2012-2013

Intermediate Energy Infobook

Fact sheets about energy, the major energy sources, electricity, energy consumption, and energy efficiency and conservation.

ENERGY SOURCES

E
GENERAL ENERGY

Grade Level:
- Intermediate

Subject Areas:
- Science
- Social Studies
- Math
- Language Arts
- Technology

NEED
National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Teacher Advisory Board Statement

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Energy Data Used in NEED Materials

NEED believes in providing the most recently reported energy data available to our teachers and students. Most statistics and data are derived from the U.S. Energy Information Administration's Annual Energy Review that is published in June of each year. Working in partnership with EIA, NEED includes easy to understand data in our curriculum materials. To do further research, visit the EIA web site at www.eia.gov. EIA's Energy Kids site has great lessons and activities for students at www.eia.gov/kids.

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National Energy
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Intermediate Energy Infobook

INTRODUCTORY ACTIVITIES	Energy Games and Icebreakers Energy Polls (Blueprint for Success)
STEP ONE: Science of Energy	EnergyWorks Intermediate Energy Infobook Science of Energy
STEP TWO: Sources of Energy	Energy Enigma Energy Expos Energy From the Sun Energy From the Wind Energy From Uranium Energy of Moving Water Exploring Oil and Gas Great Energy Debate H_2 Educate Intermediate Energy Infobook
STEP THREE: Electricity and Magnetism	ElectroWorks Intermediate Energy Infobook Smart Meters
STEP FOUR: Transportation	Energy Expos Exploring Hybrid Buses H_2 Educate Transportation Fuels Infobook
STEP FIVE: Efficiency and Conservation	Building Science Energy Conservation Contract Energy Expos Intermediate Energy Infobook Monitoring and Mentoring Plug Loads Saving Energy at Home and School Understanding Climate Change
STEP SIX: Synthesis and Reinforcement	Energy Carnival Energy Games and Icebreakers Energy on Stage
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NEED Curriculum Resources

For more in-depth information, inquiry investigations, and engaging activities, download these curriculum resources from www.NEED.org.

Correlations to National Science Education Standards: Grades 6-8

This book has been correlated to National Science Education Content Standards.

For correlations to individual state standards, visit **www.NEED.org**.

Content Standard B | *PHYSICAL SCIENCE*

- **Transfer of Energy**
  - Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
  - Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.
  - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.
  - In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.
  - The sun is a major source of energy for changes on the Earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the Earth, transferring energy from the sun to the Earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Content Standard C | *LIFE SCIENCE*

- **Populations and Ecosystems**
  - For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.

Content Standard D | *EARTH AND SPACE SCIENCE*

- **Structure of the Earth System**
  - The solid Earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.
  - Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.
  - Water, which covers the majority of Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the Earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
  - The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
  - Clouds, formed by the condensation of water vapor, affect weather and climate.
  - Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.
- **Earth in the Solar System**
  - The sun is the major source of energy for phenomena on the Earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the Earth's rotation on its axis and the length of the day.

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings about Science and Technology**
  - Many different people in different cultures have made and continue to make contributions to science and technology.
  - Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Correlations to National Science Education Standards: Grades 6-8

This book has been correlated to National Science Education Content Standards.

For correlations to individual state standards, visit **www.NEED.org**.

Content Standard F | *SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES*

- **Personal Health**
  - Food provides energy and nutrients for growth and development. Nutrition requirements vary with body weight, age, sex, activity, and body functioning.
  - Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air.

- **Populations, Resources, and Environments**
  - When an area becomes overpopulated the environment will become degraded due to the increased use of resources.
  - Causes of environmental degradation and resource depletion vary from region to region and from country to country.

- **Natural Hazards**
  - Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.

- **Risks and Benefits**
  - Individuals can use a systematic approach to thinking critically about risks and benefits. Examples include applying probability estimates to risks and comparing them to estimated personal and social benefits.
  - Important personal and social decisions are made based on perceptions of benefits and risks.

- **Science and Technology in Society**
  - Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental.
  - Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
  - Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.
  - Science and technology have advanced through contributions of many different people, in different cultures, at different times in history. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.
  - Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.
  - Scientists and engineers have ethical codes requiring that human subjects involved with research be fully informed about the risks and benefits associated with the research before the individuals choose to participate. This ethic extends to potential risks to communities and property. In short, prior knowledge and consent are required for research involving human subjects or potential damage to property.
  - Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should understand the difference between scientific and other questions. They should appreciate what science and technology can reasonably contribute to society and what they cannot do. For example, new technologies often will decrease some risks and increase others.

Content Standard G | *HISTORY AND NATURE OF SCIENCE*

- **Science as a Human Endeavor**
  - Science requires different abilities, depending on such factors as the field of study and the type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

- **History of Science**
  - Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.
  - In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.

Introduction to Energy

What is Energy?

Energy makes change; it does things for us. It moves cars along the road and boats over the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs on the radio and lights our homes. Energy makes our bodies grow and allows our minds to think. Scientists define energy as the ability to do work.

Forms of Energy

Energy is found in different forms, such as light, heat, sound, and motion. There are many forms of energy, but they can all be put into two categories: potential and kinetic.

POTENTIAL ENERGY

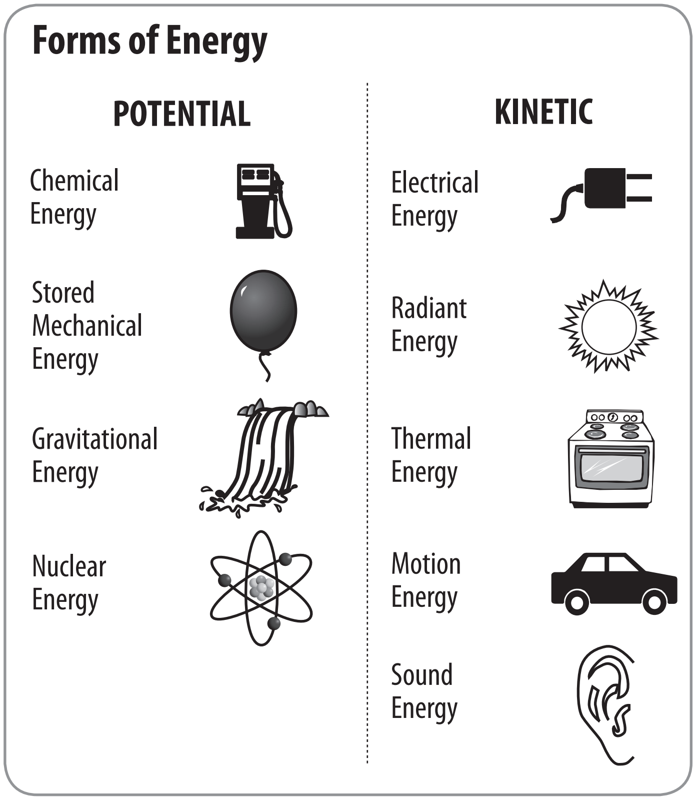
Potential energy is stored energy and the energy of position, or gravitational energy. There are several forms of potential energy.

- **Chemical energy** is energy stored in the bonds of atoms and molecules. It is the energy that holds these particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.
- **Stored mechanical energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.
- **Nuclear energy** is energy stored in the nucleus of an atom; it is the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms in a process called **fusion**.
- **Gravitational energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

KINETIC ENERGY

Kinetic energy is motion; it is the motion of waves, electrons, atoms, molecules, substances, and objects.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrons moving through a wire is called circuit electricity. Lightning is another example of electrical energy.
- **Radiant energy** is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. Solar energy is an example of radiant energy.
- **Thermal energy**, or heat, is the internal energy in substances; it is the vibration and movement of the atoms and molecules within substances. The more thermal energy in a substance, the faster the atoms and molecules vibrate and move. Geothermal energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. Objects and substances move when a force is applied according to **Newton's Laws of Motion**. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate; the energy is transferred through the substance in a longitudinal wave.



Forms of Energy

POTENTIAL	KINETIC
Chemical Energy	Electrical Energy
Stored Mechanical Energy	Radiant Energy
Gravitational Energy	Thermal Energy
Nuclear Energy	Motion Energy
	Sound Energy

Conservation of Energy

To scientists, **conservation of energy** is not saving energy. The law of conservation of energy says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We change it from one form of energy into another.

A car engine burns gasoline, converting the chemical energy in gasoline into motion energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

Efficiency

Efficiency is the amount of useful energy you get from a system. A perfect, energy efficient machine would change all the energy put in it into useful work—a technological impossibility today. Converting one form of energy into another form always involves a loss of usable energy.

Most energy transformations are not very efficient. The human body is a good example. Your body is like a machine, and the fuel for your machine is food. Food gives you the energy to move, breathe, and think.

Your body isn't very efficient at converting food into useful work. Your body's overall efficiency is about 15 percent most of the time. The rest of the energy is transformed into heat. You can really feel that heat when you exercise!

Sources of Energy

We use many different energy sources to do work for us. They are classified into two groups—renewable and nonrenewable.

In the United States, most of our energy comes from **nonrenewable** energy sources. Coal, petroleum, natural gas, propane, and uranium are nonrenewable energy sources. They are used to make electricity, heat our homes, move our cars, and manufacture all kinds of products. These energy sources are called nonrenewable because their supplies are limited. Petroleum, for example, was formed millions of years ago from the remains of ancient sea plants and animals. We can't make more crude oil deposits in a short time.

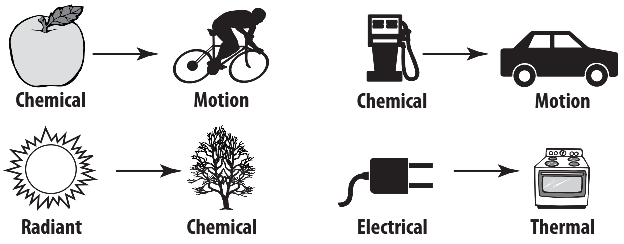
Renewable energy sources include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable because they are replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity.

Electricity

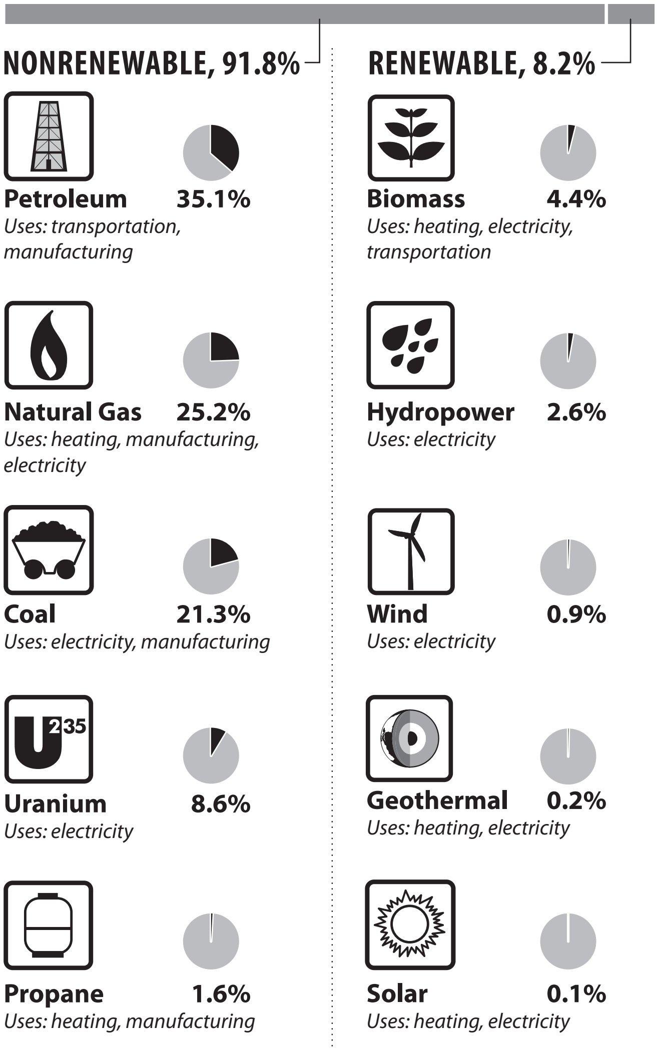
Electricity is different from the other energy sources because it is a secondary source of energy. We must use another energy source to produce electricity. In the U.S., coal is the number one energy source used for generating electricity.

Electricity is sometimes called an **energy carrier** because it is an efficient and safe way to move energy from one place to another, and it can be used for so many tasks. As we use more technology, the demand for electricity grows.

Energy Transformations



U.S. Energy Consumption by Source, 2010



NONRENEWABLE, 91.8%

Petroleum **35.1%**
Uses: transportation, manufacturing

Natural Gas **25.2%**
Uses: heating, manufacturing, electricity

Coal **21.3%**
Uses: electricity, manufacturing

Uranium **8.6%**
Uses: electricity

Propane **1.6%**
Uses: heating, manufacturing

RENEWABLE, 8.2%

Biomass **4.4%**
Uses: heating, electricity, transportation

Hydropower **2.6%**
Uses: electricity

Wind **0.9%**
Uses: electricity

Geothermal **0.2%**
Uses: heating, electricity

Solar **0.1%**
Uses: heating, electricity

Data: Energy Information Administration

Biomass

What is Biomass?

Biomass is any **organic matter** (anything that was once alive) that can be used as an energy source. Wood, crops, and yard and animal waste are examples of biomass. People have used biomass longer than any other energy source. For thousands of years, people have burned wood to heat their homes and cook their food.

Biomass gets its energy from the sun. Plants absorb sunlight in a process called **photosynthesis**. With sunlight, air, water, and nutrients from the soil, plants make sugars called carbohydrates. Foods that are rich in carbohydrates (like spaghetti) are good sources of energy for the human body. Biomass is called a **renewable** energy source because we can grow more in a short period of time.

Use of Biomass

Until the mid-1800s, wood gave Americans 90 percent of the energy they used. Today, biomass provides us over four percent of the energy we use. It has been replaced by coal, natural gas, petroleum, and other energy sources.

Today, most of the biomass energy we use comes from wood. It accounts for almost half of biomass consumption. Other biomass sources include biofuels (alcohol fuels), crops, garbage, and landfill gas.

Industry is the biggest biomass consumer today; it uses 51.9 percent of biomass to make products. The transportation sector uses 25.6 percent of biomass to make **ethanol** and other biofuels. Power companies use biomass to produce electricity. Over 10 percent of biomass is used to generate electricity today.

Homes and businesses are the third biggest users; about one in ten homes burn wood in fireplaces and stoves for additional heat. About two percent use wood as their main heating fuel.

In the future, trees and other plants may be grown to fuel power plants. Farmers may also have huge farms of energy crops to produce ethanol and other biofuels for transportation.

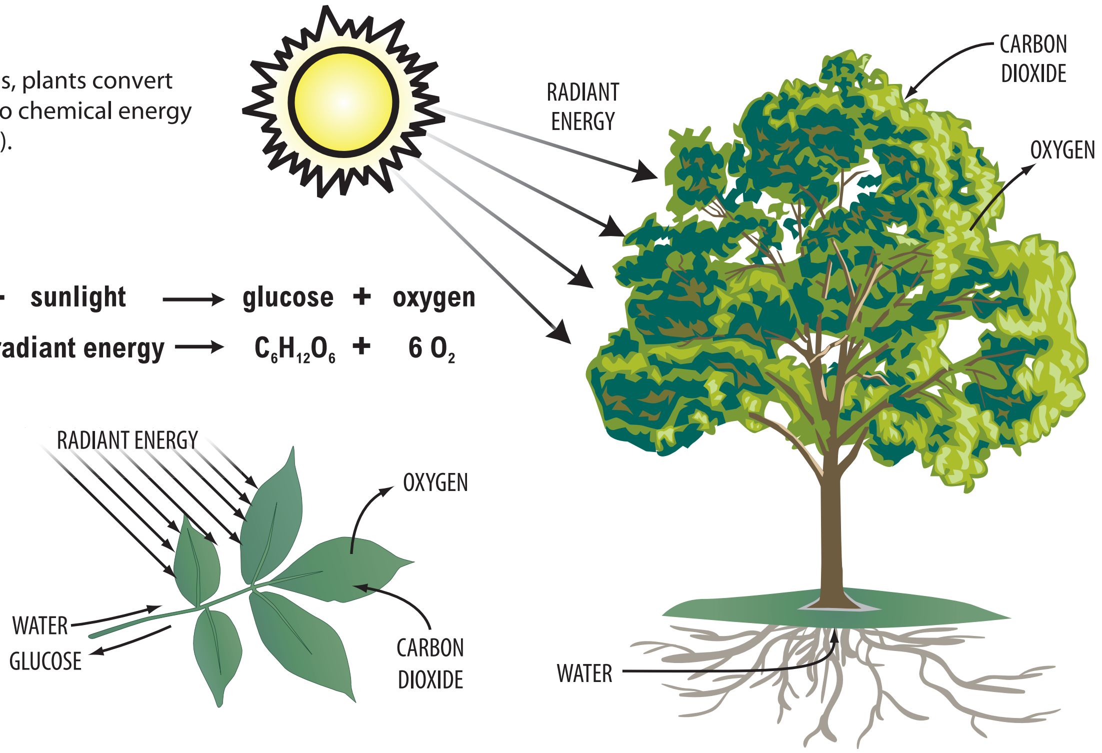
Biomass and the Environment

Biomass can pollute the air when it is burned, though not as much as fossil fuels. Burning biomass fuels does not produce pollutants like sulfur, which can cause acid rain.

Growing plants for biomass fuel may reduce greenhouse gases, since plants use carbon dioxide and produce oxygen as they grow. Carbon dioxide is considered an important greenhouse gas.

Photosynthesis

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



water + carbon dioxide + sunlight → glucose + oxygen

$$6\,H_2O + 6\,CO_2 + \text{radiant energy} \rightarrow C_6H_{12}O_6 + 6\,O_2$$

Source: Energy Information Administration

Using Biomass Energy

A log does not give off energy unless you do something to it. Usually, wood is burned to make heat. Burning is not the only way to use biomass energy, though. There are four ways to release the energy stored in biomass: burning, bacterial decay, **fermentation**, and conversion to gas/liquid fuel.

▪ Burning

Wood was the biggest energy provider in the United States and the rest of the world until the mid-1800s. Wood heated homes and fueled factories. Today, wood supplies only a little of our country's energy needs. Wood is not the only biomass that can be burned. Wood shavings, fruit pits, manure, and corn cobs can all be burned for energy.

Garbage is another source of biomass. Garbage can be burned to generate steam and electricity. Power plants that burn garbage and other waste for energy are called **waste-to-energy plants**. These plants are a lot like coal-fired plants. The difference is the fuel. Garbage doesn't contain as much heat energy as coal. It takes about 2,000 pounds of garbage to equal the heat energy in 500 pounds of coal.

Sometimes, fast-growing crops like sugar cane are grown especially for their energy value. Scientists are also researching ways to grow aquatic plants like seaweed to use for their energy value.

▪ Bacterial Decay

Bacteria feed on dead plants and animals. As the plants and animals decay, they produce a colorless, odorless gas called **methane**. Methane gas is rich in energy. Methane is the main ingredient in natural gas, the gas we use in our furnaces and stoves. Methane is a good energy source. We can burn it to produce heat or to generate electricity.

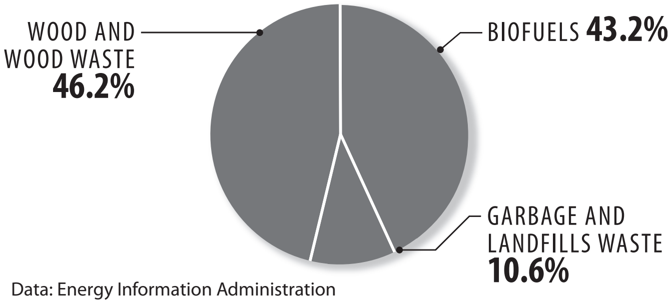
In some landfills, wells are drilled into the piles of garbage to capture methane produced from the decaying waste. The methane can be purified and used as an energy source, just like natural gas.

▪ Fermentation

We can add yeast (a fungus) to biomass to produce an alcohol called **ethanol**. For centuries, people have fermented crops to make alcoholic drinks like beer and wine. Wine is fermented from grapes. Wheat, corn, and many other crops can be used to make ethanol.

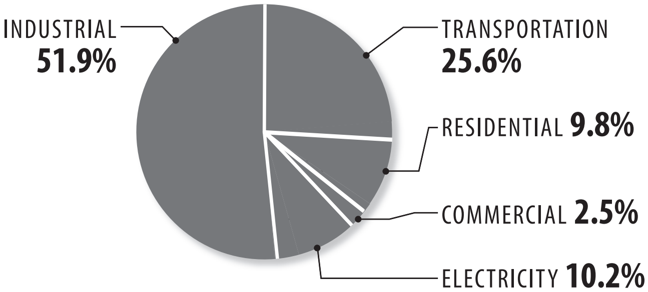
Ethanol is sometimes made from corn to produce a motor fuel. Automobile pioneer Henry Ford wanted to use ethanol to power his cars instead of gasoline. Ethanol is more expensive to use than gasoline. Usually, it is mixed with gasoline to produce a fuel called **E-10**, which is 90 percent gasoline and 10 percent ethanol. For cars to run on ethanol, their engines would have to be changed. But cars can run on E-10 without changes. Adding ethanol to gasoline lowers carbon dioxide emissions.

U.S. Sources of Biomass, 2010



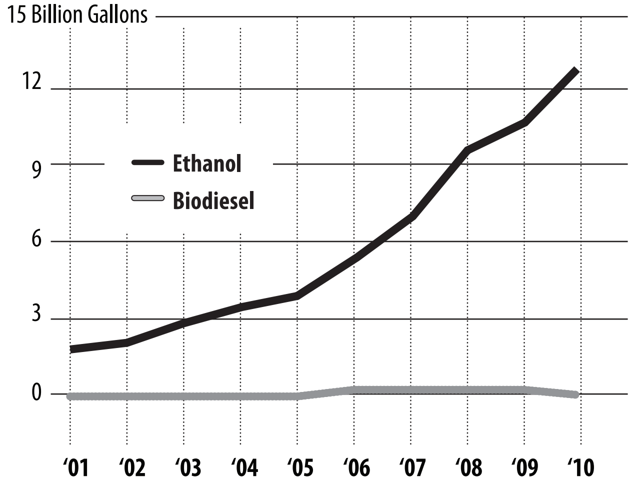
Data: Energy Information Administration

U.S. Biomass Consumption by Sector, 2010



Data: Energy Information Administration

U.S. Consumption of Biofuels, 2001-2010



Data: Energy Information Administration

▪ Conversion

Conversion means changing a material into something else. Today, we can convert biomass into gas and liquid fuels. We do this by adding heat or chemicals to the biomass. The gas and liquid fuels can then be burned to produce heat or electricity, or it can be used as a fuel for automobiles. In India, cow manure is converted to methane gas to provide heat and light.

Coal

What is Coal?

Coal is a **fossil fuel** formed from the remains of plants that lived and died millions of years ago, when parts of the Earth were covered with huge swampy forests. Coal is called a **nonrenewable** energy source because it takes millions of years to form.

The energy we get from coal today came from the energy that plants absorbed from the sun millions of years ago. All living plants store energy from the sun. After the plants die, this energy is usually released as the plants decay. Under certain conditions, however, the decay is interrupted, preventing the release of the stored solar energy.

Millions of years ago, plants that fell to the bottom of the swamp began to decay as layers of dirt and water were piled on top. Heat and pressure from these layers caused a chemical change to occur, eventually creating coal over time.

History of Coal in America

Native Americans used coal long before the first settlers arrived in the New World. Hopi Indians used coal to bake the pottery they made from clay.

European settlers discovered coal in North America during the first half of the 1600s. They used very little coal at first. Instead, they relied on water wheels and burning wood to power colonial industries.

