Secondary Energy Infobook

(19 Activities)

Grades: 9-12

Topics: Energy Basics

Owner: NEED

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SECONDARY ENERGY INFOBOOK

Fact sheets about the major energy sources, electricity, efficiency, conservation, transportation, and emerging technologies.

GENERAL ENERGY

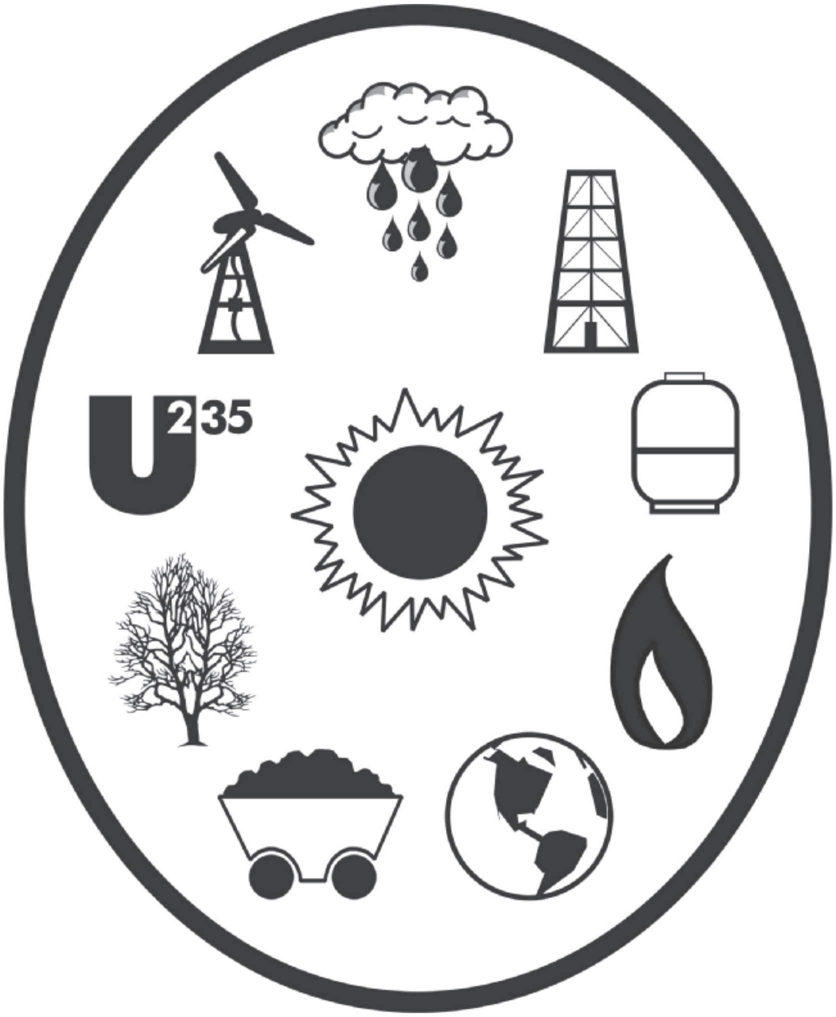
ENERGY SOURCES

GRADE LEVEL

Secondary

SUBJECT AREAS

Science
Social Studies
Math
Language Arts



NEED

2007

Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 www.NEED.org

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 Vision 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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Correlations to National Science Standards

(Bolded standards are emphasized in the infobook.)

INT = Intermediate National Science Content Standards (Grades 5-8)

INT–B: 3.a **Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.**

INT–B: 3.b **Energy is transferred in many ways.**

INT–B: 3.c Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

INT–B: 3.d Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).

INT–B: 3.e **Electrical circuits provide a means of transferring electrical energy.**

INT–B: 3.f **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.**

INT–B: 3.g **The sun is the 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 earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths.**

INT–C: 4.a **For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. The energy then passes from organism to organism in food webs.**

INT–D: 1.a **The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.**

INT–D: 1.b **Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the water cycle.**

INT–D: 2.a **Gravity governs the motion in the solar system. Gravity explains the phenomenon of the tides.**

INT–D: 2.b **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.**

INT–E: 2.c **Technological solutions are temporary and have side effects. Technologies cost, carry risks, and have benefits.**

INT–E: 2.d Many different people in different cultures have made and continue to make contributions to science and technology.

INT–E: 2.e Science and technology are reciprocal. Science helps drive technology, as it asks 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 quantity, distance, location, size, and/or speed.

