	rating system used to compare efficiency of heat pumps and cooling systems (see also *EER*)
	secondary source of energy	also known as energy carriers, these sources require another source of energy to be created; electricity is an example of a secondary source of energy

	sedimentary	a type of rock formed by deposits of earth materials, or within bodies of water; oil and gas formations, as well as fossils are found within sedimentary rock formations; coal is a sedimentary rock
	semiconductor	any material that has a limited capacity for conducting an electric current; semiconductors are crystalline solids, such as silicon, that have an electrical conductivity between that of a conductor and an insulator
	smart meters	digital two-way electric meters that allow for communication between the meter (consumer) and the utility
	smelting	producing a metal from its ore, separating the metallic parts of an ore
	solar cell	an electric cell that changes radiant energy from the sun into electrical energy by the photovoltaic process
	solar energy	the radiant energy of the sun, which can be converted into other forms of energy, such as thermal energy or electricity
	solar power tower	the conceptual method of producing electrical energy from solar rays; involves the focusing of a large number of solar rays on a single source (boiler), usually located on an elevated tower, to produce high temperatures; a fluid located in or passed through the source changes into steam and is used in a turbine generator to produce electrical energy
	sound energy	energy that travels in longitudinal waves
	space heating	the heating of an area for comfort
	spent fuel	irradiated fuel that is permanently discharged from a nuclear reactor
	spillway gate	a gate or apparatus at a dam that helps to control the water level of a reservoir; gates release excess water following heavy rainfall
	steam generator	a generator in which the prime movers (turbines) are powered by steam
	steam reforming	a process to create hydrogen through the heating of a fuel (typically fossil fuels)
	superconductivity	having little to almost no electrical resistance
	surface mining	takes place within a few hundred feet of the surface; earth above or around the coal (overburden) is removed to expose the coal bed, which is then mined with surface excavation equipment
	sustainable	describing a behavior or practice that is capable of being continued with minimal effects on the environment
t	**tank farm**	an installation used by trunk and gathering pipeline companies, crude oil producers, and terminal operators (except refineries) to store crude oil
	thermal energy	the total potential and kinetic energy associated with the random motions of the atoms and molecules of a material; the more the molecules move and vibrate the more energy they possess
	thermostat	a device that adjusts the amount of heating and cooling produced and/or distributed by automatically responding to the temperature in the environment
	tide	rising and falling of sea level due to the gravitational force of the moon and sun, as well as the rotation of the Earth
	transformer	a device that converts the generator's low-voltage electricity to higher-voltage levels for transmission to the load center, such as a city or factory
	transmission line	a set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points
	transmutation	changing one element into another; can be accomplished through fusion
	transportation sector (of the economy)	the part of the economy having to do with how people and goods are transported (moved) from place to place; the transportation sector is made up of automobiles, airplanes, trucks, ships, trains, etc.
	turbine	a device with blades, which is turned by a force, such as that of wind, water, or high pressure steam; the mechanical (motion) energy of the spinning turbine is converted into electricity by a generator
u	**U-factor**	indicator of insulative capacity for windows

	underground (deep) mining	coal mining that takes place several hundred feet below the surface of the Earth; workers and coal enter and exit through a vertical shaft; see *longwall mining* or *room-and-pillar mining*
	uranium	a heavy, naturally-occurring, radioactive element of which isotopes can be used for nuclear fission
	uranium fuel cycle	the series of steps involved in supplying fuel for nuclear power reactors; it includes mining, refining, the making of fuel elements, their use in a reactor, chemical processing to recover spent (used) fuel, re-enrichment of the fuel material, and remaking into new fuel elements
V	**volt (V)**	the International System of Units (SI) measure of electric potential or electromotive force; a potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance; reduced to SI base units, 1 V = 1 kg times m2 times s-3 times A-1 (kilogram meter squared per second cubed per ampere) 1 kgm^2/s^3A
	voltage	the difference in electric potential between any two conductors or between a conductor and the ground; it is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors
W	**waste-to-energy plant**	a power plant that generates electricity by burning garbage
	water cycle	water constantly moves through a vast global cycle, in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, then flows back to the ocean; the energy of this water cycle, which is driven by the sun, is tapped most efficiently with hydropower
	watt (W)	a metric unit of power, usually used in electric measurements, which gives the rate at which work is done or energy is used
	well	a hole drilled in the Earth for the purpose of finding or producing crude oil or natural gas, or producing services related to the production of crude oil or natural gas
	wind	the term given to any natural movement of air in the atmosphere; a renewable source of energy used to turn turbines to generate electricity
	wind farm	a series or group of wind turbines in the same location
	wind turbine	device powered by the wind that produces mechanical (motion) or electric power
Y	**yellowcake**	a natural uranium concentrate that takes its name from its color and texture; yellowcake typically contains 70 to 90 percent U_3O_8 (uranium oxide) by weight; used as feedstock for uranium fuel enrichment and fuel pellet fabrication

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