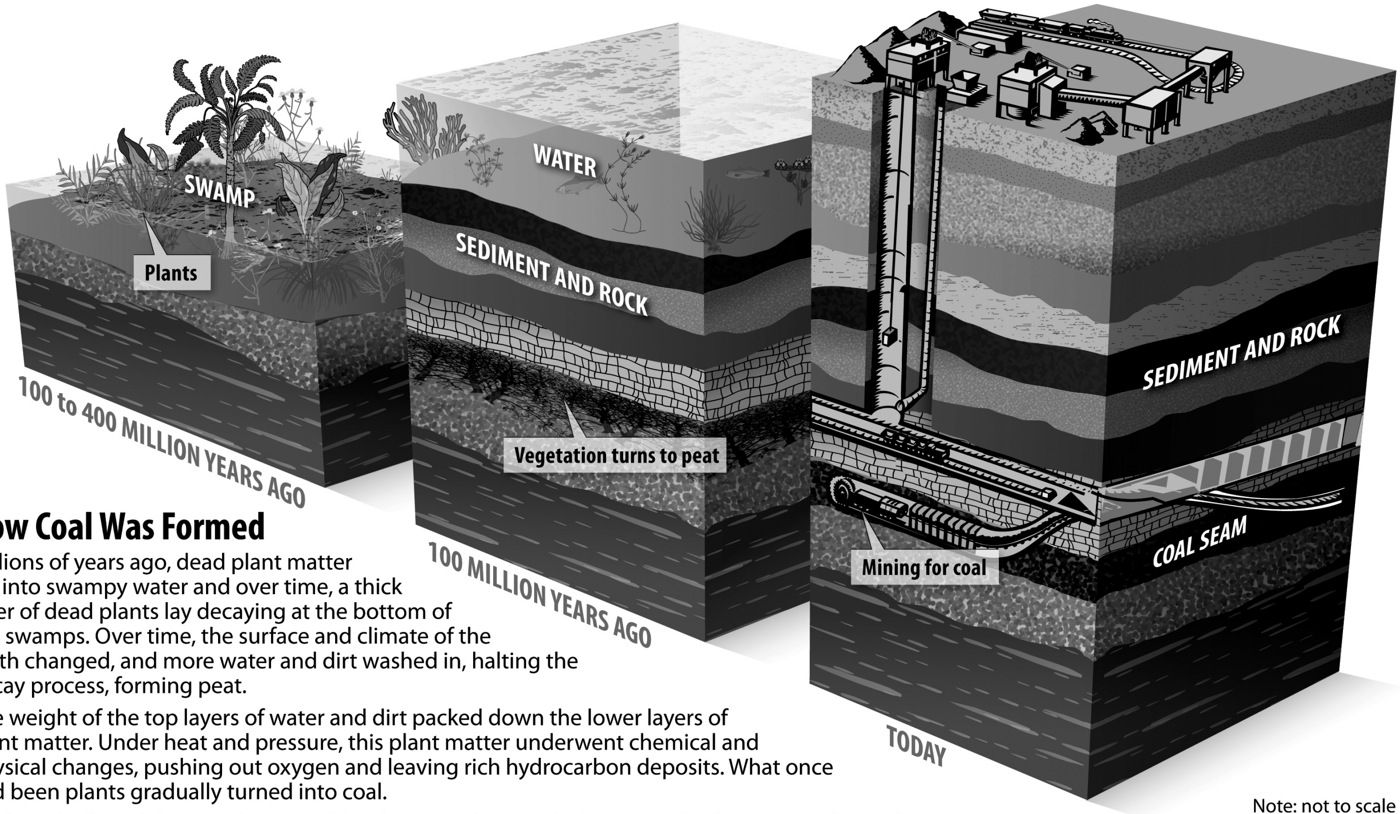
Coal became a powerhouse by the 1800s. People used coal to manufacture goods and to power steamships and railroad engines. By the time of the American Civil War, people also used coal to make iron and steel. And by the end of the 1800s, people began using coal to make electricity.

Today, coal provides one-fifth (21.3 percent) of America's energy needs. Almost half of our electricity comes from coal-fired plants.

Coal Mining

Coal companies use two methods to mine coal: surface mining and underground mining.

Surface mining is used to extract about two-thirds of the coal in the United States. Surface mining can be used when the coal is buried less than 200 feet underground. In surface mining, the topsoil and layers of rock are removed to expose large deposits of coal. The coal is then removed by huge machines. Once the mining is finished, the



How Coal Was Formed

Millions of years ago, dead plant matter fell into swampy water and over time, a thick layer of dead plants lay decaying at the bottom of the swamps. Over time, the surface and climate of the Earth changed, and more water and dirt washed in, halting the decay process, forming peat.

The weight of the top layers of water and dirt packed down the lower layers of plant matter. Under heat and pressure, this plant matter underwent chemical and physical changes, pushing out oxygen and leaving rich hydrocarbon deposits. What once had been plants gradually turned into coal.

Coal can be found deep underground (as shown in this graphic), or it can be found near the surface.

mined area is **reclaimed**. The dirt and rock are returned to the pit, the topsoil is replaced, and the area is seeded. The land can then be used for croplands, wildlife habitats, recreation, or offices and stores.

Deep or **underground mining** is used when the coal is buried deep within the Earth. Some underground mines are 1,000 feet deep! To remove coal from underground mines, miners are transported down mine shafts to run machines that dig out the coal.

Processing and Transporting Coal

After coal comes out of the ground, it goes to a **preparation plant** for cleaning. The plant removes rock, ash, sulfur, and other impurities from the coal. Cleaning improves the heating value of coal.

After cleaning, the coal is ready to be shipped to market. Trains are used to transport most coal. Sometimes, river barges and trucks are used to ship coal. In one place, coal is crushed, mixed with water, and shipped through a pipeline. Deciding how to ship coal is very important because it can cost more to ship it than to mine it.

Coal Reserves and Production

Coal reserves are beds of coal still in the ground that can be mined. The United States has the world's largest known coal reserves.

Depending on consumption rates, the U.S. has enough coal to last for 120 to 250 years.

Coal production is the amount of coal that is mined and sent to market. Coal is mined in 25 states. Wyoming mines the most, followed by West Virginia, Kentucky, Pennsylvania, and Montana.

How Coal is Used

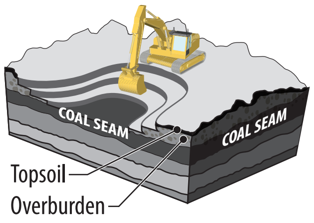
Almost 92 percent of the coal mined in the U.S. today is used to make electricity. The steel and iron industries use coal for smelting metals. Other industries use coal, too. Paper, brick, limestone, and cement industries all use coal to make products. Very little coal is used for heating homes and buildings.

Coal and the Environment

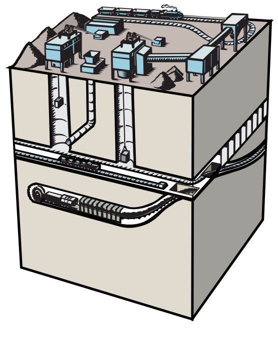
Burning coal produces emissions that can pollute the air. It also produces carbon dioxide, a greenhouse gas. When coal is burned, a chemical called sulfur may also be released. Sulfur mixes with oxygen to form sulfur dioxide, a chemical that can affect trees and water when it combines with moisture to produce **acid rain.**

Coal companies look for low-sulfur coal to mine. They work hard to remove sulfur and other impurities from the coal. Power plants are installing machines called **scrubbers** to remove most of the sulfur from coal smoke so it doesn't get into the air. Other by-products, like the ash that is left after coal is burned, once were sent to landfills. Now they are being used to build roads, make cement, and make ocean reefs for animal habitats.

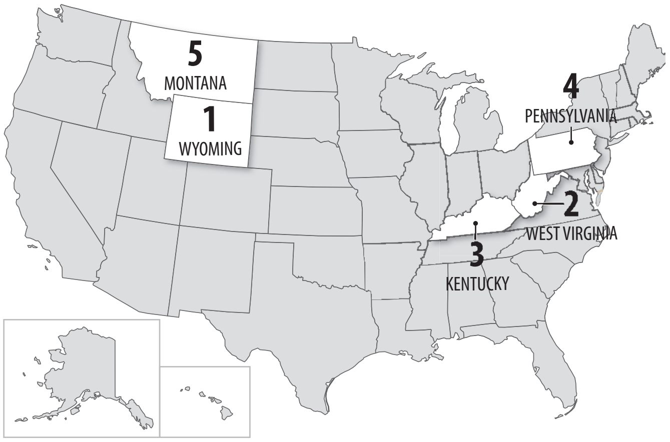
Surface Mining



Deep Mining

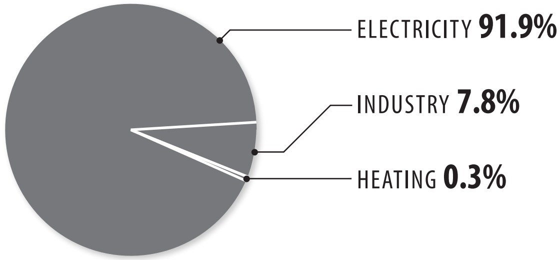


Top Coal Producing States, 2010



Data: Energy Information Adminstration

U.S. Coal Consumption by Sector, 2010



Data: Energy Information Administration

COAL MINERS

Geothermal

What is Geothermal Energy?

The word geothermal comes from the Greek words *geo* (Earth) and *therme* (heat). Geothermal energy is heat from within the Earth.

Geothermal energy is generated in the Earth's **core**, almost 4,000 miles beneath the Earth's surface. The double-layered core is made up of very hot **magma** (melted rock) surrounding a solid iron center. Very high temperatures are continuously produced inside the Earth by the slow decay of radioactive particles. This process is natural in all rocks.

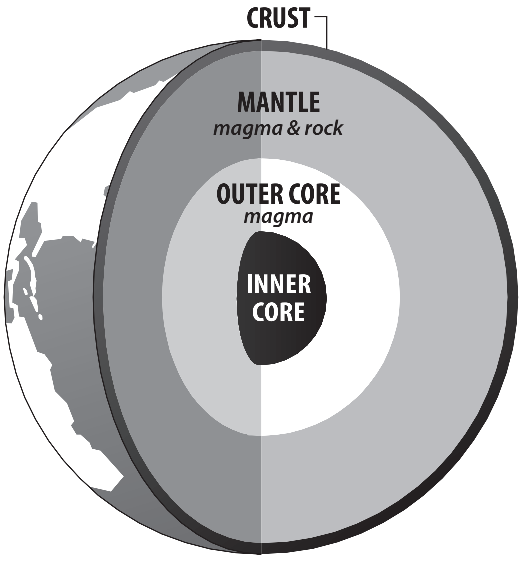
Surrounding the outer core is the **mantle**, which is about 1,800 miles thick and made of magma and rock. The outermost layer of the Earth, the land that forms the continents and ocean floors, is called the **crust**. The crust is three to five miles thick under the oceans and 15 to 35 miles thick on the continents.

The crust is not a solid piece, like the shell of an egg, but is broken into pieces called **plates**. Magma comes close to the Earth's surface near the edges of these plates. This is where volcanoes occur. The lava that erupts from volcanoes is partly magma. Deep underground, the rocks and water absorb the heat from this magma.

We can dig wells and pump the heated, underground water to the surface. People around the world use geothermal energy to heat their homes and to produce electricity.

Geothermal energy is called a **renewable** energy source because the water is replenished by rainfall and the heat is continuously produced deep within the Earth. We won't run out of geothermal energy.

The Earth's Interior



History of Geothermal Energy

Geothermal energy was used by ancient people for heating and bathing. Even today, hot springs are used worldwide for bathing, and many people believe hot mineral waters have natural healing powers.

Using geothermal energy to produce electricity is a new industry. A group of Italians first used it in 1904. The Italians used the natural steam erupting from the Earth to power a turbine generator.

The first successful American geothermal plant began operating in 1960 at The Geysers in northern California. There are now just under 60 geothermal power plants in five states, with many more in development. Most of these geothermal power plants are in California with the remainder in Nevada, Hawaii, Idaho, and Utah.

Finding Geothermal Energy

What are the characteristics of geothermal resources? Some visible features of geothermal energy are volcanoes, hot springs, geysers, and fumaroles. But you cannot see most geothermal resources. They are deep underground. There may be no clues above ground that a geothermal reservoir is present below.

Geologists use different methods to find geothermal reservoirs. The only way to be sure there is a reservoir is to drill a well and test the temperature deep underground.

The most active geothermal resources are usually found along major plate boundaries where earthquakes and volcanoes are concentrated. Most of the geothermal activity in the world occurs in an area called the **Ring of Fire**. This area borders the Pacific Ocean.

Hydrothermal Resources

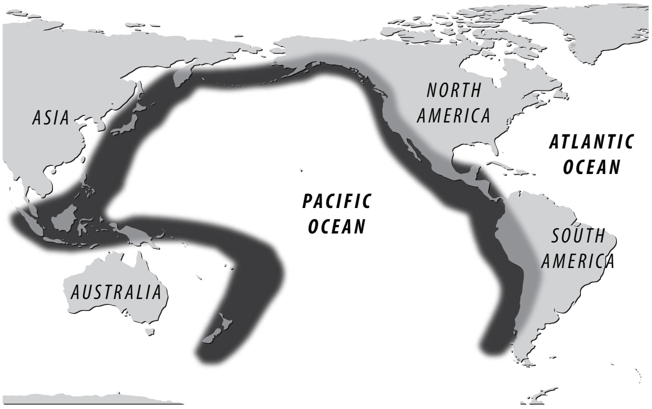
There is more than one type of geothermal energy, but only one kind is widely used to make electricity. It is called hydrothermal energy. **Hydrothermal resources** have two common ingredients: water *(hydro)* and heat *(thermal)*. Depending on the temperature of the hydrothermal resource, the heat energy can either be used for making electricity or for heating.

▪ Low Temperature Resources: Heating

Hydrothermal resources at low temperatures (50 to 300 degrees Fahrenheit) are located everywhere in the United States, just a few feet below the ground. This low temperature geothermal energy is used for heating homes and buildings, growing crops, and drying lumber, fruits, and vegetables.

In the U.S., geothermal heat pumps are used to heat and cool homes and public buildings. In fact, each year about 50,000 geothermal exchange systems are installed in the U.S. Almost 90 percent of the homes and businesses in Iceland use geothermal energy for space heating.

Ring of Fire



Most of the geothermal activity in the world occurs around the Pacific Ocean in an area called the Ring of Fire.

▪ High Temperature Resources: Electricity

Hydrothermal resources at high temperatures (300 to 700 degrees Fahrenheit) can be used to make electricity.

These high-temperature resources may come from either dry steam wells or hot water wells. We can use these resources by drilling wells into the Earth and piping the steam or hot water to the surface. Geothermal wells are one to two miles deep.

In a dry steam power plant, the steam from the geothermal reservoir is piped directly from a well to a turbine generator to make electricity. In a hot water plant, some of the hot water is turned into steam. The steam powers a turbine generator just like a dry steam plant. When the steam cools, it condenses to water and is injected back into the ground to be used over and over again.

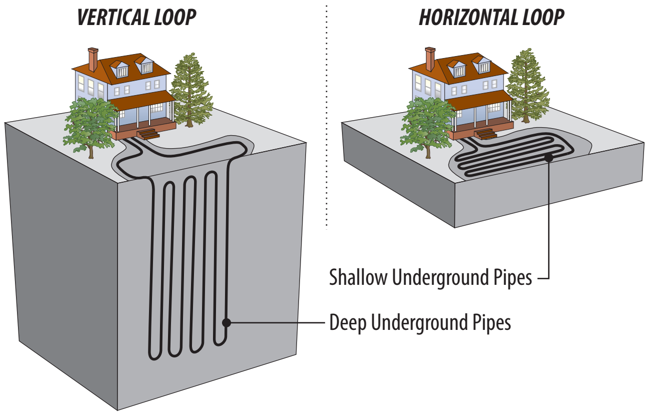
Geothermal energy produces only a small percentage of U.S. electricity. Today, it produces almost 16 billion kilowatt-hours, or less than one percent of the electricity produced in this country.

Geothermal Energy and the Environment

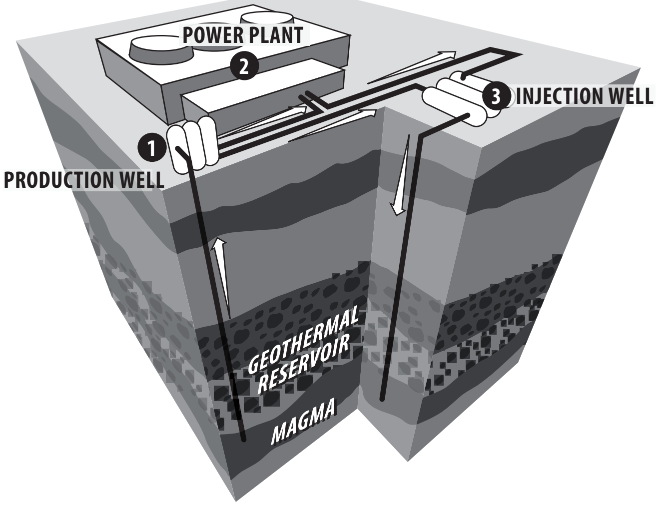
Geothermal energy does little damage to the environment. Another advantage is that geothermal plants don't have to transport fuel, like most power plants. Geothermal plants sit on top of their fuel source. Geothermal power plants have been built in deserts, in the middle of crops, and in mountain forests.

Geothermal plants produce almost no emissions because they do not burn fuel to generate electricity.

Residential Geoexchange Units



Geothermal Power Plant



1. **Production Well:** Geothermal fluids, such as hot water and steam, are brought to the surface and piped into the power plant.
2. **Power Plant:** Inside the power plant, the geothermal fluid turns the turbine blades, which spins a shaft, which spins magnets inside a large coil of wire to generate electricity.
3. **Injection Well:** Used geothermal fluids are returned to the reservoir.

Hydropower

What is Hydropower?

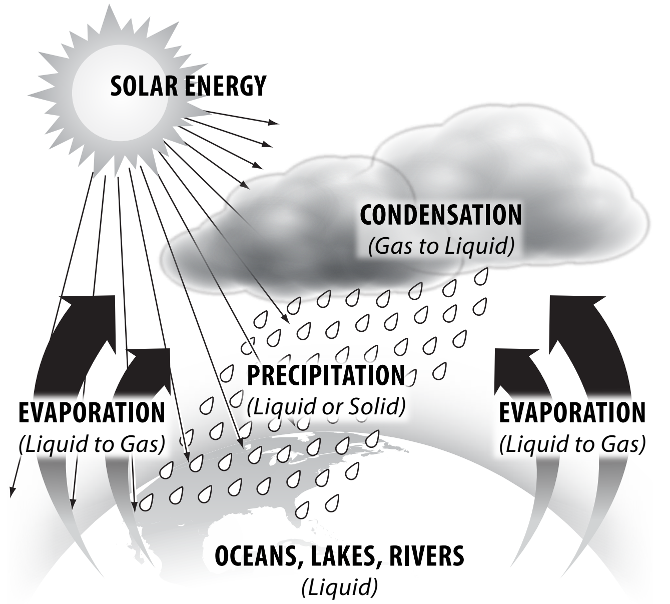
Hydropower (*hydro* means water) is energy that comes from the force of moving water.

The movement of water between the Earth and the atmosphere is part of a continuous cycle. The sun draws moisture up from the oceans and rivers, and this moisture condenses into clouds. The moisture is released from the clouds as rain or snow. The oceans and rivers are replenished with moisture, and the cycle starts again.

Gravity causes the water on the Earth to move from places of high ground to places of low ground. The force of moving water can be very powerful.

Hydropower is called a **renewable** energy source because it is replenished by snow and rainfall. As long as the sun shines and the rain falls, we won't run out of this energy source.

The Water Cycle



History of Hydropower

Water has been used as a source of energy for centuries. The Greeks used water wheels to grind wheat into flour more than 2,000 years ago. In the early 1800s, American and European factories used water wheels to power machines.

The water wheel is a simple machine. The wheel picks up water in buckets located around the wheel. The weight of the water causes the wheel to turn. Water wheels convert the energy of the moving water into useful energy to grind grain, drive sawmills, or pump water.

In the late 19th century, hydropower was first used on the Fox River in Appleton, WI to generate electricity. The first hydroelectric plant was built in 1882. In the years that followed, many more hydropower dams were built. By the 1940s, most of the best sites in the United States for large dams had been developed.

At about the same time, fossil fuel power plants began to be popular. These plants could make electricity more cheaply than hydropower plants. It wasn't until the price of oil skyrocketed in the 1970s that people became interested in hydropower again.

Hydropower Dams

It is easier to build a hydropower plant on a river where there is a natural waterfall, which is why the first hydropower plant was built at Niagara Falls. Building **dams** across rivers to produce artificial waterfalls is the next best way.

Dams are built on rivers where the terrain of the land produces a lake or **reservoir** behind it. Today there are about 84,000 dams in the United States, but only 2,200 have equipment to generate electricity.

Most of the dams in the United States were built to control flooding or irrigate farm land, not for electricity production. We could increase the amount of hydropower produced in this country by putting equipment to generate electricity on many of the existing dams.

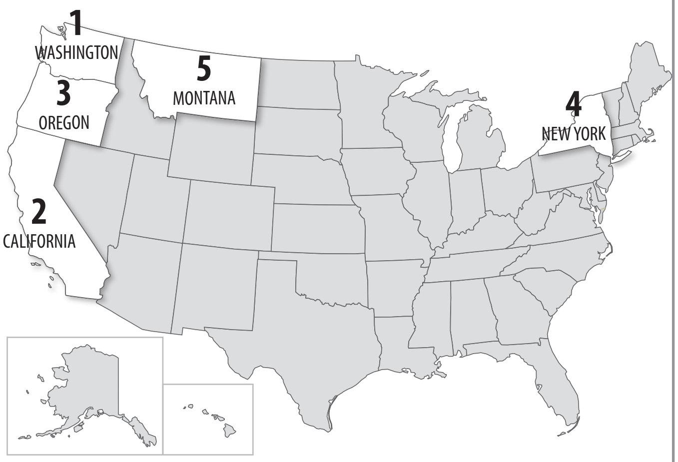
Hydropower Plants

Hydropower plants use modern turbine **generators** to produce electricity just as coal, oil, or nuclear power plants do. The difference is the fuel.

A typical hydropower plant is a system that has three main parts: a reservoir where water can be stored, a dam with gates to control water flow, and a power plant where the electricity is produced.

A hydropower plant uses the force of flowing water to produce electricity. A dam opens gates at the top to allow water from the reservoir to flow down large tubes called **penstocks**. At the bottom of the penstocks, the fast-moving water spins the blades of turbines. The turbines are attached to generators to produce electricity, which is transported along transmission lines to a utility company.

Top Hydropower Producing States, 2010



Data: Energy Information Association

Storing Energy

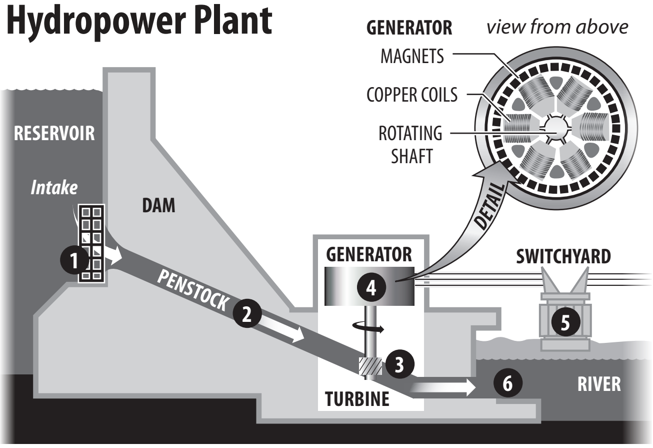
One of the biggest advantages of hydropower dams is their ability to store energy. After all, the water in the reservoir has potential gravitational energy. Water can be stored in a reservoir and released when electricity is needed. During the night, when consumers use less electricity, the gates can be closed and water held in the reservoir. Then, during the day, when consumers need more electricity, the gates can be opened so that the water can flow through the plant to generate electricity.

Amount and Cost of Hydropower

Depending upon the amount of rainfall during the year, hydropower provides between five and ten percent of the country's electricity. Globally, hydropower is a significant energy source, producing almost 17 percent of the world's electricity. In South America, most of the electricity is produced by hydropower.

Hydropower is the cheapest way to generate electricity in the United States today. Hydropower is cheaper than electricity from coal or nuclear plants because the fuel—flowing water—is free to use.

Hydropower Plant



1. Water in a reservoir behind a hydropower dam flows through an intake screen, which filters out large debris, but allows fish to pass through.
2. The water travels through a large pipe, called a penstock.
3. The force of the water spins a turbine at a low speed, allowing fish to pass through unharmed.
4. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
5. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.
6. Water flows out of the penstock into the downstream river.