INT–E: 2.f **Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world. Reducing risk often results in new technology.**

INT–E: 2.g **Technological designs have constraints. Some constraints are unavoidable, such as properties of materials, or effects of weather and friction. Other constraints limit choices in design, such as environmental protection, human safety, and aesthetics.**

INT–F: 1.a Food provides energy and nutrients for growth and development.

INT–F: 1.b Natural environments may contain substances that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air.

INT–F: 2.b Causes of environmental degradation and resource depletion vary from region to region and from country to country.

INT–F: 3.a Internal and external processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans.

INT–F: 3.b **Human activities can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal.**

INT–F: 3.c	**Hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.**
INT–F: 4.b	**Students should understand the risks associated with natural hazards, chemical hazards, biological hazards, social hazards, and personal hazards.**
INT–F: 4.c	**Students can use a systematic approach to thinking critically about risks and benefits.**
INT–F: 4.d	**Important personal and social decisions are made based on perceptions of benefits and risks.**
INT–F: 5.a	Science influences society through its knowledge and world view. The effect of science on society is neither entirely beneficial nor entirely detrimental.
INT–F: 5.b	**Societal challenges often inspire questions for scientific research, and societal priorities often influence research priorities.**
INT–F: 5.c	**Technology influences society through its products and processes. 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.**
INT–F: 5.d	**Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.**
INT–F: 5.e	**Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students 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.**
INT–G: 2.c	It is normal for scientists to differ with one another about the interpretation of new evidence. It is part of scientific inquiry to evaluate the results and explanations of other scientists. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists.

SEC = Secondary National Science Content Standards (Grades 9-12)

SEC–B: 1.a	**Matter is made of minute particles called atoms, which are composed of even smaller components. These components have measurable properties, such as mass and electrical charge.**
SEC–B: 1.b	**Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.**
SEC–B: 1.c	**The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called isotopes of the element.**
SEC–B: 1.f	**Fission is the splitting of a large nucleus into smaller pieces.**
SEC–B: 1.g	**Fusion is the joining of two nuclei at extremely high temperature and pressure and is the process responsible for the energy of the sun and other stars.**
SEC–B: 1.h	Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation.
SEC–B: 2.e	Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.
SEC–B: 3.b	**Chemical reactions may release or consume energy. Some reactions, such as the burning of fossil fuels, release large amounts of energy by losing heat and by emitting light.**
SEC–B: 3.c	**Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.**
SEC–B: 3.d	**A large number of important reactions involve the transfer of electrons or hydrogen ions. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.**
SEC–B: 4.c	The electrical force is a universal force that exists between two charged objects.
SEC–B: 4.e	Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces.
SEC–B: 5.a	**The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.**
SEC–B: 5.b	All energy can be considered either kinetic energy—the energy of motion; potential energy—which depends on relative position; or energy contained by a field, such as electromagnetic waves.
SEC–B: 5.c	Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.
SEC–B: 5.d	Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.
SEC–B: 6.a	Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.
SEC–B: 6.d	In some materials, such as metal, electrons flow easily, whereas in insulating materials such as glass, they can hardly flow at all.
SEC–C: 1.a	**Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This photosynthesis provides a vital connection between the sun and the energy needs of living systems.**
SEC–C: 4.b	Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores to decomposers.
SEC–C: 4.c	**Humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through harvesting, pollution, atmospheric changes, and other factors is threatening global stability, and if not addressed, ecosystems will be irreversibly affected.**
SEC–C: 5.a	All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations.

SEC–C: 5.b	**The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong chemical bonds. The energy stored in the bonds (chemical energy) can be used as sources of energy for life processes.**
SEC–C: 5.c	The chemical bonds of food molecules contain energy. Energy is released when the bonds are broken and new compounds with lower energy bonds are formed.
SEC–C: 5.e	As matter and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.
SEC–D: 1.a	**Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation.**
SEC–D: 1.b	**The outward transfer of earth's internal heat drives convection circulation in the mantle.**
SEC–D: 1.c	**Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.**
SEC–D: 1.d	**Global climate is determined by energy transfer from the sun at and near the earth's surface.**
SEC–D: 4.a	**Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium.**
SEC–F: 3.a	**Human populations use resources in the environment to maintain and improve their existence.**
SEC–F: 3.b	**The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and depletes those resources that cannot be renewed.**
SEC–F: 3.c	**Humans use many natural systems as resources. Natural systems have the capacity to reuse waste but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically.**
SEC–F: 4.a	**Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.**
SEC–F: 4.b	**Materials from human societies affect both physical and chemical cycles of the earth.**
SEC–F: 4.c	**Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.**
SEC–F: 5.b	**Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.**
SEC–F: 5.c	Some hazards are rapid and spectacular, others are slow and progressive.
SEC–F: 5.d	**Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. tudents should understand the costs and trade-offs of various hazards—ranging from those with minor risk to a few people to major catastrophes with major risk to many people.**
SEC–F: 6.b	**Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national, and global challenges.**
SEC–F: 6.c	**Individuals and society must decide on proposals involving new research and the introduction of new technologies into society.**
SEC–F: 6.d	Humans have a major effect on other species.
SEC–G: 1.a	Individuals and teams contribute to the scientific enterprise.
SEC–G: 1.c	Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society, but a part of it.