Hydropower and the Environment

Hydropower is a clean energy source. A hydropower plant produces no air pollution because it does not burn fuel, but it does affect the environment in other ways.

When dams were built, water patterns and the amount of flow in rivers were altered. Some wildlife and natural resources were also affected. Many dams today have fish ladders, elevators, and other devices to help fish swim up the river.

On the positive side, hydropower's fuel supply (flowing water) is clean and renewable, replenished by the water cycle. There are also other benefits. Dams can be designed to control flood water, and reservoirs provide lakes for boating, swimming, fishing, and other recreational activities.

Natural Gas

What is Natural Gas?

Natural gas is a **fossil fuel** like petroleum and coal. Natural gas is called a fossil fuel because most scientists believe that it was formed from the remains of ancient sea plants and animals. When the plants and tiny sea animals died, they sank to the bottom of the oceans where they were buried by sediment and sand, which turned into **sedimentary rock**. The layers of plant and animal matter and sedimentary rock continued to build until the pressure and heat from the Earth turned the remains into petroleum and natural gas.

Natural gas is trapped in underground rocks much like a sponge traps water in pockets. Natural gas is really a mixture of gases. The main ingredient is **methane**. Methane has no color, odor, or taste. As a safety measure, natural gas companies add an odorant, **mercaptan**, to the gas so that leaking gas can be detected (it smells like rotten eggs). People use natural gas mostly for heating. Natural gas should not be confused with gasoline, which is made from petroleum.

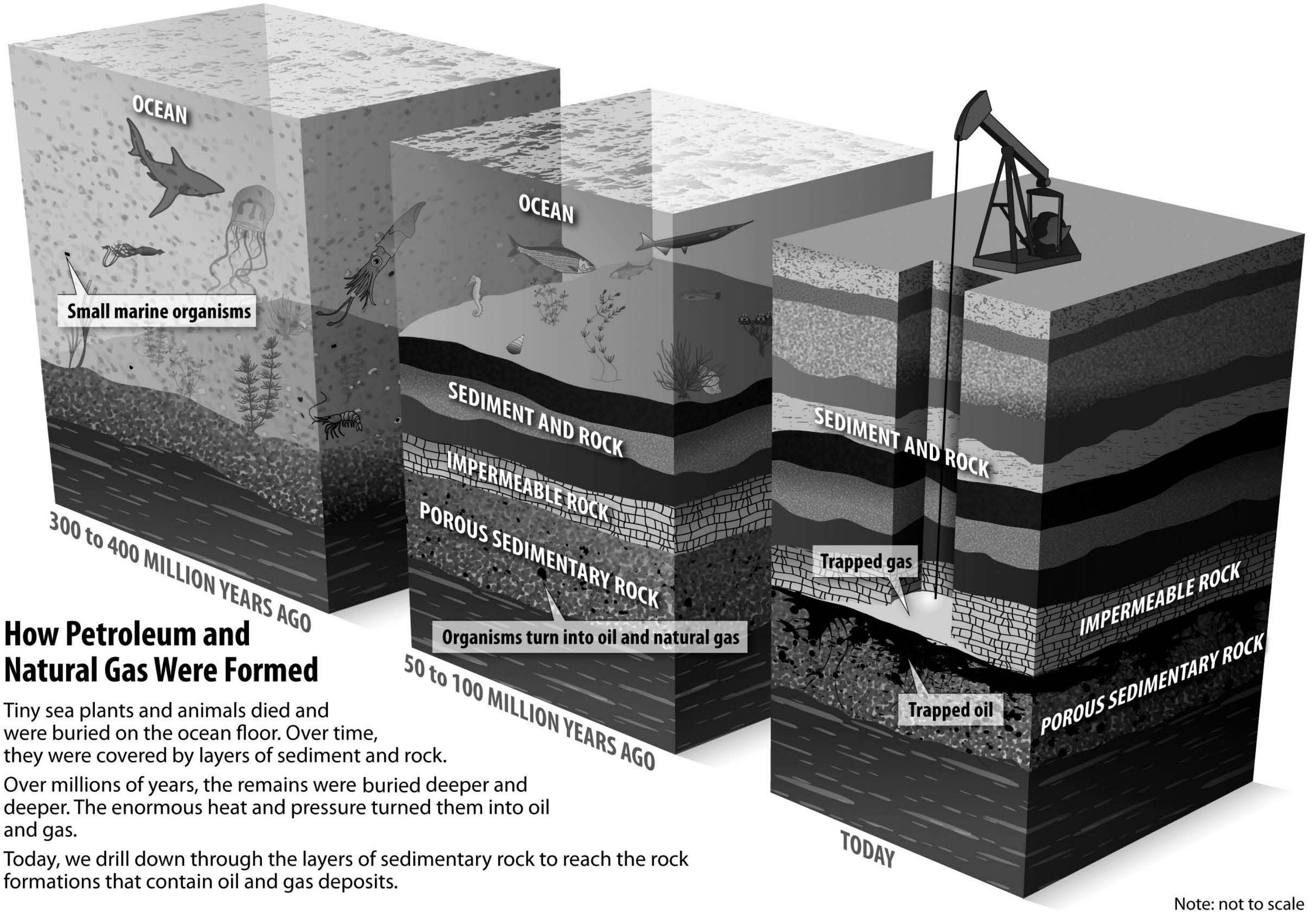
Natural gas is almost always considered **nonrenewable**, which means we cannot make more in a short time. However, there are some renewable sources of methane, such as landfills.

History of Natural Gas

The ancient people of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeped from cracks in the ground and was ignited by lightning. They sometimes built temples around these eternal flames and worshipped the fire.

About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate sea water to make salt.

In 1816, natural gas was first used in America to fuel street lamps in Baltimore, Maryland. Soon after, in 1821, William Hart dug the United States' first successful natural gas well in Fredonia, New York. It was just 27 feet deep, quite shallow compared to today's wells. Today, natural gas is the country's second largest supplier of energy, after petroleum.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

Note: not to scale

Producing Natural Gas

Natural gas can be hard to find since it is trapped in porous rocks deep underground. Scientists use many methods to find natural gas deposits. They may look at surface rocks to find clues about underground formations. They may set off small explosions or drop heavy weights on the surface to record the sound waves as they bounce back from the rock layers underground.

Natural gas can be found in pockets by itself or in petroleum deposits. Natural gas wells average 5,000 feet deep!

After natural gas comes out of the ground, it is sent to a plant where it is cleaned of impurities and separated into its various parts. Natural gas is mostly methane, but it also contains small amounts of other gases such as propane and butane.

Today natural gas is produced in 32 states, though just five states—Texas, Wyoming, Oklahoma, Louisiana, and Colorado—produce 65 percent of our supply. Natural gas is also produced offshore. Ten percent of natural gas production came from offshore wells in 2010. Scientists estimate that we have enough natural gas to last over 100 years at current prices and rate of consumption.

Natural gas can also come from other sources, such as the methane gas found in coal. **Coal bed methane** was once considered just a safety hazard to miners, but now it is a valuable source of energy. Another source of natural gas is the gas produced in landfills. Landfill gas is considered a renewable source of natural gas since it comes from something continually produced—trash.

Shipping Natural Gas

Natural gas is usually shipped by pipeline. About two million miles of pipelines connect gas fields, to cities, to homes and businesses. Natural gas is sometimes transported thousands of miles in these pipelines to its final destination. It takes about five days to move natural gas from Texas to New York.

Eventually, the gas reaches the city gate of a local gas utility. Smaller pipes carry the gas the last few miles to homes and businesses. A gas meter measures the volume of gas a consumer uses.

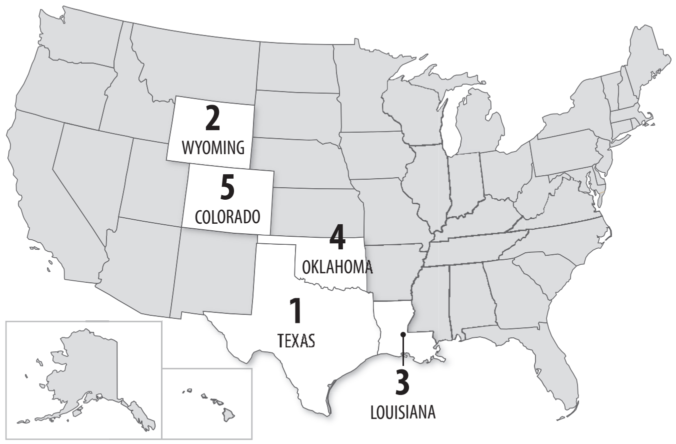
Who Uses Natural Gas?

Just about everyone in the United States uses natural gas. **Industry** burns natural gas for heat to manufacture goods. Natural gas is also used as an ingredient in fertilizer, glue, paint, laundry detergent, and many other items.

Residences, or homes, use natural gas for heating. Like residences, commercial buildings use natural gas mostly for heating. **Commercial** users include stores, offices, schools, churches, and hospitals.

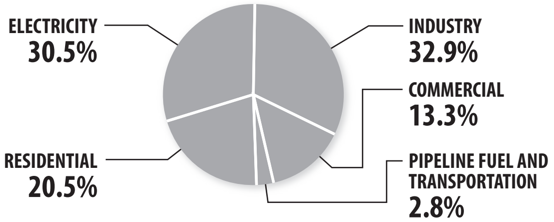
Natural gas can also be used to generate electricity. Many new power plants are using natural gas as fuel because it is so clean-burning and can produce electricity quickly when it is needed for periods of high demand.

Top Natural Gas Producing States, 2010



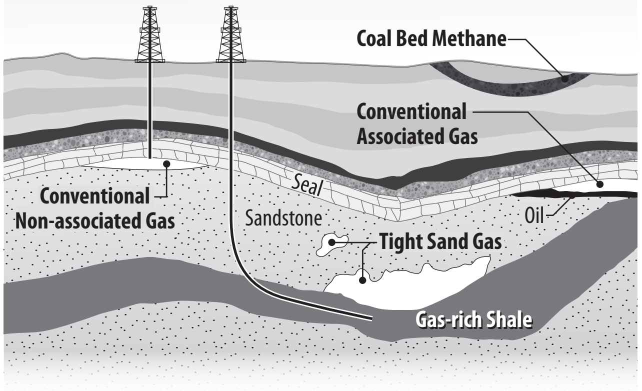
Data: Energy Information Administration

U.S. Natural Gas Consumption by Sector, 2010



Data: Energy Information Administration

Locations of Natural Gas



A small amount of natural gas is also used as fuel for automobiles. Natural gas is cleaner burning than gasoline, but to use it, vehicles must have special equipment.

Natural Gas and the Environment

Burning any fossil fuel, including natural gas, releases emissions into the air, including carbon dioxide, a greenhouse gas.

Natural gas and propane are the cleanest burning fossil fuels. Compared to coal and petroleum, natural gas releases much less sulfur, carbon dioxide, and ash when it is burned. Scientists are looking for new sources of natural gas and new ways to use it.

Petroleum

What is Petroleum?

Petroleum is a **fossil fuel**. Petroleum is often called **crude oil**, or oil. It is called a fossil fuel because it was formed from the remains of tiny sea plants and animals that died millions of years ago. When the plants and animals died, they sank to the bottom of the oceans.

Here, they were buried by thousands of feet of sand and sediment, which turned into **sedimentary rock**. As the layers increased, they pressed harder and harder on the decayed remains at the bottom. The heat and pressure changed the remains and, eventually, petroleum was formed.

Petroleum deposits are locked in porous rocks almost like water is trapped in a wet sponge. When crude oil comes out of the ground, it can be as thin as water or as thick as tar. Petroleum is called a **nonrenewable** energy source because it takes millions of years to form. We cannot make new petroleum reserves.

History of Oil

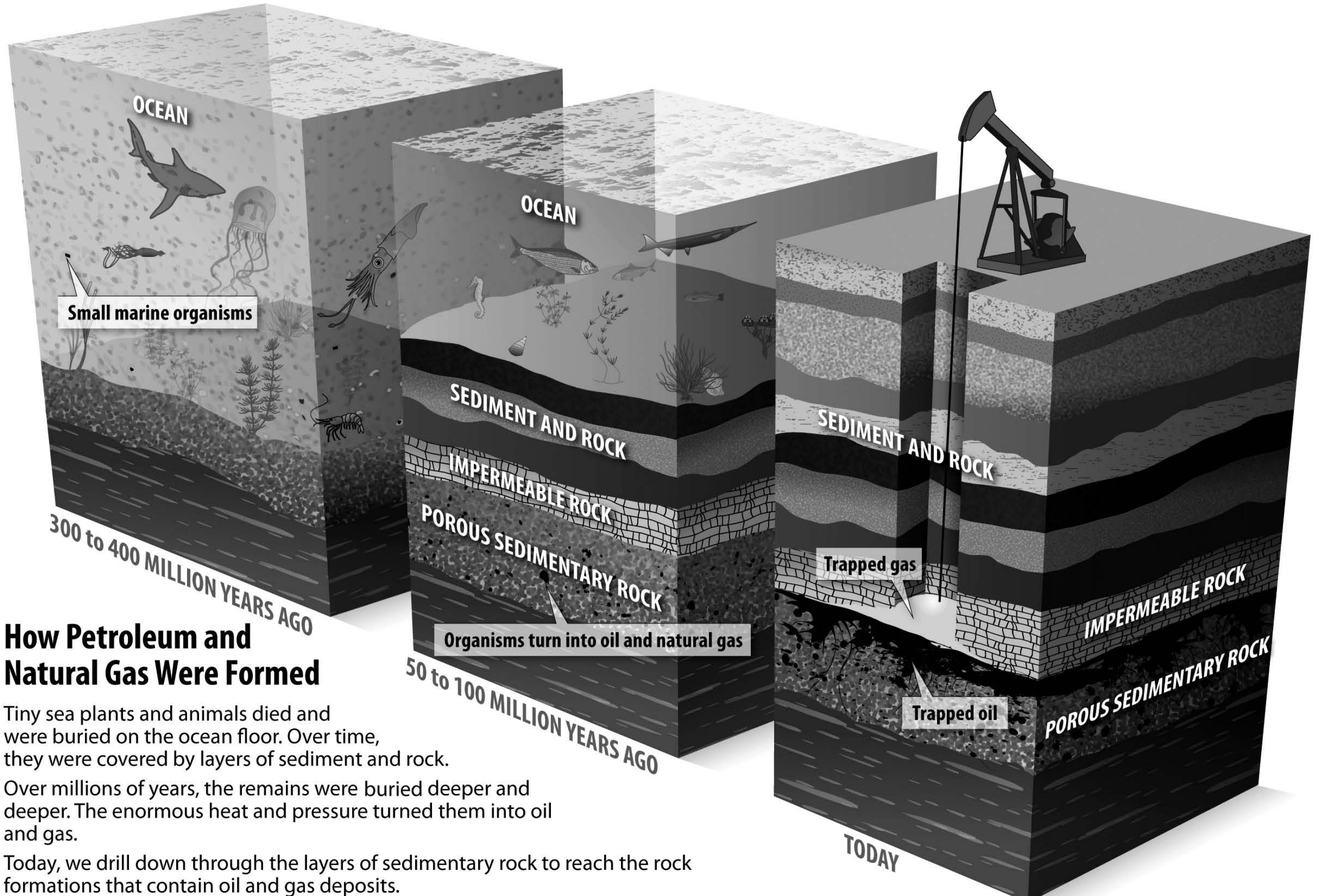
People have used petroleum since ancient times. The ancient Chinese and Egyptians burned oil to light their homes. Before the 1850s, Americans used whale oil to light their homes. When whale oil became scarce, people skimmed the oil that seeped to the surface of ponds and streams. The demand for oil grew, and in 1859, Edwin Drake drilled the first oil well near Titusville, Pennsylvania.

At first, the crude oil was refined or made into kerosene for lighting. Gasoline and other products made during refining were thrown away because people had no use for them. This all changed when Henry Ford began mass producing automobiles in 1913. Everyone wanted an automobile and they all ran on gasoline. Gasoline was the fuel of choice because it provided the greatest amount of energy in relation to cost and ease of use.

Today, Americans use more petroleum than any other energy source, mostly for transportation. Petroleum provides 35 percent of the energy we use.

Producing Oil

Geologists look at the types of rocks and the way they are arranged deep within the Earth to determine whether oil is likely to be found at a specific location. Even with new technology, oil exploration is expensive and often unsuccessful. Only 61 percent of exploratory wells produced oil in 2010. When scientists think there may be oil in a certain place, a petroleum company brings in a **drilling rig** and raises an **oil derrick** that houses the tools and pipes they need to drill a well. The typical oil well is about one mile deep. If oil is found, a pump moves the oil through a pipe to the surface.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

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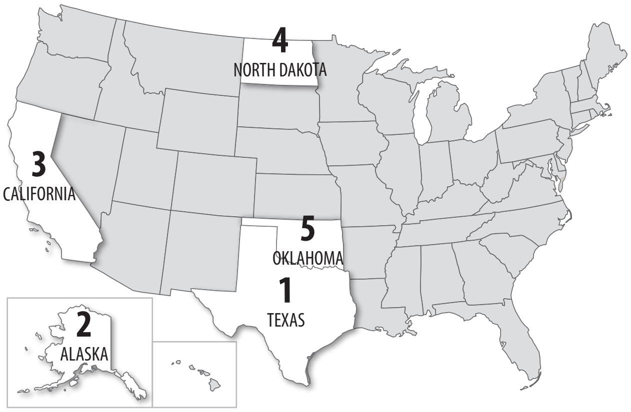
Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

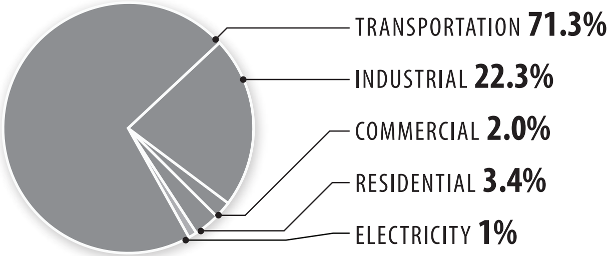
Note: not to scale

Top Petroleum Producing States, 2010



Data: Energy Information Administration

Petroleum Consumption by Sector, 2010



Data: Energy Information Administration

About one-third of the oil the U.S. produces comes from offshore wells. Some wells are a mile under the ocean. Some of the rigs used to drill these wells float on top of the water. It takes a lot of money and technology to drill and find oil in the ocean.

Texas produces more oil than any other state, followed by Alaska, California, North Dakota, and Oklahoma. Americans use much more oil than we produce. Today, the U.S. imports about half of the oil it consumes from other countries.

From Well to Market

We can't use **crude oil** as it comes out of the ground. We must change it into fuels that we can use. The first stop for crude oil is at a **petroleum refinery.** A refinery is a factory that processes oil.

The refinery cleans and separates the crude oil into many fuels and products. The most important one is gasoline. Other petroleum products are diesel fuel, heating oil, and jet fuel. Industry uses petroleum to make plastics and many other products.

Shipping Petroleum

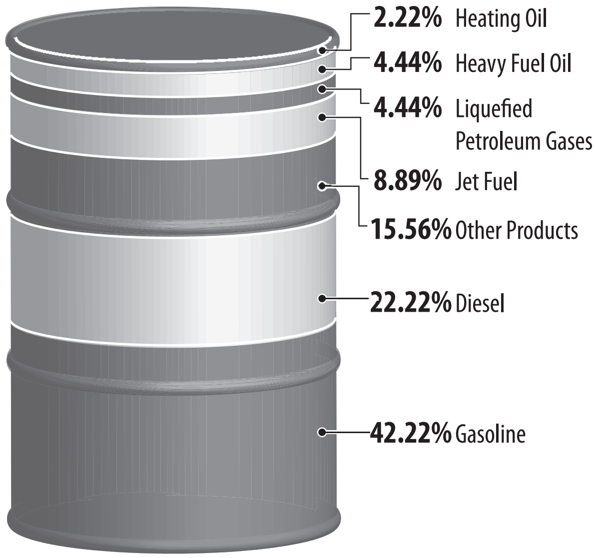
After the refinery, most petroleum products are shipped out through pipelines. There are about 95,000 miles of underground pipelines in the United States transporting refined petroleum products. Pipelines are the safest and cheapest way to move big shipments of petroleum. It takes about 15 days to move a shipment of gasoline from Houston, Texas to New York City.

Special companies called **jobbers** buy petroleum products from oil companies and sell them to gasoline stations and to other big users such as industries, power companies, and farmers.

Other Petroleum Products

Ink
Hand lotion
Nail polish
Heart valves
Toothbrushes
Dashboards
Crayons
Toothpaste
Luggage
Parachutes
Guitar strings
DVDs
Enamel
Movie film
Balloons
Antiseptics
Aspirin
Paint brushes
Purses
Sunglasses
Footballs
Deodorant
Glue
Dyes
Pantyhose
Artificial limbs
Antihistamines
Oil filters
Ballpoint pens
Skis
Pajamas
Golf balls
Perfumes
Cassettes
Contact lenses
Shoe polish
Fishing rods
Dice
Fertilizers
Electrical tape
Trash bags
Insecticides
Floor wax
Shampoo
Cold cream
Tires
Cameras
Detergents

Products Produced From a Barrel of Oil, 2010



Data: Energy Information Administration

Oil and the Environment

Petroleum products—gasoline, medicines, fertilizers, and others—have helped people all over the world, but there is a trade-off. Petroleum production, exploration, and the use of petroleum products may cause air and water pollution.

Drilling for and transporting oil can endanger wildlife and the environment if it spills into rivers or oceans. Leaking underground storage tanks can pollute groundwater and create noxious fumes. Processing oil at the refinery can contribute to air and water pollution. Burning gasoline to fuel our cars contributes to air pollution. Even the careless disposal of waste oil drained from the family car can pollute rivers and lakes.

The petroleum industry works hard to protect the environment. Gasoline and diesel fuel have been changed to burn cleaner. And oil companies work to make sure that they drill and transport oil as safely as possible.

Propane

What is Propane?

Propane is an energy-rich gas that is related to petroleum and natural gas. Propane is usually found mixed with deposits of natural gas and petroleum underground. Propane is called a **fossil fuel** because it was formed millions of years ago from the remains of tiny sea animals and plants.

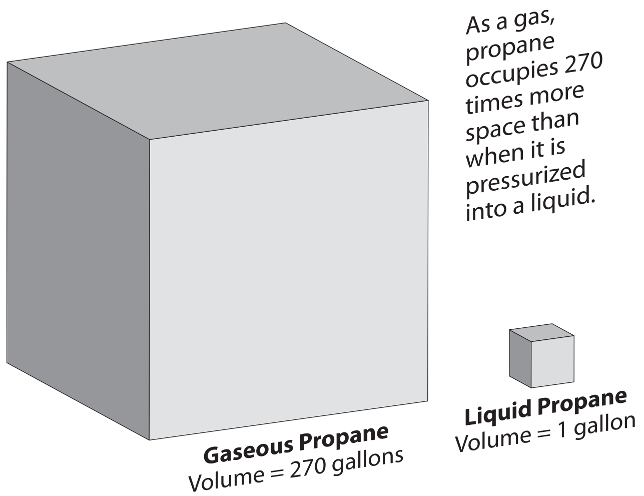
When the plants and animals died, they sank to the bottom of the oceans where they were buried by layers of sediment and sand that turned into **sedimentary rock.** Over the years, the layers became thousands of feet thick. The layers were subjected to enormous heat and pressure, changing the remains into petroleum and natural gas deposits. Pockets of these fossil fuels became trapped in rocks like a sponge holds water.

Propane is one of the many fuels that are included in the **liquefied petroleum gas** (or LPG) family. In the United States, propane and **LPG** often mean the same thing, because propane is the most common type of LPG used. Just as water can be a liquid or a gas (steam), so can propane. Under normal conditions, propane is a gas. Under **pressure**, propane becomes a liquid.

Propane is stored as a liquid fuel in pressurized tanks because it takes up much less space in that form. Gaseous propane takes up 270 times more space than liquid propane. A thousand gallon tank holding gaseous propane would provide a family enough cooking fuel for one week. The same tank holding liquid propane would provide enough cooking fuel for over five years! Propane becomes a gas when it is released to fuel gas appliances.

Propane is very similar to natural gas. Like natural gas, propane is colorless and odorless. An odor is added to propane so escaping gas can be detected. And like all fossil fuels—coal, petroleum, natural gas—propane is a **nonrenewable** energy source. That means we cannot renew our propane supplies in a short time.

Liquefied Propane (LPG)



As a gas, propane occupies 270 times more space than when it is pressurized into a liquid.

History of Propane

Propane has been around for millions of years, but it wasn't discovered until 1912. Scientists were trying to find a better way to store gasoline, which had a tendency to evaporate when it was stored.

An American scientist, Dr. Walter Snelling, discovered that propane gas could be changed into a liquid and stored at moderate pressure. Just one year later, the commercial propane industry began heating American homes with propane.

Producing Propane

Propane comes from natural gas and petroleum wells. Approximately half of the propane used in the United States comes from raw natural gas. Raw natural gas is about 90 percent methane, five percent propane, and five percent other gases. The propane is separated from the other gases at a natural gas processing plant.

The other half of our propane supply comes from petroleum refineries or is imported. Many gases are separated from petroleum at refineries and propane is the most important one. Since the U.S. imports half of the petroleum we use, much of the propane is separated from this imported oil.

Transporting Propane

How does propane get to consumers? It is usually moved through pipelines to **distribution terminals** across the nation. These distribution terminals are like warehouses that store goods before shipping it to stores. Sometimes in the summer, when people need less propane for heating, it is stored in large underground caverns.

From the distribution terminals, propane goes by railroad, trucks, barges, and supertankers to bulk plants. A **bulk plant** is where local propane dealers come to fill their small tank trucks. People who use very little propane—backyard barbecue cooks, for example—must take their propane tanks to dealers to be filled.

How Propane is Used

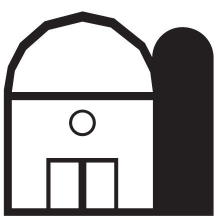
Propane provides the U.S. with less than two percent of its energy. Propane is used by industry, homes, farms, and businesses—mostly for heating. It is also used as a transportation fuel.

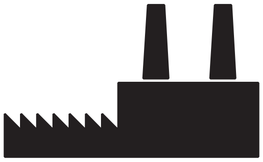
▪ Industry

Almost three-quarters of the propane is used by industry. Many industries find propane well-suited for special needs. Metal workers use small propane tanks to fuel cutting torches. Portable propane heaters give construction and road workers warmth in cold weather.

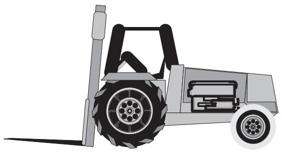
Propane is also used to heat asphalt for highway construction and repairs. And because propane burns so cleanly, fork-lift trucks powered by propane can operate safely inside factories and warehouses.

How Propane is Used


To heat barns and operate farm equipment


To make products and fuel industry

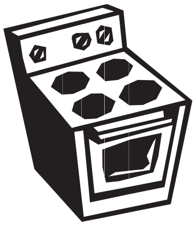

To fuel hot air balloons


To fuel machinery that is used indoors


To fuel backyard grills


To heat homes


To fuel fleet vehicles


To fuel appliances

▪ Homes

Propane is mostly used in rural areas that do not have natural gas service. Homes use propane for heating, hot water, cooking, and clothes drying. Many families have barbecue grills fueled by propane gas. Some families have recreational vehicles equipped with propane appliances.

▪ Farms

About 40 percent of America's farms rely on propane. Farmers use propane to dry crops, power tractors, and heat greenhouses and chicken coops.

▪ Businesses

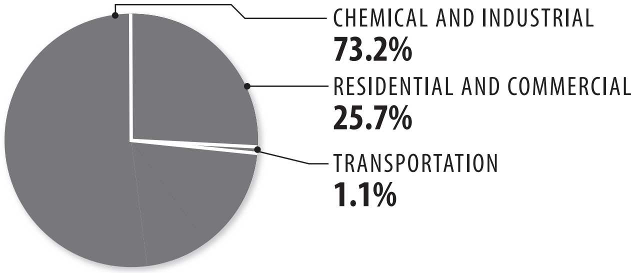
Businesses—office buildings, laundromats, fast-food restaurants, and grocery stores—use propane for heating and cooking.

▪ Transportation Fuel

Propane has been used as a transportation fuel for many years. Today, many taxicab companies, government agencies, and school districts use propane instead of gasoline to fuel their fleets of vehicles. Propane has several advantages over gasoline. First, propane is clean-burning and leaves engines free of deposits. Second, engines that use propane emit fewer pollutants into the air than engines that use gasoline.

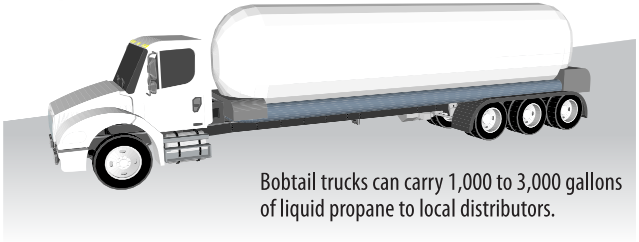
Why isn't propane used as a transportation fuel more often? For one reason, it's not as easy to find as gasoline. Have you ever seen a propane filling station? Second, automobile engines have to be adjusted to use propane fuel, and these adjustments can be costly. Third, there is a slight drop in miles per gallon when propane is used to fuel vehicles.

U.S. Propane Consumption by Sector, 2010



Data: Energy Information Administration

Propane Truck


Bobtail trucks can carry 1,000 to 3,000 gallons of liquid propane to local distributors.

Solar Energy

What is Solar Energy?

Every day, the sun radiates (sends out) an enormous amount of energy—called **solar energy**. It radiates more energy in one second than the world has used since time began. This energy comes from within the sun itself.

Like most stars, the sun is a big gas ball made up mostly of hydrogen and helium gas. The sun makes energy in its inner core in a process called nuclear **fusion**.

It takes the sun's energy just a little over eight minutes to travel the 93 million miles to Earth. Solar energy travels at a speed of 186,000 miles per second, the speed of light.

Only a small part of the **radiant energy** that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy needs. Every day enough solar energy reaches the Earth to supply our nation's energy needs for a year! Solar energy is considered a **renewable energy** source.

Today, people use solar energy to heat buildings and water and to generate electricity.

Solar Collectors

Heating with solar energy is not as easy as you might think. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the Earth is spread out over a large area. The sun does not deliver that much energy to any one place at any one time.

The amount of solar energy an area receives depends on the time of day, the season of the year, the cloudiness of the sky, and how close you are to the Earth's equator.

A **solar collector** is one way to capture sunlight and change it into usable heat energy. A closed car on a sunny day is like a solar collector. As sunlight passes through the car's windows, it is absorbed by the seat covers, walls, and floor of the car. The absorbed light changes into heat. The car's windows let light in, but they don't let all the heat out. A closed car can get very hot!

Solar Space Heating

Space heating means heating the space inside a building. Today, many homes use solar energy for space heating. A passive solar home is designed to let in as much sunlight as possible. It is like a big solar collector.

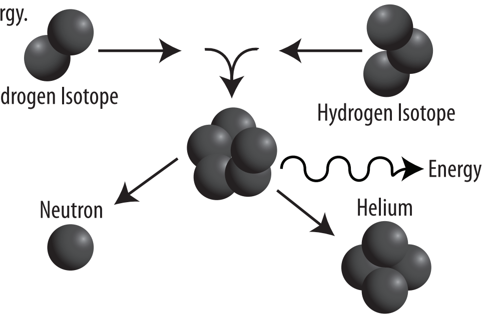
Sunlight passes through the windows and heats the walls and floor inside the house. The light can get in, but the heat is trapped inside. A **passive solar home** does not depend on mechanical equipment, such as pumps and blowers, to heat the house.

An **active solar home**, on the other hand, uses special equipment to collect sunlight. An active solar house may use special collectors that look like boxes covered with glass.

These collectors are mounted on the rooftop facing south to take advantage of the winter sun. Dark-colored metal plates inside the boxes absorb sunlight and change it into heat. (Black absorbs sunlight better than any other color.) Air or water flows through the collectors and is warmed by the heat. The warm air or water is distributed to the house, just as it would be with an ordinary furnace system.

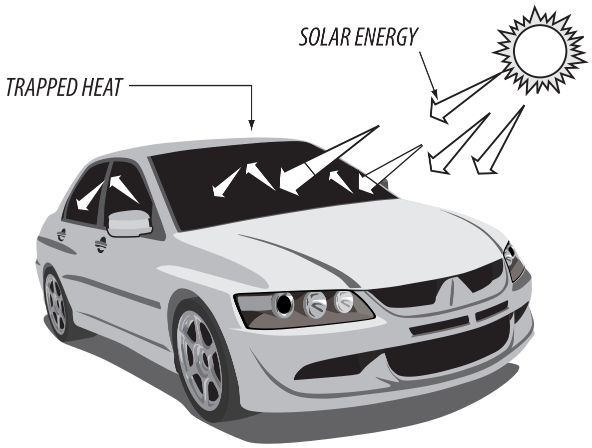
Fusion

The process of fusion most commonly involves hydrogen isotopes combining to form a helium atom with a transformation of matter. This matter is emitted as radiant energy.

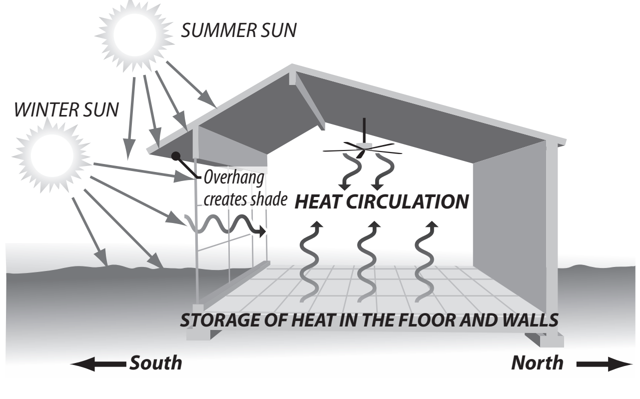


Solar Collector

On a sunny day, a closed car becomes a solar collector. Light energy passes through the window glass, is absorbed by the car's interior, and converted into heat energy. The heat energy becomes trapped inside.



Passive Solar Home



Solar Water Heating

Solar energy can be used to heat water. Heating water for bathing, dishwashing, and clothes washing is the second largest home energy cost. Installing a solar water heater can reduce your water heating bill 50 to 80 percent.

A solar water heater works a lot like solar space heating. In our hemisphere, a solar collector is mounted on the south side of a roof where it can capture sunlight. The sunlight heats water in a tank. The hot water is piped to faucets throughout a house, just as it would be with an ordinary water heater.

Solar Electricity

Solar energy can also be used to produce electricity. Two ways to make electricity from solar energy are photovoltaics and solar thermal systems.

▪ Photovoltaic Electricity

Photovoltaic comes from the words *photo,* meaning light, and *volt*, a measurement of electricity. Sometimes **photovoltaic cells** are called PV cells or **solar cells** for short. You are probably familiar with photovoltaic cells. Solar-powered toys, calculators, and roadside telephone call boxes all use solar cells to convert sunlight into electricity.

Solar cells are made up of **silicon**, the same substance that makes up sand. Silicon is the second most common substance on Earth. Solar cells can supply energy to anything that is powered by batteries or electrical power.

Electricity is produced when sunlight strikes the solar cell, causing the electrons to move around. The action of the electrons starts an electric current. The conversion of sunlight into electricity takes place silently and instantly. There are no mechanical parts to wear out.

You won't see many photovoltaic power plants today. Compared to other ways of making electricity, photovoltaic systems are expensive. In 2009, the DeSoto Next Generation Solar Energy Center in Florida opened. It is the largest photovoltaic plant in the country, generating 25 megawatts of electricity—enough to power 3,000 homes.

It costs 10 to 20 cents a kilowatt-hour to produce electricity from solar cells. Most people pay their electric companies about 12 cents a kilowatt-hour for the electricity they use, and large industrial consumers pay less. Today, solar systems are mainly used to generate electricity in remote areas that are a long way from electric power lines.

▪ Solar Thermal Electricity

Like solar cells, **solar thermal systems**, also called **concentrated solar power (CSP)**, use solar energy to produce electricity, but in a different way. Most solar thermal systems use a solar collector with a mirrored surface to focus sunlight onto a receiver that heats a liquid. The super-heated liquid is used to make steam to produce electricity in the same way that coal plants do. There are CSP plants in California, Arizona, Nevada, and Florida.

Solar energy has great potential for the future. Solar energy is free, and its supplies are unlimited. It does not pollute or otherwise damage the environment. It cannot be controlled by any one nation or industry. If we can improve the technology to harness the sun's enormous power, we may never face energy shortages again.

SOLAR WATER HEATER

SOLAR PANELS

SOLAR THERMAL ELECTRICITY

Image courtesy of U.S. Department of Energy

Parabolic troughs concentrate the sun's radiant energy, heating fluid that is used to create steam. The steam turns a generator, which produces electricity.

Uranium (Nuclear)

What is Nuclear Energy?

Nuclear energy is energy in the **nucleus** (core) of an **atom**. Atoms are tiny particles that make up every object in the universe. There is enormous energy in the bonds that hold atoms together.

Nuclear energy can be used to make electricity, but first the energy must be released. It can be released from atoms in two ways: nuclear fusion and fission.

In nuclear **fusion**, energy is released when atoms are combined or fused together to form a larger atom. This is how the sun produces energy.

In nuclear **fission**, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity.

The fuel most widely used by nuclear plants for nuclear fission is **uranium**. Uranium is **nonrenewable**, though it is a common metal found in rocks all over the world. Nuclear plants use uranium as fuel because its atoms are easily split apart. During nuclear fission, a small particle called a **neutron** hits the uranium atom, it splits, releasing a great amount of energy as heat and radiation. More neutrons are also released. These neutrons go on to bombard other uranium atoms, and the process repeats itself over and over again. This is called a **chain reaction.**

History of Nuclear Energy

Compared to other energy sources, fission is a very new way to produce energy. It wasn't until the early 1930s that scientists discovered that the nucleus of an atom is made up of particles called **protons** and **neutrons**.

A few years later, scientists discovered that the nucleus of an atom could be split apart by bombarding it with a neutron—the process we call fission. Soon they realized that enormous amounts of energy could be produced by nuclear fission.

During World War II, nuclear fission was first used to make a bomb. After the war, nuclear fission was used to generate electricity. Today, it provides 20 percent of the electricity used in the United States.

How a Nuclear Plant Works

Most power plants burn fuel to produce electricity, but not nuclear power plants. Instead, nuclear plants use the heat given off during fission. Fission takes place inside the **reactor** of a nuclear power plant. At the center of the reactor is the **core**, which contains the uranium fuel.

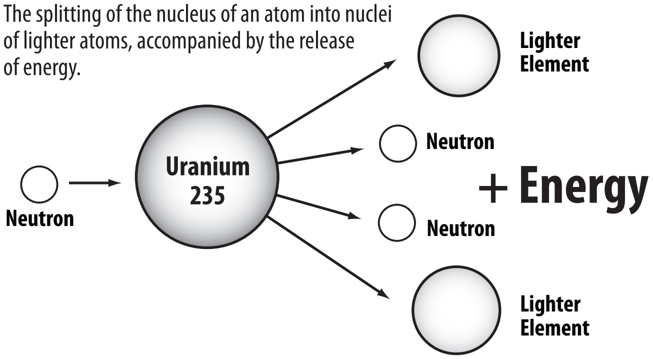
The uranium fuel is formed into **ceramic pellets**. The pellets are about the size of your fingertip, but each one produces the same amount of energy as 150 gallons of oil. These energy-rich pellets are stacked end-to-end in 12-foot metal **fuel rods**. A bundle of fuel rods is called a **fuel assembly**.

Fission generates heat in a reactor just as coal generates heat in a boiler. The heat is used to boil water into steam. The steam turns huge **turbine** blades. As they turn, they drive **generators** that make electricity.

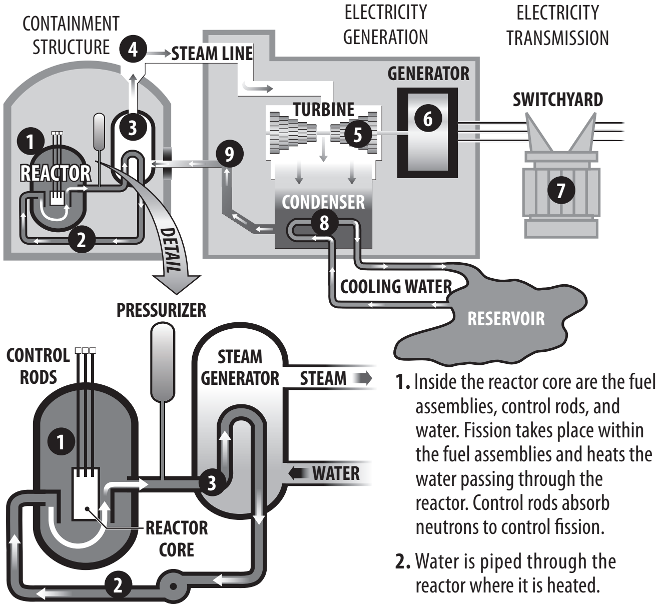
Afterward, the steam is changed back into water and cooled. Some plants use a local body of water for the cooling process; others use a separate structure at the power plant called a **cooling tower**.

Fission

The splitting of the nucleus of an atom into nuclei of lighter atoms, accompanied by the release of energy.



Pressurized Water Reactor



1. Inside the reactor core are the fuel assemblies, control rods, and water. Fission takes place within the fuel assemblies and heats the water passing through the reactor. Control rods absorb neutrons to control fission.

2. Water is piped through the reactor where it is heated.

3. It then travels to the steam generator where it heats a secondary system of water.

4. The steam generator keeps the steam at a high pressure. The steam travels through a steam line to the turbine.

5. The high pressure steam turns the turbine as it passes through, which spins a shaft. The steam then travels through the condenser where it is condensed by cooling water and is pumped back into the steam generator to repeat its cycle.

6. The turbine spins a shaft which travels into the generator. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This generates electricity.

7. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

8. The unused steam continues into the condenser where cool water from the environment (river, ocean, lake, reservoir) is used to condense it back into water. The cooling water never comes in direct contact with the steam, so it is safe to return to the environment.

9. The resulting water is pumped out of the condenser with a series of pumps, reheated and pumped back to the reactor vessel.

Used Nuclear Fuel

Every few years, the fuel rods must be replaced. Fuel that has been removed from the reactor is called **used fuel**. Nuclear power plants do not produce a large quantity of waste, but the used fuel is highly **radioactive**.

The used fuel is usually stored near the reactor in a deep pool of water called the used fuel pool. Here, the used fuel cools down and begins to lose most of its radioactivity through a natural process called **radioactive decay**.

In three months, the used fuel will have lost 50 percent of its radiation; in a year, it will have lost about 80 percent; and in ten years, it will have lost 90 percent. Nevertheless, because some radioactivity remains for as long as 1,000 years, the used fuel must be carefully isolated from people and the environment.

Used Nuclear Fuel Repository

Most scientists think the safest place to store used nuclear fuel is in underground rock formations—called **repositories**. In 1982, Congress agreed and passed the Nuclear Waste Policy Act. This law directed the Department of Energy to design and build America's first repository.

The U.S. Department of Energy (DOE) originally looked at **Yucca Mountain**, Nevada to be the site of a national used nuclear fuel repository. In 2002, after many tests and studies, Congress and President George W. Bush approved Yucca Mountain as the repository site. In 2008, an application was submitted to the Nuclear Regulatory Commission to move forward with building the repository. Some people supported the site at Yucca Mountain as a safe site for used nuclear fuel. However, some people living in Nevada were worried about possible safety hazards and did not want the repository in their state.

In 2010, the U.S. Department of Energy withdrew its Yucca Mountain application with the intention of pursuing new long-term storage solutions. Until a final storage solution is found, nuclear power plants will continue storing used fuel at their sites in used fuel pools or dry cask storage.

Nuclear Energy and the Environment

Nuclear power plants have very little impact on the environment unless there is an accident. Nuclear plants produce no air pollution or carbon dioxide, because no fuel is burned. Using nuclear energy may be one way to solve air pollution problems and reduce greenhouse gas emissions that contribute to global climate change.

Nuclear power plants do require a lot of water for cooling. If the water is taken from nearby rivers or lakes and returned at a higher temperature, it can change the ecology of the water habitat.

The major challenge of nuclear power is storage of the radioactive used fuel. Right now, all of the used fuel is stored on site at the power plants. People also worry that an accident at a power plant could cause widespread damage and radioactive contamination.

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.

Nuclear Safety

The greatest potential risk from nuclear power plants is the release of high-level radiation and radioactive material. Radiation is energy given off by some elements and energy transformations. There are natural and man-made sources of radiation that we are exposed to everyday. Very small amounts of radiation are harmless to humans. Very high levels of radiation can damage or destroy the body's cells and can cause serious diseases such as cancer, or even death.

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 water 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. No injuries or fatalities occurred as a result of the error.

In 1986, in the Ukraine (former Soviet Union) at the Chernobyl nuclear power plant, two explosions blew the top off the reactor building. 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 100,000 people were evacuated from their homes and about 200 workers were treated for radiation sickness and burns. Thirty-one people were killed immediately, 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. Japan generates 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. The damage caused a loss of power that was required to keep the reactor and fuel rods 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 are all working to make sure the evacuation zone is safe and restoring it so residents can 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 Energy

What is Wind?

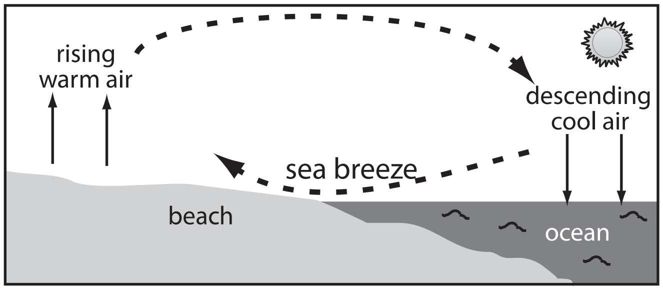
Wind is simply air in motion. It is caused by the uneven heating of the Earth's surface by radiant energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's energy at different rates. Water usually does not heat or cool as quickly as land because of its physical properties.

An ideal situation for the formation of local wind is an area where land and water meet. During the day, the air above the land heats up more quickly than the air above water. The warm air over the land expands, becomes less dense and rises.

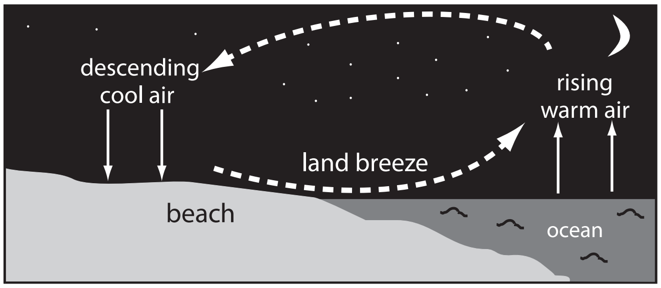
The heavier, denser, cool air over the water flows in to take its place, creating wind. In the same way, the atmospheric winds that circle the Earth are created because the land near the equator is heated more by the sun than land near the North and South Poles.

Today, people use wind energy to make electricity. Wind is called a **renewable** energy source because the wind will blow as long as the sun shines.

Sea Breeze



Land Breeze



Wind Direction

A weather vane, or wind vane, is used to show the direction of the wind. A wind vane points toward 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 Speed

It is important in many cases to know how fast the wind is blowing. Wind speed can be measured using a wind gauge or **anemometer**.

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. A display on the anemometer shows the speed of the wind.

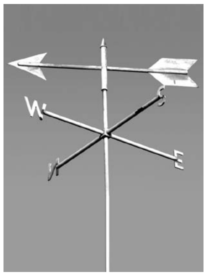
History of Wind Machines

Since ancient times, people have harnessed the wind's energy. Over 5,000 years ago, the ancient Egyptians used the wind to sail ships on the Nile River. Later, people built windmills to grind wheat and other grains. The early windmills looked like paddle wheels. Centuries later, the people in Holland improved the windmill. They gave it propeller-type blades, still made with sails. Holland is famous for its windmills.

In this country, the colonists used windmills to grind wheat and corn, to pump water, and to cut wood at sawmills. Today, people occasionally use windmills to grind grain and pump water, but they also use modern wind turbines to make electricity.

Windmill

Weather Vane



Anemometer

Today's Wind Turbines

Like old-fashioned windmills, today's **wind turbines** use blades to capture the wind's kinetic energy. Wind turbines work because they slow down the speed of the wind. When the wind blows, it pushes against the blades of the wind turbine, making them spin. They power a generator to produce electricity.