Introduction to Energy

ENERGY at a Glance

World Population 2005*	6,451,000,000
U.S. Population 2005*	296,410,000
World Energy Production 2003*	417.61 Q
U.S. Energy Production 2004*	70.37 Q
Renewables 2004*	6.12 Q
Nonrenewables 2004*	64.25 Q
World Energy Consumption 2003*	421.51 Q
U.S. Energy Consumption 2004*	99.74 Q
Renewables 2004*	6.12 Q
Nonrenewables 2004*	93.88 Q
Adjustments 2004*	- 0.26 Q

Q = Quad (10^{15} Btu) see Measuring Energy on page 10.

*the latest years for which final data is available from EIA.

What Is Energy?

Energy does things for us. It moves cars along the road and boats on the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs and lights our homes at night so that we can read good books. Energy helps our bodies grow and our minds think. Energy is a changing, doing, moving, working thing.

Energy is defined as the ability to produce change or do work, and that work can be divided into several main tasks we easily recognize:

Energy produces light.
Energy produces heat.
Energy produces motion.
Energy produces sound.
Energy produces growth.
Energy powers technology.

Forms of Energy

There are many forms of energy, but they all fall into two categories–potential or kinetic.

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

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.

During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are broken, the stored chemical energy is released as heat, light, motion and sound.

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—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 into helium atoms in a process called **fusion**. In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $\mathbf{E = mc^2}$.

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 *is motion—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 are called electricity. Lightning is another example of electrical energy.

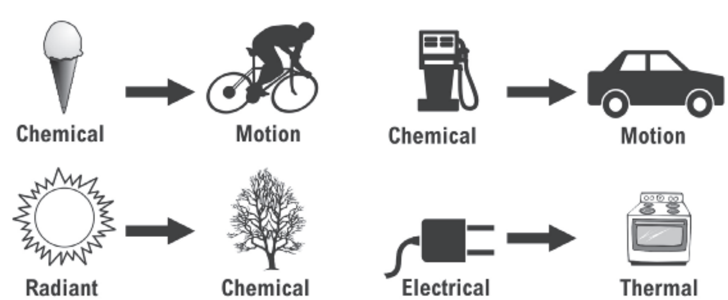
Radiant Energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Solar energy is an example of radiant energy.

Thermal Energy, or **heat**, is the internal energy in substances—the vibration and movement of atoms and molecules within substances. The faster molecules and atoms vibrate and move within substances, the more energy they possess and the hotter they become. Geothermal energy is an example of thermal energy.

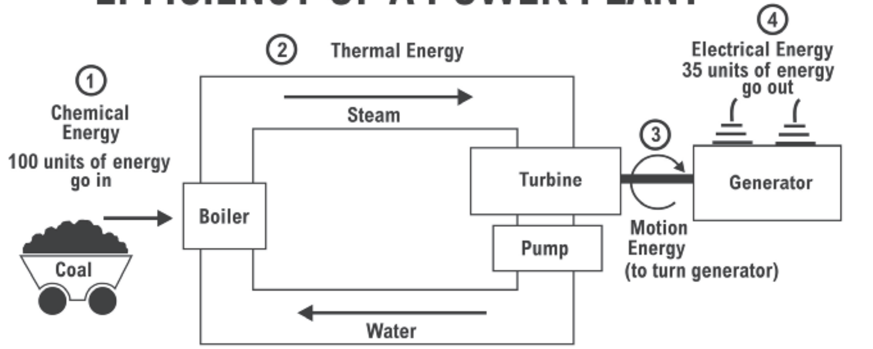
Motion Energy is the movement of objects and substances from one place to another. Objects and substances move when a force is applied according to **Newton's Laws of Motion**. Wind is an example of motion energy.