Most wind turbines have the same basic parts: blades, shafts, gears, a generator, and a cable. (Some turbines do not have gearboxes.) These parts work together to convert the wind's energy into electricity.

1. The wind blows and pushes against the blades on top of the tower, making them spin.
2. The turbine blades are connected to a low-speed drive shaft. When the blades spin, the shaft turns. The shaft is connected to a gearbox. The gears in the gearbox increase the speed of the spinning motion on a high-speed drive shaft.
3. The high-speed drive shaft is connected to a generator. As the shaft turns inside the generator, it produces electricity.
4. The electricity is sent through a cable down the turbine tower to a transmission line.

The amount of electricity that a turbine produces depends on its size and the speed of the wind. Wind turbines come in many different sizes. A small turbine may power one home. Large wind turbines can produce enough electricity to power up to 1,000 homes. Large turbines are sometimes grouped together to provide power to the electricity grid. The grid is the network of power lines connected together across the entire country.

Wind Power Plants

Wind power plants, or **wind farms**, are clusters of wind turbines used to produce electricity. A wind farm usually has dozens of wind turbines scattered over a large area.

Choosing the location of a wind farm is known as siting a wind farm. The wind speed and direction must be studied to determine where to put the turbines. As a rule, wind speed increases with height, as well as over open areas with no windbreaks.

Turbines are usually built in rows facing into the prevailing wind. Placing turbines too far apart wastes space. If turbines are too close together, they block each other's wind.

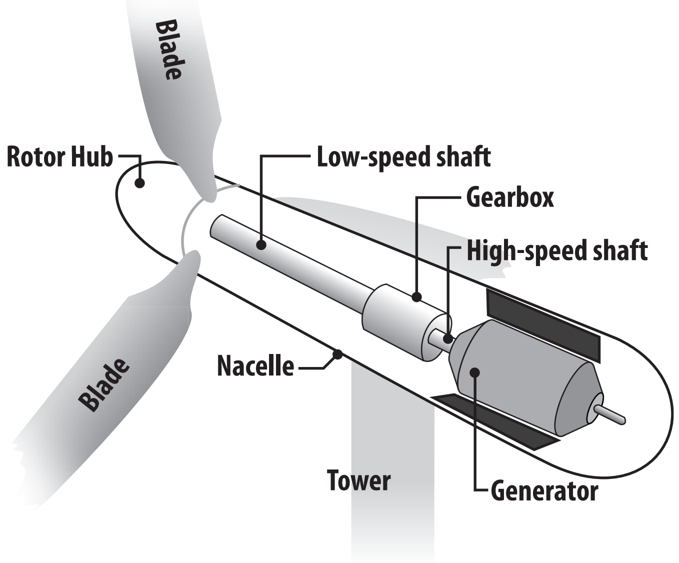
The site must have strong, steady winds. Scientists measure the winds in an area for several years before choosing a site. The best sites for wind farms are on hilltops, on the open plains, through mountain passes, and near the coasts of oceans or large lakes.

The wind blows stronger and steadier over water than over 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. Offshore turbines produce more electricity than turbines on land, but they cost more to build and operate.

The first offshore wind farm in the United States, off the coast of Massachusetts, was approved in April 2011. Construction is expected to begin in 2013.

Wind Turbine Diagram



WIND FARM

Wind Production

Every year, wind produces only a small amount of the electricity this country uses, but the amount is growing every year. One reason wind farms don't produce more electricity is that they can only run when the wind is blowing at certain speeds. On Midwestern wind farms, the wind is optimum for producing electricity between 65 and 90 percent of the time.

Environmental Impacts

In some areas, people worry about the birds and bats that may be injured by wind turbines. Some people believe wind turbines produce a lot of sound, and some think turbines affect their view of the landscape.

On the other hand, wind is a clean, renewable energy source that produces no air pollution. And wind is free to use. Wind power is not the perfect answer to our electricity needs, but it is a valuable part of the solution.

Climate Change

Earth's Atmosphere

Our Earth is surrounded by a blanket of gases called the **atmosphere**. Without this blanket, our 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 oxygen and nitrogen. The other one percent is a mixture of greenhouse gases. These greenhouse gases are mostly water vapor, carbon dioxide (CO_2), methane, CFCs, ozone, and nitrous oxide.

Carbon dioxide is the gas we produce when we breathe and when we burn wood and fossil fuels. Methane is the main gas in natural gas. It is also produced when plants and animals decay. The other greenhouse gases are produced by burning fuels and in other ways.

Sunlight and the Atmosphere

Rays of sunlight (**radiant energy**) shine down on the Earth every day. Some of these rays bounce off clouds and are reflected back into space. Some rays are absorbed by molecules in the atmosphere. About half of the sunlight passes through the atmosphere and reaches the Earth.

When the sunlight hits the Earth, most of it turns into heat (thermal energy). The Earth absorbs some of this heat. The rest flows back out toward the atmosphere. This keeps the Earth from getting too warm.

When this thermal energy reaches the atmosphere, it stops. It can't pass through the atmosphere like sunlight. Most of the heat becomes trapped and flows back to the Earth. We usually think it's sunlight that warms the Earth, but actually it's this contained thermal energy that gives us most of our warmth.

The Greenhouse Effect

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

Greenhouse Gases

What is in the atmosphere that lets light through, but traps heat? It's the greenhouse gases, mostly carbon dioxide and methane. These gases are very good at absorbing thermal energy and sending it back to Earth.

The Greenhouse Effect

Radiant energy (light rays and arrows) 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 heat (dark arrows).

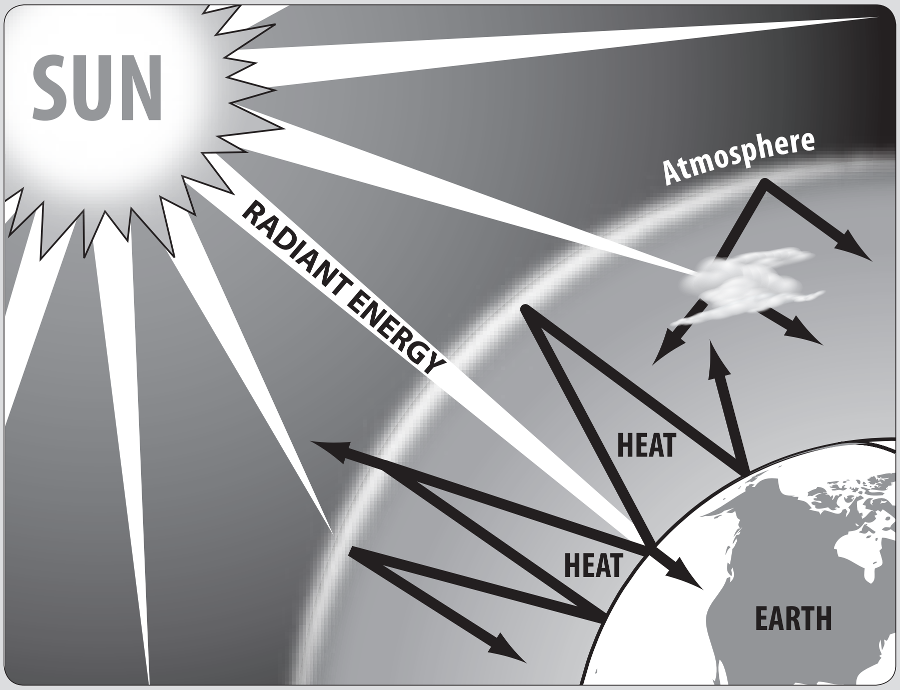
Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into heat.

The Earth absorbs some of this heat.

Most of the heat flows back into the air. The atmosphere traps the heat.

Very little of the heat escapes back into space.

The trapped heat flows back to Earth.



In the last 50 years, the amount of some greenhouse gases in the atmosphere has increased dramatically. We produce carbon dioxide when we breathe and when we burn wood and fossil fuels such as coal, oil, natural gas, and propane. Since the Industrial Revolution, CO_2 levels have risen by approximately 39 percent.

Some methane escapes from coal mines and oil wells. Some is produced when plants and garbage decay. Some animals also produce methane gas. One cow can give off enough methane in a year to fill a hot air balloon!

Global Climate Change

Scientists all over the world are studying the effects of increased levels of greenhouse gases in the Earth's atmosphere. They believe the greenhouse gases are trapping more heat in the atmosphere as levels increase. They believe the average temperature of the Earth is beginning to rise. This phenomenon is called **global warming**.

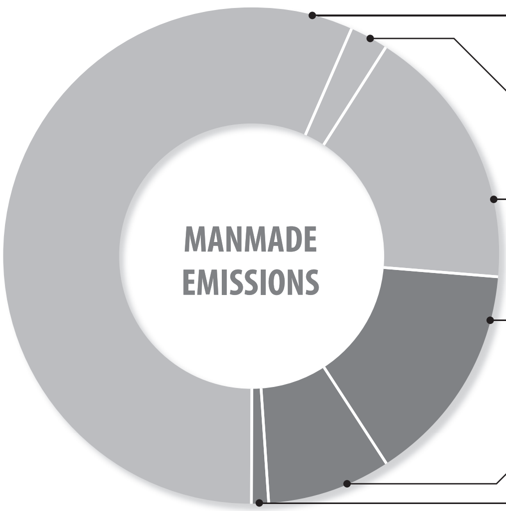
Scientists at NASA, the National Aeronautics and Space Administration, have found that the average temperature of the Earth has risen about 0.74°C in the last 100 years. They believe this increase in global temperature is the major cause of a 12 to 22 centimeter rise in the sea level over the same period of time.

Climate change experts predict that if the temperature of the Earth rises just a few degrees Fahrenheit, it will cause major changes in the world's climate. They predict there will be more floods in some places and more droughts in others. They believe the level of the oceans will rise as the ice at the North and South Poles melts. They think there might be stronger storms and hurricanes.

These scientists believe that countries all over the world need to act now to lower the amount of carbon dioxide that is emitted into the atmosphere. They believe we should reduce the amount of fossil fuels that we burn. The solutions being implemented include reducing CO_2 emissions from transportation and electricity by switching to less carbon intensive fuels. Experts around the world are trying to find ways to lower greenhouse gas emissions without causing major impacts on the economy.

Greenhouse Gases

Carbon dioxide accounts for more than 75 percent of all global greenhouse gas emissions, mainly due to the increased use of fossil fuels.
Since the Industrial Revolution, the concentration of all greenhouse gasses has increased.



GLOBAL GREENHOUSE GAS EMISSIONS		ATMOSPHERIC CONCENTRATIONS	
	2007	PRE-INDUSTRIAL (1750)	2010
CARBON DIOXIDE FROM FOSSIL FUELS	56.6%	278 parts per million	388.5 parts per million
OTHER CARBON DIOXIDE	2.8%	ALL CARBON DIOXIDE	
CARBON DIOXIDE FROM DEFORESTATION AND BIOMASS DECAY	17.3%		
METHANE	14.3%	0.72 parts per million	1.7 parts per million
NITROUS OXIDE	7.9%	0.27 parts per million	0.32 parts per million
F-GASES*	1.1%	0 parts per trillion	84.5 parts per trillion

* F-gases include HFCs, PFCs, and SF_6 which are used in many different industrial applications including as refrigerants, propellants, and tracer chemicals.

Data: U.S. Environmental Protection Agency, Intergovernmental Panel on Climate Change, Oak Ridge National Laboratory

Hydrogen

What is Hydrogen?

Hydrogen is the simplest element known to man. Each atom of hydrogen has only one proton and one electron. It is also the most plentiful gas in the universe. Stars are made primarily of hydrogen.

Like all stars, our sun's energy comes from hydrogen. The sun is a giant ball of hydrogen and helium gases. Inside the sun, hydrogen atoms combine to form helium atoms. This process, called **fusion**, gives off **radiant energy**.

This radiant energy sustains life on Earth. It gives us light and makes plants grow. It makes the wind blow and rain fall. It is stored in fossil fuels. Most of the energy we use today came from the sun.

Hydrogen as a gas (H_2) doesn't exist on Earth. It is always mixed with other elements. Combined with oxygen, it is water (H_20). Combined with carbon, it makes different compounds such as methane (CH_4), coal, and petroleum. Hydrogen is also found in all growing things—biomass.

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 Can Store Energy

Most of the energy we use comes from fossil fuels. Only eight percent comes from renewable energy sources. They are usually cleaner and can be replenished in a short period of time.

Renewable energy sources—like solar and wind—can't produce energy all the time. The sun doesn't always shine. The wind doesn't always blow. Renewables don't always make energy when or where we need it. We can use many energy sources to produce hydrogen. Hydrogen can store the energy until it's needed and move it to where it's needed.

Energy Carrier

Every day, we use more energy, mostly coal, to make electricity. Electricity is a **secondary energy source**. Secondary sources of energy—sometimes called **energy carriers**—store, move, and deliver energy to consumers. We convert energy to electricity because it is easier for us to move and use.

Electricity gives us light, heat, hot water, cold food, TVs, and computers. Life would be really hard if we had to burn the coal, split the atoms, or build our own dams. Energy carriers make life easier.

Hydrogen is an energy carrier for the future. It is a clean fuel that can be used for transportation, heating, and generating. However, since hydrogen doesn't exist on Earth as a gas, we must make it.

THE SPACE SHUTTLE

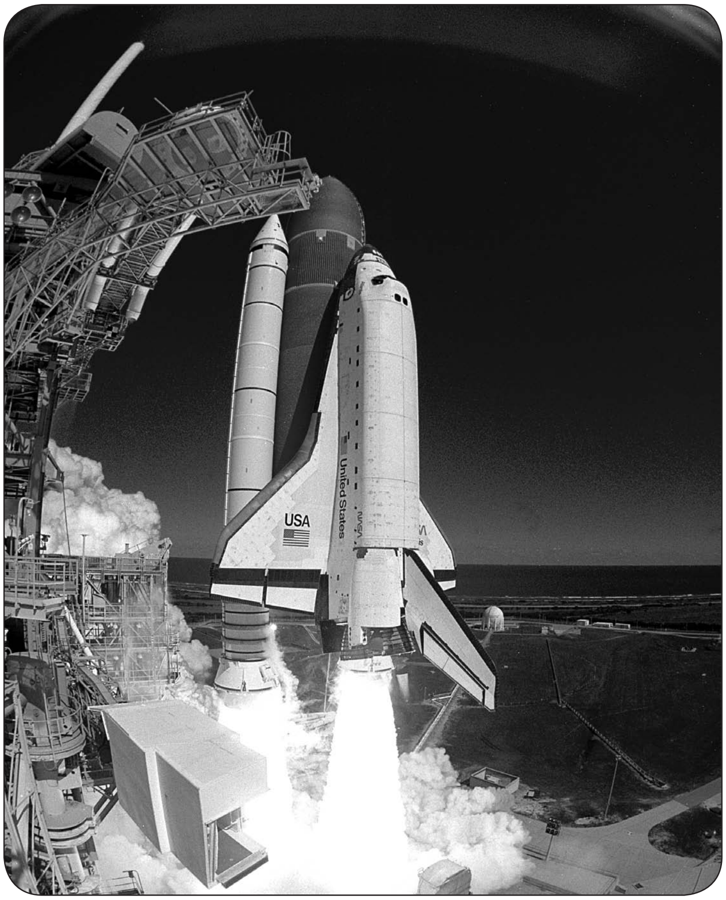
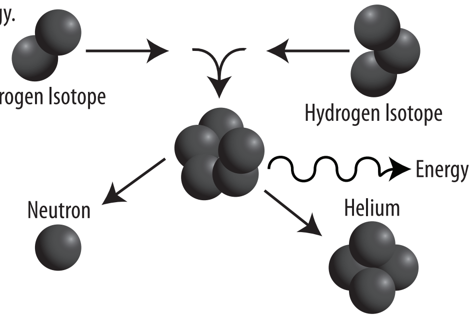


Image courtesy NASA

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

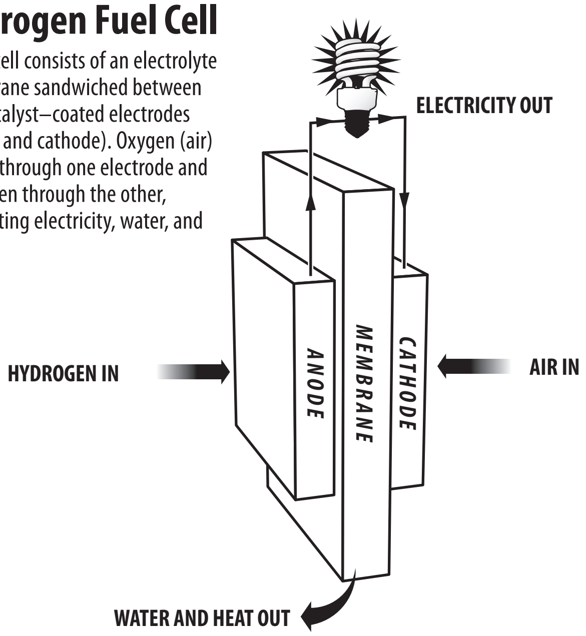
Fusion

The process of fusion most commonly involves hydrogen isotopes combining to form a helium atom with a transformation of matter. This matter is emitted as radiant energy.



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.



How is Hydrogen Made?

Hydrogen is made by separating it from water, biomass, or natural gas—from domestic resources. Scientists have even discovered that some algae and bacteria give off hydrogen. It's expensive to make hydrogen right now, but new technologies are being developed.

Hydrogen can be produced at large central facilities or at small plants for local use. Every region of the country (and the world) has some resource that can be used to make hydrogen. Its flexibility is one of its main advantages.

Uses of Hydrogen

Twenty million metric tons of hydrogen are produced in the U.S. today. Most of this hydrogen is used by industry in refining, treating metals, and processing foods.

NASA is the primary user of hydrogen as an energy fuel; it has used hydrogen for years in the space program. Hydrogen fuel lifted the space shuttle into orbit. Hydrogen batteries—called **fuel cells**—powered the shuttle's electrical systems. The only by-product was pure water, which the crew used as drinking water.

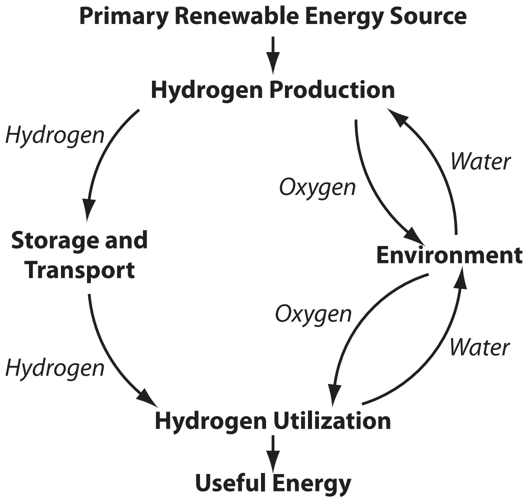
Hydrogen fuel cells make electricity. They are very efficient, but expensive to build. Small fuel cells can power electric cars. Large fuel cells can provide electricity in remote areas.

Hydrogen as a Fuel

Because of the cost, hydrogen power plants won't be built for a while. Hydrogen may soon be added to natural gas though, to reduce pollution from existing plants.

Soon hydrogen will be added to gasoline to boost performance and reduce pollution. Adding just five percent hydrogen to gasoline can significantly lower emissions of nitrogen oxides (NO_x), which contribute to ground-level ozone pollution.

Hydrogen Life Cycle



HYDROGEN-FUELED VEHICLE

Image courtesy U.S. Department of Energy

An engine that burns pure hydrogen produces almost no pollution. It will be a while though before you can walk into your local car dealer and drive away in a hydrogen-powered car.

The Future of Hydrogen

Before hydrogen becomes a significant fuel in the U.S. energy picture, many new systems must be built. We will need systems to produce hydrogen efficiently and to store and move it safely. We will need many miles of new pipelines and economical fuel cells. And consumers will need the technology and the education to use it.

The goal of the U.S. Department of Energy's Hydrogen Program is to reduce petroleum use, greenhouse gas emissions, and air pollution. With advancements in hydrogen and fuel cell technologies, hydrogen has the potential to provide a large amount of clean, renewable energy in the future.

Electricity

Electricity: The Mysterious Force

What exactly is the mysterious force we call electricity? It is simply moving **electrons**. And what exactly are electrons? They are tiny particles found in **atoms**.

Everything in the universe is made of atoms—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. There are over 100 different types of atoms found in the world around us that make up elements. Each element is identified and organized into the periodic table. Atoms of these elements are so small that millions of them would fit on the head of a pen.

Atoms are made of even smaller particles. The center of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but electrons are much, much smaller. Electrons spin around the nucleus in energy levels a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be several kilometers. Atoms are mostly empty space.

If you could see an atom, it would look a little like a tiny center of balls surrounded by giant invisible clouds (energy levels). The electrons would be on the surface of the clouds, constantly spinning and moving to stay as far away from each other as possible. Electrons are held in their levels by an electrical force.

The protons and electrons of an atom are attracted to each other. They both carry an **electrical charge**. An electrical charge is a force within the particle. Protons have a **positive charge** (+) and electrons have a **negative charge** (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. When an atom is in balance, it has an equal number of protons and electrons. Neutrons carry no charge, and their number can vary.

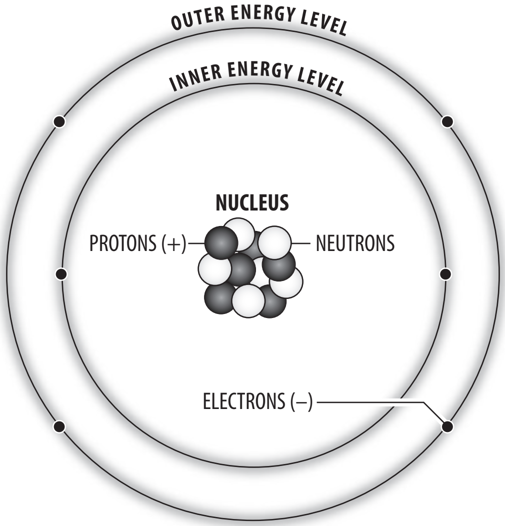
The Periodic Table of the Elements

Atomic Number — 58
Symbol — Ce
Name — Cerium
Atomic Weight — 140.116

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.989770	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Cesium 132.90545	56 Ba Barium 137.327		72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Uun Ununnilium (281)	111 Uuu Unununium (272)	112 Uub Ununbium (285)		114 Uuq Ununquadium (289)		116 Uuh Ununhexium (292)		
			Lanthanides	57 La Lanthanum 138.9055	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
			Actinides	89 Ac Actinium (227)	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Carbon Atom

A carbon atom has six protons and six neutrons in the nucleus, two electrons in the inner energy level, and four electrons in the outer energy level.



The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance in which all of the atoms are identical. An atom of hydrogen, for example, has one proton and one electron, and almost always no neutrons. Every stable atom of carbon has six protons, six electrons, and typically six neutrons. The number of protons determines which element it is; this is called the atomic number.

Electrons usually remain a relatively constant distance from the nucleus in well defined regions called energy levels. The level closest to the nucleus can hold two electrons. The next level can hold up to eight. The outer levels can hold even more. Some atoms with many protons can have as many as seven levels with electrons in them.

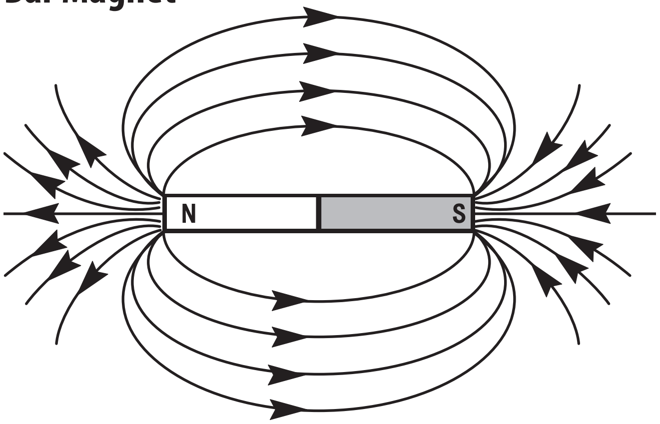
The electrons in the levels closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in the outermost levels do not. These electrons can be pushed out of their orbits. Applying a force can make them move from one atom to another. These moving electrons are electricity.

Magnets

In most objects, the molecules are arranged randomly. They are scattered evenly throughout the object.

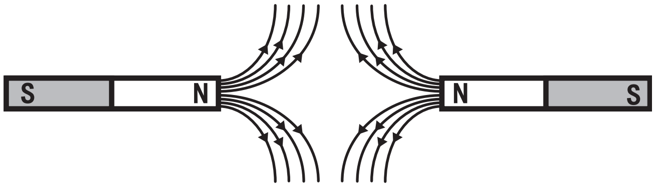
Magnets are different—they are made of molecules that have north- and south-seeking poles. Each molecule is really a tiny magnet. The molecules in a magnet are arranged so that most of the north-seeking poles point in one direction and most of the south-seeking poles point in the other. This creates a magnetic field around the magnet.

Bar Magnet



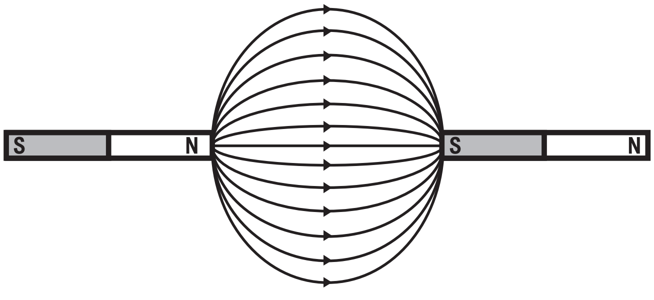
Like Poles

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



Opposite Poles

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



This creates an imbalance in the forces between the ends of a magnet and a **magnetic field** around a magnet. A magnet is labelled with north (N) and south (S) poles. The magnetic force in a magnet flows from the **north pole** to the **south pole**.

Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the south poles together, they repel each other. Two north poles also repel each other.

If you turn one magnet around, the north (N) and the south (S) poles are attracted to each other. The magnets come together with a strong force. Just like protons and electrons, opposites attract.

Magnets Can Produce Electricity

We can use magnets to make electricity. A magnetic field can move electrons. Some metals, like copper, have electrons that are loosely held; they are easily pushed from their levels.

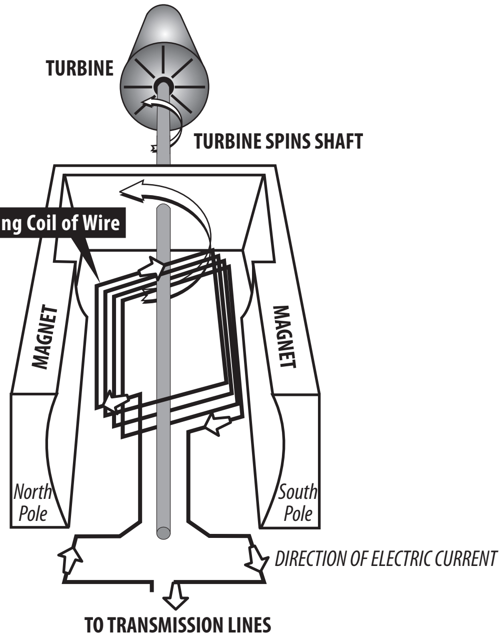
Magnetism and electricity are related. Magnets can create electricity and electricity can produce magnetic fields. Every time a magnetic field changes, an electric field is created. Every time an electric field changes, a magnetic field is created. Magnetism and electricity are always linked together; you can't have one without the other. This phenomenon is called **electromagnetism**.

Power plants use huge turbine generators to make the electricity that we use in our homes and businesses. Power plants use many fuels to spin **turbines**. They can burn coal, oil, or natural gas to make steam to spin turbines. Or they can split uranium atoms to heat water into steam. They can also use the power of rushing water from a dam or the energy in the wind to spin the turbine.

The turbine is attached to a shaft in the generator. Inside the **generator** are magnets and coils of copper wire. The magnets and coils can be designed in two ways—the turbine can spin the magnets inside the coils or can spin coils inside the magnets. Either way, the electrons are pushed from one copper atom to another by the moving magnetic field.

Coils of copper wire are attached to the turbine shaft. The shaft spins the coils of wire inside two huge magnets. The magnet on one side has its north pole to the front. The magnet on the other side has its south pole to the front. The magnetic fields around these magnets push and pull the electrons in the copper wire as the wire spins. The electrons in the coil flow into transmission lines. These moving electrons are the electricity that flows to our houses. Electricity moves through the wire very fast.

Turbine Generator



HYDROELECTRIC PLANT

HYDROPOWER TURBINE GENERATORS

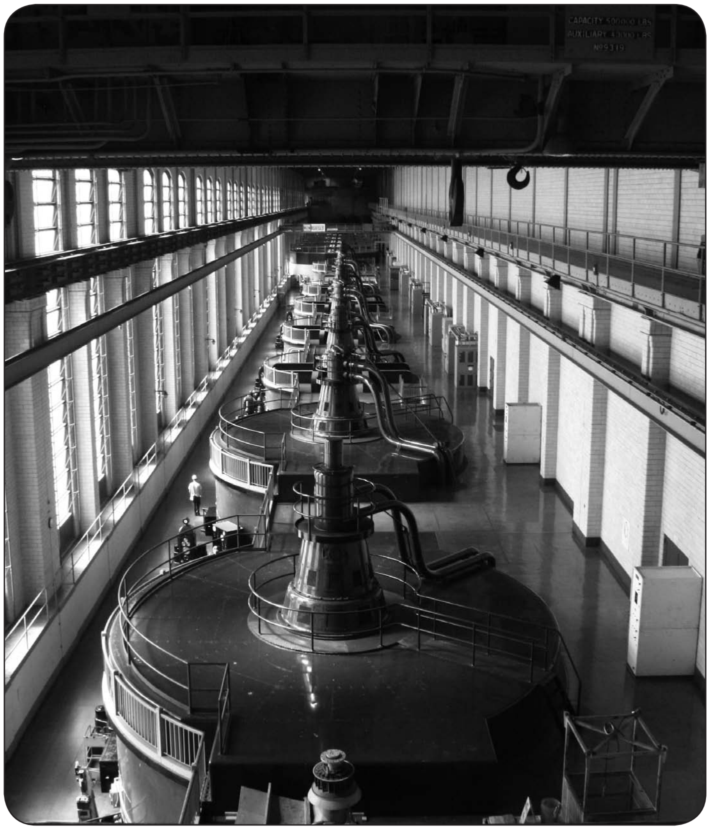


Photo of Safe Harbor Water Power Corporation on the Lower Susquehanna River in Pennsylvania.

Batteries Produce Electricity

A **battery** produces electricity using two different metals in a chemical solution. A **chemical reaction** between the metals and the chemicals frees more electrons in one metal than in the other.

One end of the battery is attached to one of the metals; the other end is attached to the other metal. The end that frees more electrons develops a positive charge, and the other end develops a negative charge. If a wire is attached from one end of the battery to the other, electrons flow through the wire to balance the electrical charge.

A **load** is a device that does work or performs a job. If a load—such as a light bulb—is placed along the wire, the electricity can do work as it flows through the wire. In the *Electrical Circuits* diagram, electrons flow from the negative end of the battery through the wire to the light bulb. The electricity flows through the wire in the light bulb and back to the battery.

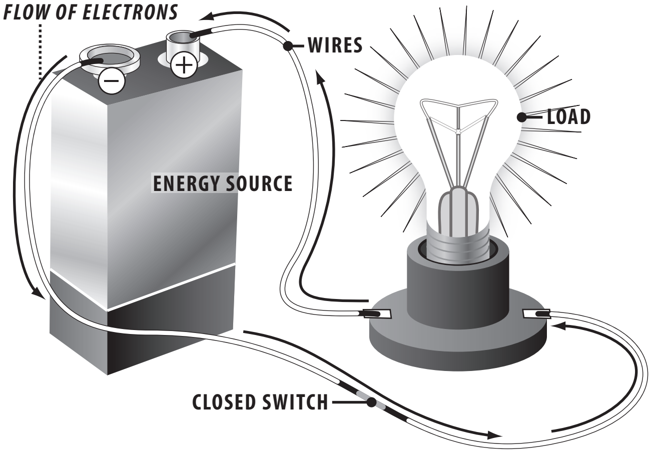
Electricity Travels in Circuits

Electricity travels in closed loops, or **circuits** (from the word circle). It must have a complete path before the electrons can move. If a circuit is open, the electrons cannot flow. When we flip on a light switch, we close a circuit. The electricity flows from the electric wire through the light and back into the wire. When we flip the switch off, we open the circuit. No electricity flows to the light.

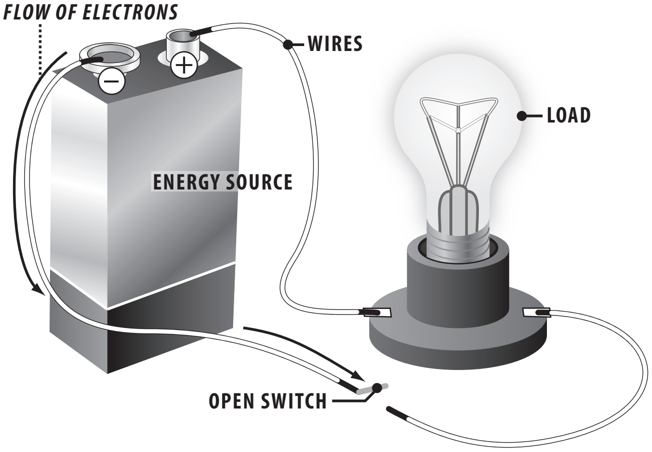
When we turn on the TV, electricity flows through wires inside the set, producing pictures and sound. Sometimes electricity runs motors—in washers or mixers. Electricity does a lot of work for us. We use it many times each day.

In the United States, we use electricity to light our homes, schools, and businesses. We use it to warm and cool our homes and help us clean them. Electricity runs our TVs, DVD players, video games, and computers. It cooks our food and washes the dishes. It mows our lawns and blows the leaves away. It can even run our cars.

Electrical Circuits

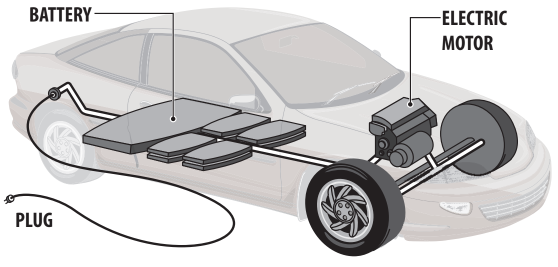


A **closed circuit** is a complete path allowing electricity to flow from the energy source to the load.



An **open circuit** has a break in the path. There is no flow of electricity because the electrons cannot complete the circuit.

How an Electric Vehicle Works



Recently, there has been more interest in using electricity to help reduce the amount of petroleum consumed by the transportation sector.

The plug-in hybrid vehicle and the dedicated electric vehicle are now available to consumers in the open market. By 2015, it is expected that many car manufacturers will be offering plug-in hybrids or dedicated electric vehicles in more models.

As the diagram to the left shows, electric vehicles store electricity in large battery banks. They are plugged into a wall outlet (either a 240-volt or standard 120-volt) for several hours to charge. An electric motor powers the wheels, and acts as a generator when the brakes are applied, recharging the battery.

Electricity

Secondary Energy Source

Electricity is different from primary sources of energy. Unlike coal, petroleum, or solar energy, electricity is a **secondary energy source**. That means we must use other energy sources to make electricity. It also means we can't classify electricity as renewable or nonrenewable.

Coal, which is nonrenewable, can be used to make electricity. So can hydropower, a renewable energy source. The energy source we use can be renewable or nonrenewable, but electricity is neither.

Generating Electricity

Most of the electricity we use in the United States is generated by large power plants. These plants use many fuels to produce electricity. Thermal power plants use coal, biomass, petroleum, or natural gas to superheat water into steam, which powers a generator to produce electricity. Nuclear power plants use fission to produce the heat. Geothermal power plants use heat from inside the Earth.

Wind farms use the kinetic energy in the wind to generate electricity, while hydropower plants use the energy in moving water.

Moving Electricity

We use more electricity every year. One reason we use so much electricity is that it's easy to move from one place to another. It can be made at a power plant and moved long distances before it is used. There is also a standard system in place so that all of our machines and appliances can operate on electricity. Electricity makes our lives simpler and easier.

Let's follow the path of electricity from a power plant to a light bulb in your home. First, the electricity is generated at a power plant. It travels through a wire to a **transformer** that **steps up** the **voltage**. Power plants step up the voltage because less electricity is lost along the power lines when it is at higher voltage.

The electricity is then sent to a nationwide network of **transmission lines**. This is called the **electric grid**. Transmission lines are the huge tower lines you see along the highway. The transmission lines are interconnected, so if one line fails, another can take over the load.

Step-down transformers, located at substations along the lines, reduce the voltage from 350,000 volts to 12,000 volts. **Substations** are small fenced-in buildings that contain transformers, switches, and other electrical equipment.

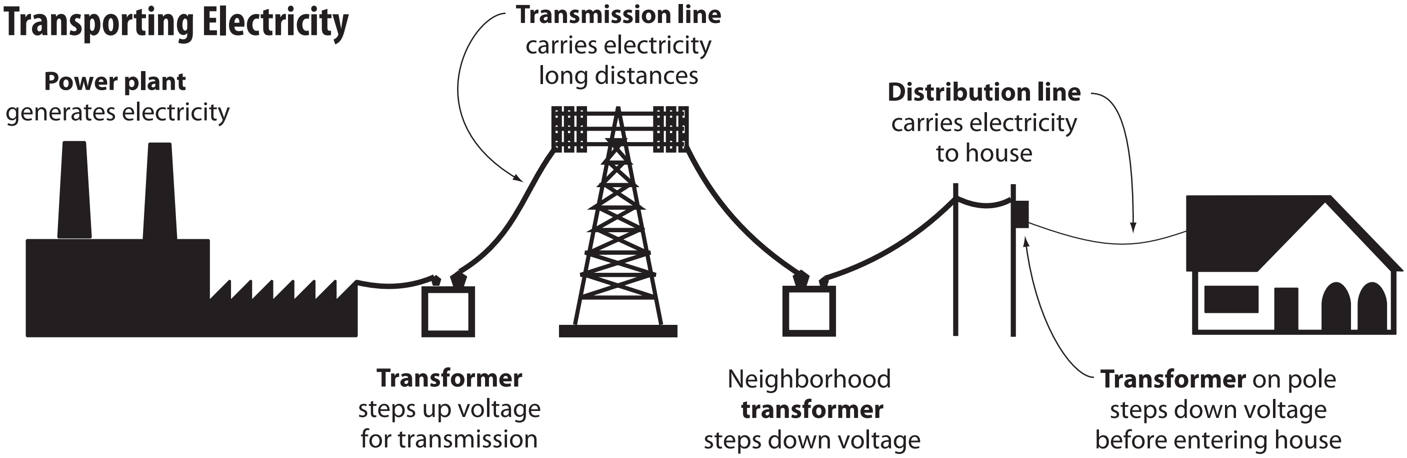
The electricity is then carried over **distribution lines** that deliver electricity to your home. These distribution lines can be located overhead or underground. The overhead distribution lines are the power lines you see along streets.

Before the electricity enters your house, the voltage is reduced again at another transformer, usually a large gray metal box mounted on an electric pole. This transformer reduces the electricity to the 120 volts that are used to operate the appliances in your home.

Electricity enters your home through a three-wire cable. Wires are run from the circuit breaker or fuse box to outlets and wall switches in your home. An electric meter measures how much electricity you use so that the utility company can bill you.

TRANSMISSION LINES

Transporting Electricity



Fuels that Make Electricity

Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydropower. Coal plants generate almost half of the electricity we use. There are also wind, geothermal, trash-to-energy, and solar power plants, which generate three percent of the electricity produced in the United States.

▪ Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or oil to produce electricity. These energy sources are called fossil fuels because they were formed from the remains of ancient sea plants and animals. Most of our electricity comes from fossil fuel plants.

Power plants burn the fossil fuels and use the heat to boil water into steam. The steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants produce emissions that can pollute the air and contribute to global climate change.

Fossil fuel plants are sometimes called **thermal power plants** because they use heat energy to make electricity. (*Therme* is the Greek word for heat.) Coal is used by most power plants because it is cheap and abundant in the United States.

There are many other uses for petroleum and natural gas, but the main use of coal is to produce electricity. Almost 92 percent of the coal mined in the United States is sent to power plants to make electricity.

▪ Nuclear Power Plants

Nuclear power plants are called thermal power plants, too. They produce electricity in much the same way as fossil fuel plants, except that the fuel they use is **uranium**, which isn't burned.

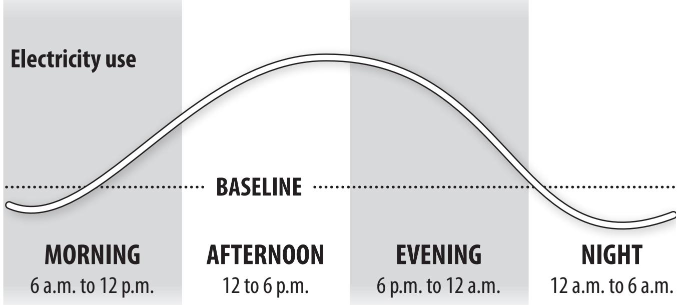
Uranium is a mineral found in rocks underground. A nuclear power plant splits the nuclei (centers) of uranium atoms to make smaller atoms in a process called **fission** that produces enormous amounts of heat. The heat is used to turn water into steam, which drives a turbine generator.

Nuclear power plants don't produce carbon dioxide emissions, but their waste is radioactive. Nuclear waste must be stored carefully to prevent contamination of people and the environment.

▪ Hydropower Plants

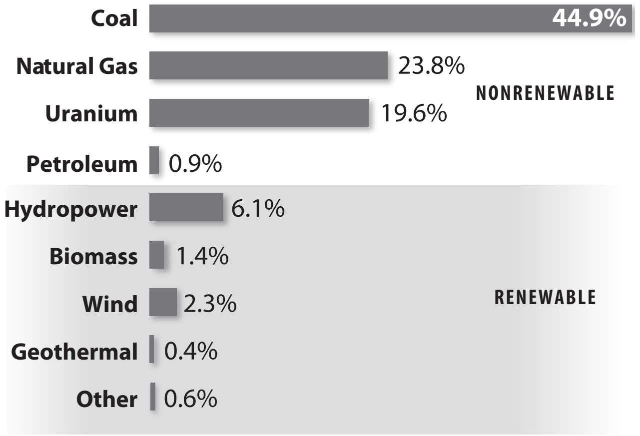
Hydropower plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

Peak Demand



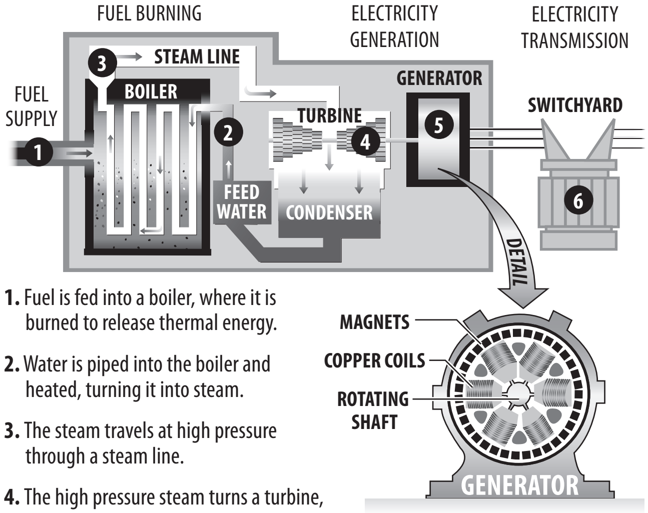
Peak load is the maximum load during a specified period of time.

U.S. Electricity Net Generation, 2010



Data: Energy Information Administration

Thermal Power Plant



1. Fuel is fed into a boiler, where it is burned to release thermal energy.

2. Water is piped into the boiler and heated, turning it into steam.

3. The steam travels at high pressure through a steam line.

4. The high pressure steam turns a turbine, which spins a shaft.

5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.

6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

Electricity

What's a Watt?

We use electricity to perform many tasks. We use units called watts, kilowatts, and kilowatt-hours to measure the electricity that we use.

A **watt** is a measure of the electric power an appliance uses. Every appliance requires a certain number of watts to work correctly. Traditional light bulbs were rated by watts (60, 75, 100), as well as home appliances, such as a 1500-watt hairdryer. A **kilowatt** is 1,000 watts. It is used to measure larger amounts of electricity.

A **kilowatt-hour** measures the amount of electricity used in one hour. Sometimes it's easier to understand these terms if you compare them to water in a pool. A kilowatt is the *rate* of electric flow, or how fast the water goes into a pool. A kilowatt-hour is the *amount* of electricity, or how much water is added to the pool. We pay for the electricity we use in kilowatt-hours. Our power company sends us a bill for the number of kilowatt-hours we use every month. Most residential consumers in the United States pay about 12 cents per kilowatt-hour of electricity. In 2010, Idaho residents paid the least for electricity: less than 8 cents per kilowatt-hour. Hawaii residents paid the most: more than 28 cents per kilowatt-hour.

How Much is a Watt?

1 WATT
Small, LED flashlight

1.5 KILOWATTS =
1500 WATTS
Blow dryer

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

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

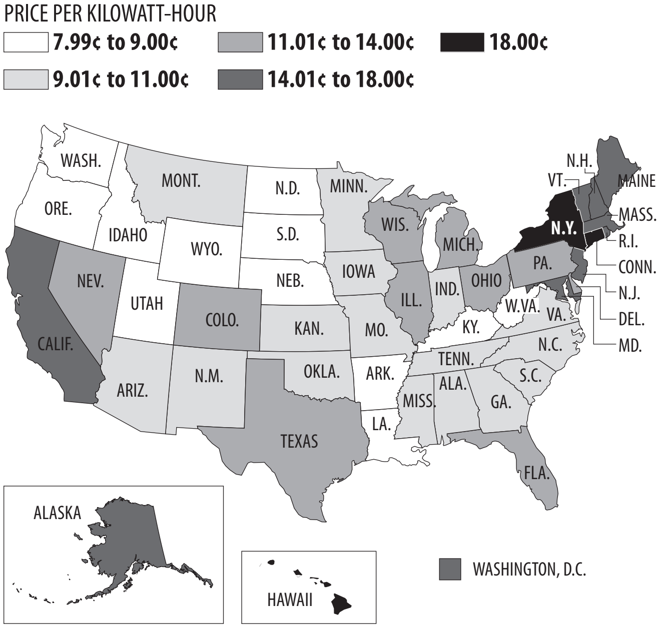
Cost of Electricity

How much does it cost to make electricity? It depends on several factors, such as:

- **Fuel Cost**: The major cost of generating electricity is the cost of the fuel. Many energy sources can be used. Hydropower is the cheapest way and solar cells are probably the most expensive way to generate power.
- **Building Cost**: Another key is the cost of building the power plant itself. A plant may be very expensive to build, but the low cost of the fuel can make the electricity economical to produce. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is inexpensive. Coal-fired plants, on the other hand, are cheaper to build, but their fuel—coal—is more expensive.
- **Efficiency**: When figuring cost, you must also consider a plant's efficiency. Efficiency is the amount of useful energy you get out of a system. A totally efficient machine would change all the energy put in it into useful work. Changing one form of energy into another always involves a loss of usable energy.

In general, today's power plants use three units of fuel to produce one unit of electricity. Most of the lost energy is waste heat. You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on some power plants. A typical coal plant burns about 8,000 tons of coal each day. About two-thirds of the chemical energy in the coal (5,300 tons) is lost as it is converted first to heat energy, and then to motion energy, and finally into electrical energy.

Average Residential Price for Electricity, 2010



Data: Energy Information Administration

Measuring Electricity

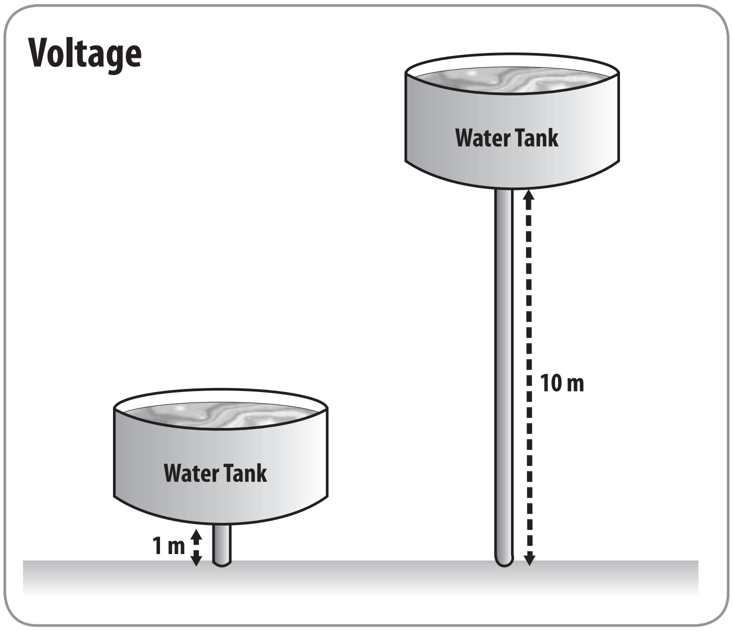
Electricity Measurement

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 may not have a clear understanding of these terms. We buy a 60-watt light bulb, a tool that needs 120 volts, or a vacuum cleaner that uses 8.8 amps, and we don't think about what those units mean.

Again, 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 one-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.

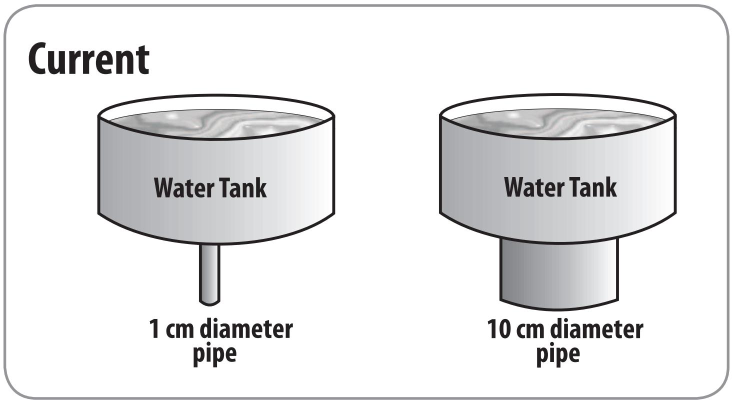
Voltage (V) is a measure of the pressure applied to electrons to make them move. It is a measure of the strength of the current in a circuit and is measured in **volts (V)**. Just as the 10-meter tank applies greater pressure than the 1-meter tank, a 10-volt power supply (such as a battery) would apply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

AA batteries are 1.5 volts; they apply a small amount of voltage or pressure 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 amount of 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 flowing past a fixed point; electrical current is the number of electrons flowing past a fixed point. **Electrical 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 X 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.

Measuring Electricity

Resistance

Resistance (R) is a property that slows the flow of electrons. Using the water analogy, resistance is anything that slows water flow, a smaller pipe or fins on the inside of a pipe. In electrical terms, the resistance of a conducting wire depends on the metal the wire is made of and its 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. In the substances he tested, 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 written in three simple formulas. If you know any two of the measurements, you can calculate the third using the formulas to the right.

Electrical Power

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

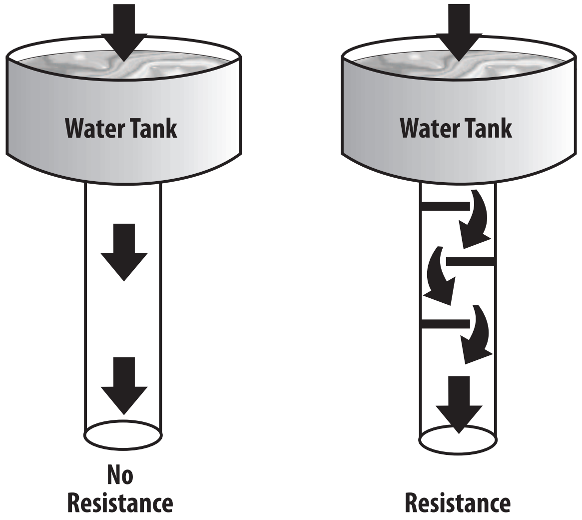
A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater force (voltage) than at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from 10 meters.

Electrical 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. Electrical power is measured in **watts (W)**.

ELECTRICAL POWER FORMULA

- **Power = voltage x current**
  P= V x I or W = V x A

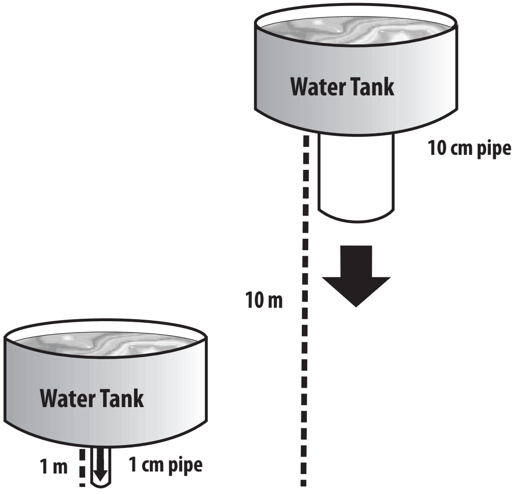
Resistance



OHM'S LAW

- **Voltage = current x resistance**
  V = I x R or V = A x Ω
- **Current = voltage / resistance**
  I = V / R or A = V / Ω
- **Resistance = voltage / current**
  R = V / I or Ω = V / A

Electrical Power



Electrical Energy

Electrical energy introduces the concept of time to electrical 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 electrical 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 (E) = Power (P) x Time (t)**
  E = P x t or E = W x 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

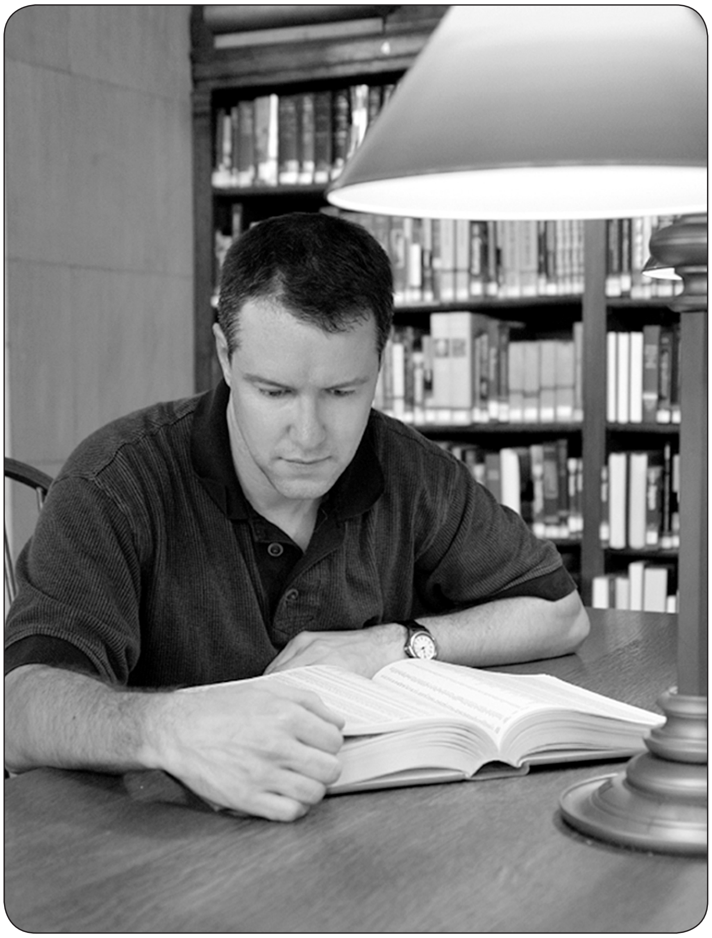
The distance traveled represents the work done by the car. When we look at power, we are talking about the rate that electrical energy is being produced or consumed. Energy is analogous to the distance traveled or the work done by the car.

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 electrical 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 5 hours with a 100-W bulb, for example, you would use the following formula:

- **Energy = Power x Time**
  E = P x t

  Energy = 100 W x 5 hours = 500 Wh



One watt-hour is a very small amount of electrical energy. Usually, we measure electrical 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 $0.12.

To calculate the cost of reading with a 100-W bulb for 5 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:

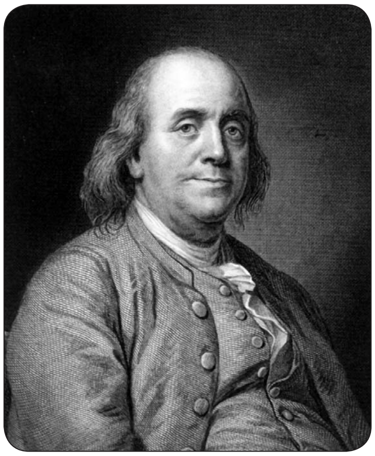
500 Wh divided by 1,000 = 0.5 kWh

0.5 kWh x $0.12/kWh = $0.06

It would cost about six cents to read for five hours using a 100-W bulb.

History of Electricity

Starting With Ben Franklin



Benjamin Franklin
Image courtesy of NOAA Photo Library

Many people think **Benjamin Franklin** discovered electricity with his famous kite-flying experiments in 1752, but electricity was not discovered all at once. At first, electricity was associated with light. People wanted a cheap and safe way to light their homes, and scientists thought electricity might be a way.

The Battery

Alessandro Volta

Learning how to produce and use electricity was not easy. For a long time there was no dependable source of electricity for experiments. Finally, in 1800, **Alessandro Volta**, an Italian scientist, made a great discovery. He soaked paper in salt water, placed zinc and copper on opposite sides of the paper, and watched the chemical reaction produce an electric current. Volta had created the first electric cell.

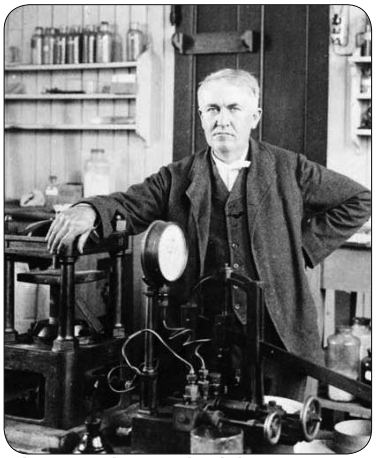
By connecting many of these cells together, Volta was able to "string a current" and create a battery. It is in honor of Volta that we rate batteries in **volts**. Finally, a safe and dependable source of electricity was available, making it easy for scientists to study electricity.

A Current Began

An English scientist, **Michael Faraday**, was the first one to realize that an electric current could be produced by passing a magnet through a copper wire. It was an amazing discovery. Almost all the electricity we use today is made with magnets and coils of copper wire in giant power plants.

Both the electric generator and electric motor are based on this principle. A **generator** converts motion energy into electricity. A **motor** converts electrical energy into **motion energy**.

Mr. Edison and His Light



Thomas Edison in his lab in 1901.
Image courtesy of U.S. Library of Congress

In 1879, **Thomas Edison** focused on inventing a practical light bulb, one that would last a long time before burning out. The problem was finding a strong material for the filament, the small wire inside the bulb that conducts electricity. Finally, Edison used ordinary cotton thread that had been soaked in carbon. This filament didn't burn at all—it became **incandescent**; that is, it glowed.

The next challenge was developing an electrical system that could provide people with a practical source of energy to power these new lights. Edison wanted a way to make electricity both practical and inexpensive. He designed and built the first electric power plant that was able to produce electricity and carry it 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, though. In today's dollars, the electricity cost $5.00 per kilowatt-hour! Today, electricity costs about 12 cents per kilowatt-hour for residential customers, and about 7 cents per kilowatt-hour for industry.

AC or DC?

The turning point of the electric age came a few years later with the development of **AC (alternating current)** power systems. With alternating current, power plants could transport electricity much farther than before. In 1895, **George Westinghouse** opened the first major power plant at Niagara Falls using alternating current. 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 more than 200 miles!

Electricity didn't have an easy beginning. Many people were thrilled with all the new inventions, but some people were afraid of electricity and wary of bringing it into their homes. 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 gas lights. Perhaps they were right, but the new electric age could not be dimmed.

In 1920, only two percent of the energy in the U. S. was used to make electricity. Today, about 40 percent of all energy is used to make electricity. As our use of technology grows, that figure will continue to rise.

Facts of Light

Facts of Light

One-third of the electricity used by schools is for lighting. In homes, up to six percent of our energy use is for lighting. Much of the light is produced by **incandescent light bulbs**, using the same technology developed in 1879 by Thomas Edison. These bulbs are surprisingly inefficient, converting up to 90 percent of the electricity they consume into heat.

The Energy Independence and Security Act of 2007 changed the standards for the efficiency of light bulbs used most often. By 2014, most general use bulbs will need to be 30 percent more effcicient 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. Most incandescent light bulbs will be slowly phased out and no longer for sale. 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, ineffcicient 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 lamps (CFLs) are four times as efficient as incandescent bulbs and last up to ten times longer. These new bulbs fit almost any socket, produce a warm glow and, unlike the earlier models, no longer flicker and dim. Over the life of the bulbs, CFLs cost the average consumer about a quarter of the cost of traditional incandescent bulbs for the same amount of light. CFLs have a small amount of mercury inside and should always be recycled rather than thrown away. Many retailers recycle CFLs for free.

Once used mainly for exit signs and power on/off indicators, technology and lower prices are enabling **light emitting diodes (LEDs)** to be used in place of incandescents and CFLs.

LEDs are one of the most energy-efficient lighting choices available today. They use even less energy than a CFL and last 25 times longer than traditional incandescent bulbs. LEDs are currently expensive, but as demand increases, their prices are expected to decrease significantly.

Cost of 25,000 Hours of Light

All bulbs provide about 850 lumens of light.

	COST OF BULB	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Life of bulb (how long it will light)	1,000 hours	3,000 hours	10,000 hours	25,000 hours
	Number of bulbs to get 25,000 hours	25 bulbs	8.3 bulbs	2.5 bulbs	1 bulb
x	Price per bulb	$0.50	$3.00	$3.00	$40.00
=	**Cost of bulbs for 25,000 hours of light**	**$12.50**	**$24.90**	**$7.50**	**$40.00**
	COST OF ELECTRICITY	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Total Hours	25,000 hours	25,000 hours	25,000 hours	25,000 hours
x	Wattage	60 watts = 0.060 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
=	Total kWh consumption	1,500 kWh	1075 kWh	325 kWh	300 kWh
x	Price of electricity per kWh	$0.12	$0.12	$0.12	$0.12
=	**Cost of Electricity**	**$180.00**	**$129.00**	**$39.00**	**$36.00**
	LIFE CYCLE COST	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Cost of bulbs	$12.50	$24.90	$7.50	$40.00
+	Cost of electricity	$180.00	$129.00	$39.00	$36.00
=	**Life cycle cost**	**$192.50**	**$153.90**	**$46.50**	**$76.00**
	ENVIRONMENTAL IMPACT	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Total kWh consumption	1500 kWh	1075 kWh	325 kWh	300 kWh
x	Pounds (lbs) of carbon dioxide per kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh
=	**Pounds of carbon dioxide produced**	**2,400 lbs carbon dioxide**	**1720 lbs carbon dioxide**	**520 lbs carbon dioxide**	**480 lbs carbon dioxide**

$
EFFICIENCY
CONSERVATION

Energy Consumption

Energy Use

Think about how you use energy every day. You wake up to an alarm clock. You take a shower with water warmed by a hot water heater. You listen to music on the radio as you dress. You catch the bus to school. That's just the energy you use before you get to school! Every day, the average American uses about as much energy as is stored in seven gallons of gasoline. Energy use is sometimes called energy consumption.

Who Uses Energy?

The U.S. Department of Energy divides energy users into different categories: residential, commercial, industrial, and transportation. These are called the sectors of the economy.

Residential and Commercial Sectors

Any place where people live is considered a **residential building**. **Commercial buildings** include offices, stores, hospitals, restaurants, and schools. Residential and commercial buildings are grouped together because they use energy in the same ways—for heating and cooling, lighting, heating water, and operating appliances.

Together, homes and buildings consume more than 40 percent of the energy used in the United States today. In the last 30 years, Americans have reduced the amount of energy used in their homes and commercial buildings. We still heat and cool rooms, and heat hot water. We have more home and office machines than ever. Most of the energy savings have come from improvements in technology and in the ways the equipment is manufactured.

▪ Heating and Cooling

It takes a lot of energy to heat rooms in winter and cool them in summer. Fifty-four percent of the energy used in the average home is for heating and cooling rooms. The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, more than half the nation's homes use natural gas for heating.

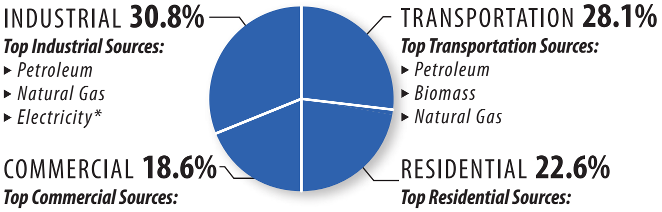
Most natural gas furnaces in the 1970s and 1980s were about 60 percent efficient. That means they converted 60 percent of the energy in the natural gas into usable heat. New gas furnaces are designed to be up to 98 percent efficient.

The second leading fuel for home heating is electricity. Electricity also provides almost all of the energy used for air conditioning. The efficiency of heat pumps and air conditioners has increased more than 50 percent in the last 30 years.

Heating oil is the third leading fuel used for home heating. In 1973, the average home used 1,300 gallons of oil a year. Today, that figure is about 660 gallons, a significant decrease. New oil furnaces burn oil more cleanly and operate more efficiently.

In the future, we may see more use of renewable energy sources, such as geothermal and solar energy, to heat and cool our homes and workspaces.

U.S. Energy Consumption by Sector, 2010



INDUSTRIAL **30.8%**

Top Industrial Sources:
- *Petroleum*
- *Natural Gas*
- *Electricity**

TRANSPORTATION **28.1%**

Top Transportation Sources:
- *Petroleum*
- *Biomass*
- *Natural Gas*

COMMERCIAL **18.6%**

Top Commercial Sources:
- *Electricity**
- *Natural Gas*
- *Petroleum*

RESIDENTIAL **22.6%**

Top Residential Sources:
- *Natural Gas*
- *Electricity**
- *Petroleum*

*Electricity is an energy carrier, not a primary energy source.
Note: Figures are rounded.
Data: Energy Information Administration

▪ Lighting

Homes and commercial buildings also use energy for lighting. The average home spends six percent of its energy bills for lighting. Schools, stores, and businesses use about 38 percent of their electricity for lighting. Most commercial buildings use fluorescent lighting. It costs more to install, but it uses a lot less energy to produce the same amount of light.

Most homes still use the type of light bulb invented by Thomas Edison over 100 years ago. These **incandescent bulbs** are not very efficient. Only about 10 percent of the electricity they consume is converted into light. The other 90 percent is converted to heat.

Due to the Energy Independence and Security Act of 2007, traditional, inefficient incandescent light bulbs are being phased out of use in the U.S. over the next few years. Consumers can choose several types of more efficient light bulbs as replacements. Energy-saving incandescent, or halogen, bulbs are more expensive than traditional incandescent, but use 25 percent less energy and last three times as long.

Compact fluorescent light bulbs (CFLs) can be used in light fixtures throughout homes. Many people think they cost too much to buy (about $3 to $10 each), but they actually cost less overall because they last longer and use less energy than incandescent bulbs.

Even more efficient than CFL light bulbs, **light emitting diodes (LEDs)** are available. They are still quite expensive, but costs will decrease as they become more widely adopted.

▪ Appliances

Over the last 100 years, appliances have changed the way we spend our time at home. Chores that used to take hours can now be done in minutes by using electricity instead of human energy. In 1990, Congress passed the National Appliance Energy Conservation Act, which requires appliances to meet strict energy efficiency standards. As a result of this Act, home appliances have become more energy efficient. Water heaters, refrigerators, clothes washers, and dryers all use much less energy today than they did 25 years ago.

Appliance Efficiency Ratings

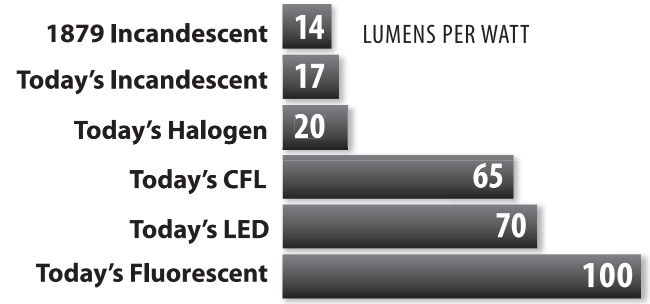
When you buy an appliance, you should pay attention to the yellow EnergyGuide label on every appliance. This label tells you the Energy Efficiency Rating (EER) of the appliance. The EER tells how much it costs to operate the appliance.

Payback Period

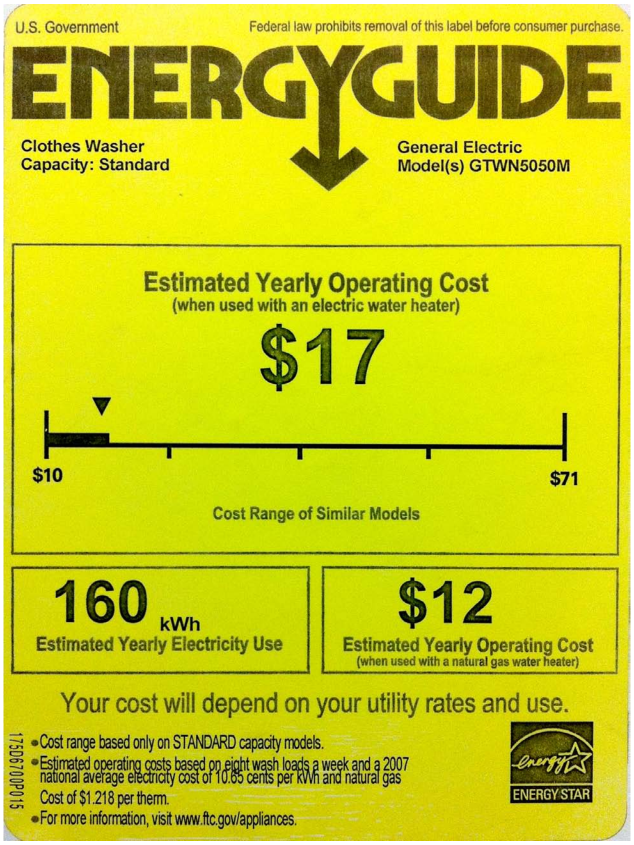
Whether you buy a furnace, hot water heater, or other home appliance, you must choose the best bargain. Since most high-efficiency systems and appliances cost more than less efficient ones, you have to know how much it will cost to operate the appliance each year and how many years you can expect to use it. The **payback period** is the amount of time you must use a system or appliance before you begin to benefit from energy savings.

For example, if you buy an efficient refrigerator that costs $100 more, but uses $20 less electricity each year, you would begin saving money after five years. Your payback period would be five years. Since refrigerators usually last ten years, you would save $100 over the life of the appliance and save natural resources.

Lighting Efficiency



ENERGYGUIDE LABEL



U.S. Government

Federal law prohibits removal of this label before consumer purchase.

ENERGYGUIDE

Clothes Washer
Capacity: Standard

General Electric
Model(s) GTWN5050M

Estimated Yearly Operating Cost
(when used with an electric water heater)

$17

$10 — $71

Cost Range of Similar Models

160 kWh
Estimated Yearly Electricity Use

$12
Estimated Yearly Operating Cost
(when used with a natural gas water heater)

Your cost will depend on your utility rates and use.

- Cost range based only on STANDARD capacity models.
- Estimated operating costs based on eight wash loads a week and a 2007 national average electricity cost of 10.65 cents per kWh and natural gas Cost of $1.218 per therm.
- For more information, visit www.ftc.gov/appliances.

175D6700P015

ENERGY STAR

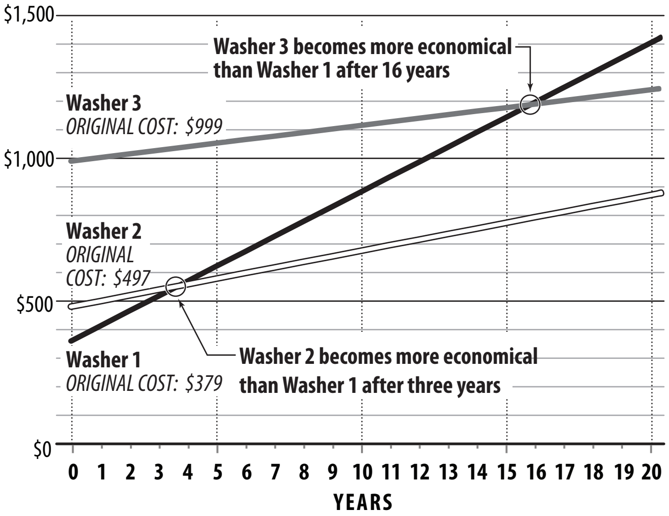
Washing Machine Payback Period

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)	$0.12	$0.12	$0.12
Operating Cost per Year	$51.24	$19.20	$12.24

Data: NEED analysis of washing machine EnergyGuide labels

COST OVER THE LIFETIME OF THE MACHINE



Washer 3 becomes more economical than Washer 1 after 16 years

Washer 2 becomes more economical than Washer 1 after three years

Energy Consumption

Industrial Sector

The United States is a highly industrialized country. We use a lot of energy. Today, the industrial sector uses 31 percent of the nation's energy. Since 1973, the **industrial sector** has grown by two-thirds, but has used only 15 percent more energy to fuel that growth. Every industry uses energy, but six energy-intensive industries use most of the energy consumed by the industrial sector.

▪ Petroleum Refining

The United States uses more petroleum than any other energy source. Petroleum provides the U.S. with about 35 percent of the energy we use each year. Petroleum can't be used as it comes out of the ground. It must be refined before it can be used.

Oil refineries use a lot of energy to convert crude oil into gasoline, diesel fuel, heating oil, chemicals, and other products. About a quarter of the energy used by the industrial sector was for refining petroleum. Refineries today use about 30 percent less energy than they did in 1973.

▪ Steel Manufacturing

The steel industry uses energy to turn iron ore and scrap metal into steel. Hundreds of the products we use every day are made of steel. It is a very hard, durable metal and it must be heated to very high temperatures to manufacture it. Producing those high temperatures takes a lot of energy. The cost of energy in the steel industry is 15 percent of the total cost of making the steel. Most of this energy comes from coal and natural gas, or electricity generated from those sources.

Since 1975, the steel industry has reduced its energy consumption by 45 percent per ton of steel. New technology has made steel stronger so that less steel is needed for many uses. For example, the Willis Tower, formerly the Sears Tower, in Chicago could be built today using 35 percent less steel.

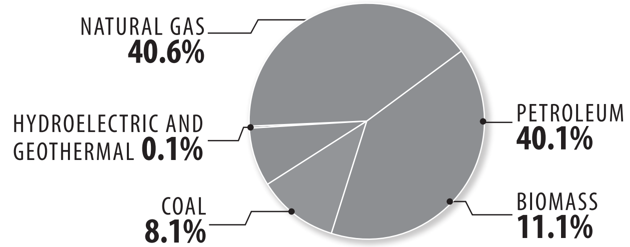
The use of recycled steel also saves energy. It requires 75 percent less energy to recycle steel than to make it from iron ore. Today, two-thirds of new steel is made from recycled scrap, making steel the nation's leading recycled product.

▪ Aluminum Manufacturing

Aluminum is a very light-weight, versatile metal. We use aluminum to make soft drink cans, building materials, car parts, and many other products. The U.S. is the world's largest consumer of aluminum.

It takes huge amounts of electricity to make aluminum from bauxite, or aluminum ore. Today, it takes 58 percent less energy to produce a pound of aluminum than it did 40 years ago. Using recycled aluminum requires about 95 percent less energy than converting bauxite into metal. In 2010, about one-third of the supply for aluminum production came from recycled materials.

U.S. Industrial Energy Consumption by Source, 2010



Data: Energy Information Administration

PETROLEUM REFINERY

Image courtesy of BP

STEEL PRODUCTION

▪ Paper Manufacturing

The United States uses enormous amounts of paper every day—newspapers, books, bags, and boxes are all made of paper. In fact, the U.S. is the world's leading producer and consumer of paper and paper products.

Energy is used in every step of paper making. Energy is used to chop, grind, and cook the wood into pulp. More energy is used to roll and dry the pulp into paper. In 1973, the amount of energy needed to make one ream (500 sheets) of copy paper was equal to 3.7 gallons of gasoline. Today, with advanced technologies, the energy used to make the same amount of paper would equal just two gallons of gasoline.

The paper and pulp industry uses 42 percent less energy today, mainly because of better technology and increased use of wood waste to generate electricity on-site. Many industries have lowered energy use by using recycled materials. In the paper and pulp industry, it is not cheaper to use recycled paper because it costs money to collect, sort, and process the waste paper.

Recycling has other benefits, though. It reduces the amount of paper in landfills and means fewer trees must be cut.

▪ Chemical Manufacturing

Chemicals are an important part of our lives. We use chemicals in our medicines, cleaning products, fertilizers and plastics, as well as in many of our foods. The U.S. has the world's largest chemical industry. Chemical manufacturing uses almost one-quarter of the energy consumed by the industrial sector.

The chemical industry uses energy in two ways. It uses coal, oil, and natural gas to power the machinery to make the chemicals. It also uses petroleum, propane, and natural gas as major sources of hydrocarbons from which the chemicals are made.

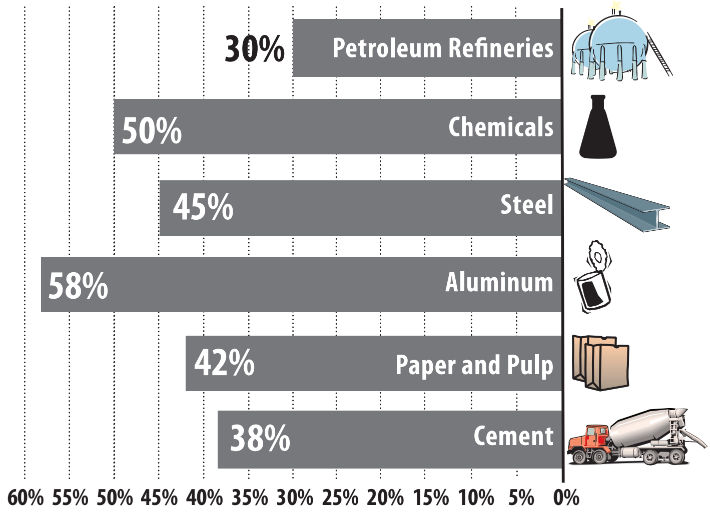
New technology has increased energy efficiency in the chemical industry by more than 50 percent in the last 35 years.

▪ Cement Manufacturing

Some people think the United States is becoming a nation of concrete. New roads and buildings are being built everywhere, every day. We use lots of concrete.

Concrete is made from cement, water, and crushed stone. A lot of energy is used in making cement. The process requires extremely high temperatures—up to 3,500 degrees Fahrenheit.

Cement plants have reduced their energy consumption by more than one-third using innovative waste-to-energy programs. Many of the cement plants in the U.S. use waste fuels to meet between 20 and 70 percent of their energy needs. These wastes, such as printing inks, dry cleaning fluids, and used tires, have high energy content. For example, the energy content of one pound of tires is greater than one pound of coal. This industry is using energy that would otherwise be wasted in a landfill.



Reduction in Energy Use, 1975 to Today

Data: U.S. Department of Energy, American Chemistry Council, Portland Cement Association

PAPER RECYCLING

Image courtesy of National Renewable Energy Laboratory

Energy Consumption

Transportation Sector

The United States is a big country. The **transportation sector** uses twenty-eight percent of the energy supply to move people and goods from one place to another.

▪ The Automobile

Americans love automobiles. We love to drive them. We don't want anyone telling us what kind of car to buy or how much to drive it. Forty years ago, most Americans drove big cars that used a lot of gas. The gas shortages of the 1970s didn't change Americans' driving habits much. What did change was the way automobiles were built. Automakers began making cars smaller and lighter. They built smaller and more efficient engines.

One reason for the changes was that the government passed laws requiring automobiles to get better gas mileage. With new technologies, cars now travel more miles on each gallon of gas. Today, new passenger cars get an average of 34 miles per gallon. If automakers hadn't made these changes, we would be using 30 percent more fuel than we do today.

In 1973, there were 102 million cars on the road. Today, there are more than 137 million cars. There are more cars being driven more miles than ever before. Fifty-one percent of the passenger vehicles sold in 2010 were sport utility vehicles and light trucks. With the recent fluctuations in fuel prices, however, demand for these big vehicles has dropped, while demand for hybrids and other fuel efficient vehicles has increased.

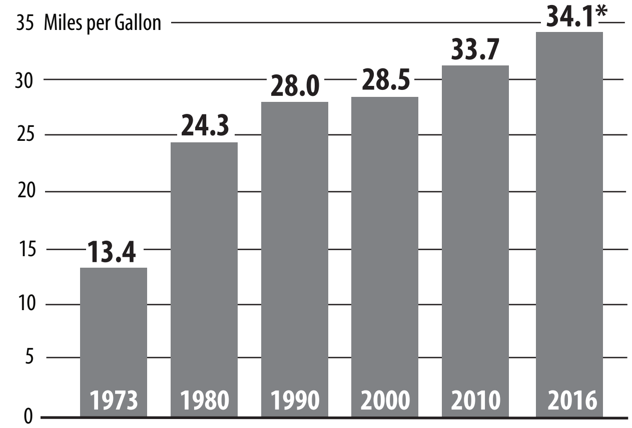
▪ Commercial Transportation

Passenger cars and light trucks consume about two-thirds of the fuel we use for transportation. Commercial vehicles consume the rest. These vehicles—trains, trucks, buses, and planes—carry people and products all across this vast country. Commercial vehicles have also become more fuel efficient in the last 40 years.

- **Trucks** use more fuel than any other commercial vehicle. Almost all products are at some point transported by truck. Trucks are big and don't get good gas mileage. They have diesel engines and can travel farther on a gallon of diesel fuel than they could on a gallon of gasoline.
- **Trains** carry most of the freight between cities. In the last 30 years, trains have improved their fuel efficiency by 52 percent. Trains are lighter and stronger and new locomotives are more efficient.
- **Airplanes** move people and products all over the country. In 2010, more than 712 million passengers flew on planes. Airlines are twice as efficient today as they were 30 years ago. Fuel is one of the biggest operating costs for airlines. Making planes more energy efficient is very important to airlines.
- **Mass Transit** is public transportation for moving people on buses, trains, light rail, and subways. In 1970, nine percent of workers who commuted to work used public transit systems. Today, only five percent travel by mass transit. Why is this? One reason is that Americans love their cars. Another is that people have moved from cities to suburbs and many businesses have followed. Most mass transit systems were designed to move people around cities or from suburbs to cities. Very few systems move people from suburb to suburb.

  Most people worry about air pollution from auto exhaust. They also worry about traffic congestion. Congress has passed legislation supporting public transit. If public transit is convenient and the cost is reasonable, people may leave their cars at home.

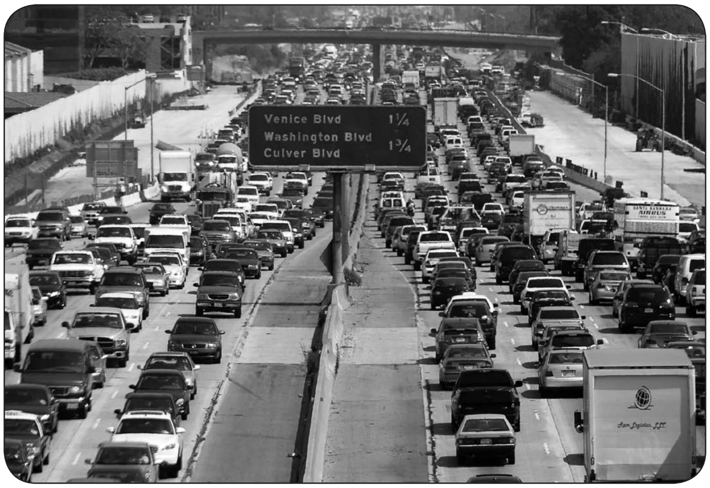
Average Fuel Economy of New Passenger Cars



*By 2016 new model cars and light trucks will have to meet a 34 mpg fuel economy standard.

Data: U.S. Department of Energy

TRAFFIC CONGESTION



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EFFICIENCY
CONSERVATION

Energy Efficiency

Energy Consumption

The United States uses a lot of energy—nearly a million dollars worth each minute, 24 hours a day, every day of the year. With less than five percent of the world's population, we consume about one-fifth (20 percent) of its energy production. People in Europe and Japan also use a large amount of energy. The average American consumes four and a half times more energy than the world average.

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, and entertainment. We rely on energy to make our lives comfortable, productive, and enjoyable. To maintain our quality of life, we must use our energy resources wisely.

The choices we make about how we use energy—turning machines off when we're not using them or choosing to buy energy efficient appliances—impact our environment and our 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 think these terms mean the same thing, but they are different.

Energy conservation is any behavior that results in the use of less energy. **Energy efficiency** is the use of technology that requires less energy to perform the same function. A compact fluorescent light bulb that uses less energy than an incandescent bulb to produce the same amount of light 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 consumers, our energy choices and actions can result in reductions in the amount of energy used in each sector of the economy—residential, commercial, industrial, and transportation.

Selected Countries and Energy Consumption*

Country	Population in in millions (2009)	Consumption quads Btu (2009)
China	1,323.6	90.3
India	1,156.9	21.7
United States	307.0	94.5
Indonesia	240.3	6.1
Brazil	198.7	10.3
Pakistan	181.5	2.5
Nigeria	149.2	0.8
Russia	140.0	26.8
Japan	127.1	20.6
Mexico	111.2	7.0
Germany	82.3	13.5
Iran	76.0	9.0
Thailand	66.6	4.0
France	63.0	10.7
Untied Kingdom	62.3	8.9
South Africa	49.1	5.5
South Korea	48.5	10.0
Canada	33.5	13.0
Saudi Arabia	25.3	7.8
Australia	21.3	5.6
Netherlands	16.7	4.0
Chile	16.6	1.2
Honduras	7.8	0.1

*2009 is the last year for which both population and energy consumption are available for comparison purposes

Data: Energy Information Administration

Residential/Commercial

Households use about one-fifth of the total energy consumed in the United States each year. The typical U.S. family spends $2,000 a year on utility bills.

Much of this energy is not put to use. Heat pours out of homes through drafty doors and windows, as well as through ceilings and walls that aren't insulated. Some appliances use energy 24 hours a day, even when they are turned off. Energy efficient improvements can make a home more comfortable and save money. Many utility companies provide energy audits to identify areas where homes are wasting energy. These audits may be free or low cost.

▪ Heating and Cooling

Heating and cooling systems use more energy than any other systems in our homes. Typically, 54 percent of an average family's energy bills is spent to keep homes at a comfortable temperature. You can save energy and money by installing insulation, maintaining and upgrading the equipment, and practicing energy efficient behaviors. A two-degree adjustment to your thermostat setting (lower in winter, higher in summer) can lower heating bills by four percent and prevent 500 pounds of carbon dioxide from entering the atmosphere each year. Programmable thermostats can automatically control temperature for time of day and season.

Energy Efficiency

Insulation and Weatherization

You can reduce heating and cooling needs by investing in insulation and weatherization products. Warm air leaking into your home in summer and out of your home in winter can waste a lot of energy.

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

Doors and Windows

About one-third of a typical home's heat loss occurs 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. Most homes have many more windows than doors. Replacing older windows with new energy efficient ones can reduce air leaks and utility bills. The best windows are constructed of two or more pieces of glass separated by a gas that does not conduct heat well.

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

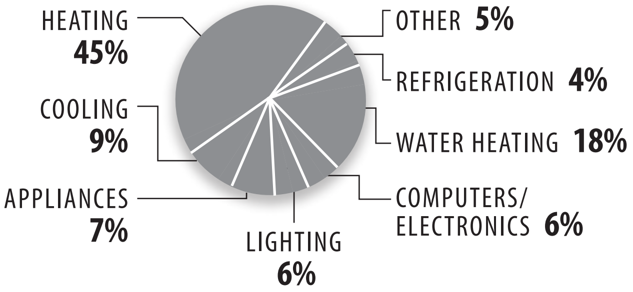
Windows, doors, and skylights are part of the government-backed **ENERGY STAR** program that certifies energy efficient products. To meet ENERGY STAR requirements, windows, doors, and skylights must meet standards tailored for the country's three broad climate regions.

CHANGE FOR THE BETTER WITH ENERGY STAR

Landscaping

Although it isn't possible to control the weather, landscaping can reduce its impact on home energy use. By placing trees, shrubs, and other landscaping to block the wind and provide shade, people can reduce the energy needed to keep their homes comfortable during heating and cooling seasons.

Home Energy Usage, 2010



Data: U.S. Department of Energy

Electricity and Appliances

Appliances account for about 13 percent of a typical household's energy use, with refrigerators, clothes washers, and dryers at the top of the list. When shopping for new appliances, you should think of two price tags. The first one is the purchase price. 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 cost more to buy, but save money in lower energy costs. Over the life of an appliance, an energy efficient model is always a better deal.

When you shop for new appliances, consider only those with the ENERGY STAR label, which means they have been rated by the U.S. Environmental Protection Agency and Department of Energy as the most energy efficient appliances in their classes.

If every clothes washer purchased in the U.S. this year earned the ENERGY STAR label, we would save 790 million kilowatt-hours of electricity, 32 billion gallons of water, and two trillion Btus of natural gas, resulting in energy bill savings of about $350 million every year.

Another way to compare appliances is by using EnergyGuide labels. The government requires appliances to display yellow and black EnergyGuide labels. These labels do not tell you which appliances are the most efficient, but they will tell you the annual energy usage and average operating cost of each appliance so that you can compare them.

- **Lighting**

Starting in 2012, legistration under the Energy Independence and Security Act puts restrictions on how much energy light bulbs use. Traditional, inefficient incandescent bulbs will be replaced with more efficient ones.

Halogen, or energy-saving incandescent bulbs, are more expensive than incandescent bulbs, but use 25 percent less energy and last three times as long.

Compact fluorescent light bulbs (CFLs) provide the same amount of light as incandescent bulbs. CFLs cost more to buy, but they save money in the long run because they use only one-quarter the energy of incandescent bulbs and last 8-12 times longer. Each ENERGY STAR CFL you install can save you $40 over the bulb's life.

Light emitting diodes (LEDs) are even more efficient than CFL bulbs. For now, they are still expensive, but expect to see costs come down as more LED bulbs are produced.

- **Water Heating**

Water heating is the second largest energy expense in your home. It typically accounts for about 18 percent of your utility bill. Heated water is used for showers, baths, laundry, dishwashing, and general cleaning. There are four main 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.

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 settings on clothes washers.

Transportation

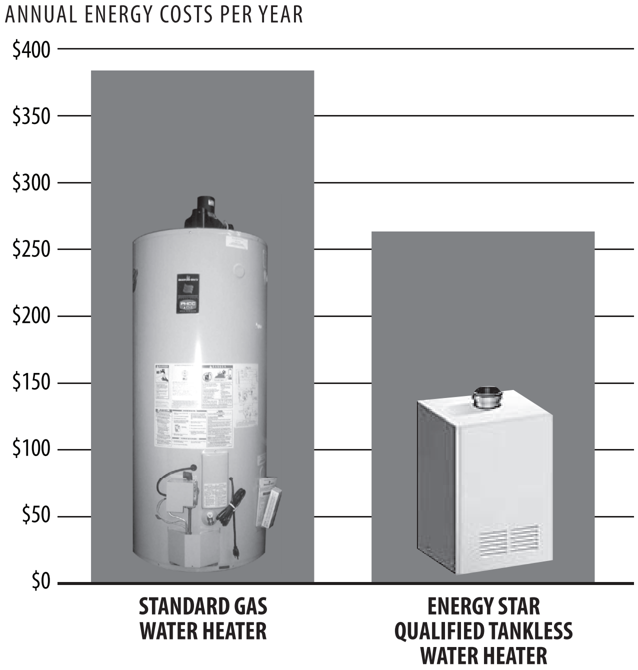
Americans make up less than five percent of the world's population, yet own one-fifth of its automobiles. The transportation sector of the U.S. economy accounts for 28 percent of total energy consumption. America is a country on the move.

The average American uses 670 gallons of gasoline every year. The average vehicle is driven about 12,000 miles per year. That number is expected to increase about 40 percent during the next 20 years if Americans don't change their driving habits by using public transportation, carpooling, walking, or bicycling. You can achieve 10 percent fuel savings by improving your driving habits and keeping your car properly maintained.

The average **fuel economy** of new cars and light trucks increased significantly from the mid-1970s through the mid-1980s. Unfortunately, it declined from a high of about 26 miles per gallon (mpg) in 1987 to 24.5 mpg in 1999 due to larger vehicles, more horsepower, and increased sales of sport utility vehicles (SUVs) and trucks. In 2010, it rose to 29.2 mpg as fuel prices have risen and the demand for hybrids and fuel efficient vehicles has increased.

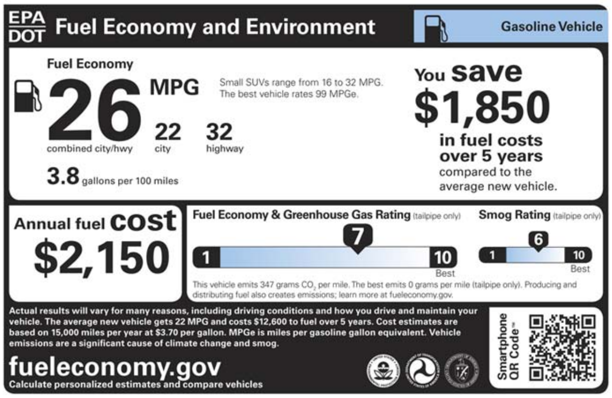
When buying a vehicle, you can save a lot by choosing a fuel-efficient model. All new cars must display a mileage performance label, or Fuel Economy Label, that lists the estimated miles per gallon for both city and highway driving. Compare the fuel economy of the vehicles you are considering and make it a priority. Over the life of the vehicle, you can save thousands of dollars and reduce emissions significantly.

Water Heater Comparison



Data: ENERGY STAR

Fuel Economy Label



EPA DOT Fuel Economy and Environment

Gasoline Vehicle

Fuel Economy

26 MPG combined city/hwy

22 city 32 highway

3.8 gallons per 100 miles

Small SUVs range from 16 to 32 MPG. The best vehicle rates 99 MPGe.

You save $1,850 in fuel costs over 5 years compared to the average new vehicle.

Annual fuel cost $2,150

Fuel Economy & Greenhouse Gas Rating (tailpipe only) 7 — 1 to 10 Best

Smog Rating (tailpipe only) 6 — 1 to 10 Best

This vehicle emits 347 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also creates emissions; learn more at fueleconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 22 MPG and costs $12,600 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at $3.70 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fueleconomy.gov

Calculate personalized estimates and compare vehicles

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HYBRID PASSENGER VEHICLE

Image courtesy of NREL

Manufacturing

Manufacturing the goods we use every day consumes an enormous amount of energy. The industrial sector of the U.S. economy consumes one-third of the energy used in the U.S.

In the industrial sector, the economy controls energy efficiency and conservation measures. Manufacturers know that they must keep their costs low 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 drives much of the research and development of new technologies.

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

▪ A Consumer Society

Every American produces about 1,600 pounds of trash a year. The most effective way for consumers to help reduce the amount of energy consumed by industry is to decrease the number of unnecessary products produced and to reuse items wherever possible. Purchasing only those items that are necessary, while also reusing and recycling products can reduce energy use in the industrial sector.

The ″three Rs″ of an energy-wise consumer are easy to put into practice. Reducing, reusing, and recycling help protect the environment and save money, energy, and natural resources.

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 less packaging also reduces the amount of waste generated and the amount of energy used.

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.

RECYCLE

Make it a priority to recycle all materials that you can. Using recycled material almost always consumes less energy than using new materials. Recycling reduces energy needs for mining, refining, and many other manufacturing processes.

Recycling a pound of steel saves enough energy to light a 60-watt light bulb for 26 hours. Recycling one glass bottle saves enough energy to power a computer for 30 minutes. Recycling aluminum cans saves 95 percent of the energy required to produce aluminum from bauxite. Recycling paper reduces energy usage by 40 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 energy needs of future generations. Energy 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 alternative energy sources, and encouraging sound environmental policies.

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

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