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 wave.

ENERGY TRANSFORMATIONS



EFFICIENCY OF A POWER PLANT



Most power plants are about 35% efficient. For every 100 units of energy that go into a plant, 65 units are lost as one form of energy is converted to other forms. Thirty-five units are produced to do usable work.

Energy Efficiency

Energy efficiency is how much useful energy you can get out of a system. In theory, a 100 percent energy-efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of heat.

Conservation of Energy

Your parents may tell you to conserve energy. "Turn out the lights," they say. But to scientists, conservation of energy means something quite different. The **law of conservation of energy** says energy is neither created nor destroyed.

When we use energy, we do not use it up—we just change its form. That's really what we mean when we say we are using energy. We change one form of energy into another. A car engine burns gasoline, converting the chemical energy in the gasoline into mechanical energy that makes the car move. Old-fashioned windmills changed the kinetic energy of the wind into mechanical energy to grind grain. Solar cells change radiant energy into electrical energy.

Energy can change form, but the total quantity of energy in the universe remains the same. The only exception to this law is when a small amount of matter is converted into energy during nuclear fusion and fission.

In fact, most energy transformations are not very efficient. The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. But your body isn't very efficient at converting food into useful work. Your body is less than five percent efficient most of the time, and rarely better than 15 percent efficient. The rest of the energy is lost as heat. You can really feel the heat when you exercise!

An incandescent lightbulb isn't efficient either. A lightbulb converts ten percent of the electrical energy into light and the rest (90 percent) is converted into thermal energy (heat). That's why a lightbulb is so hot to the touch.

Most electric power plants are about 35 percent efficient. It takes three units of fuel to make one unit of electricity. Most of the other energy is lost as waste heat. The heat dissipates into the environment where we can no longer use it as a practical source of energy.

FORMS OF ENERGY

POTENTIAL

Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples.

NUCLEAR ENERGY is the energy stored in the nucleus of an atom--the energy that holds the nucleus together. The nucleus of a uranium atom is an example.

STORED MECHANICAL ENERGY is energy stored in objects by the application of force. Compressed springs and stretched rubber bands are examples.

GRAVITATIONAL ENERGY is the energy of place or position. Water in a reservoir behind a hydropower dam is an example.

KINETIC

Motion: the motion of waves, electrons, atoms, molecules and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Solar energy is an example.

THERMAL ENERGY or heat is the internal energy in substances--the vibration or movement of atoms and molecules in substances. Geothermal is an example.

MOTION is the movement of a substance from one place to another. Wind and hydropower are examples.

SOUND is the movement of energy through substances in longitudinal waves.

ELECTRICAL ENERGY is the movement of electrons. Lightning and electricity are examples.

U.S. Energy Consumption by Source

BIOMASS	2.9%	renewable	Heating, electricity, transportation	PETROLEUM	38.3%	nonrenewable	Transportation, manufacturing
HYDROPOWER	2.7%	renewable	Electricity	NATURAL GAS	23.0%	nonrenewable	Heating, manufacturing, electricity
GEOTHERMAL	0.3%	renewable	Heating, electricity	COAL	22.5%	nonrenewable	Electricity, manufacturing
WIND	0.1%	renewable	Electricity	URANIUM (U^{235})	8.2%	nonrenewable	Electricity
SOLAR & other	0.1%	renewable	Light, heating, electricity	PROPANE	1.9%	nonrenewable	Manufacturing, heating

Sources of Energy

People have always used energy to do work for them. Thousands of years ago, early humans burned wood to provide light, heat their living spaces, and cook their food. Later, people used the wind to move their boats from place to place. A hundred years ago, people began using falling water to make electricity.

Today, people use more energy than ever from a variety of sources for a multitude of tasks and our lives are undoubtedly better for it. Our homes are comfortable and full of useful and entertaining electrical devices. We communicate instantaneously in many ways. We live longer, healthier lives. We travel the world, or at least see it on television.

Before the 1970s, Americans didn't think about energy very much. It was just there. The energy picture changed in 1973. The **Organization for Petroleum Exporting Countries**, better known as **OPEC**, placed an embargo on the United States and other countries. The embargo meant OPEC would not sell its oil to the U.S. or our allies. Suddenly, our supply of oil from the Middle East disappeared. The price of oil in the U.S. rose quickly. Long lines formed at gas stations as people waited to fill their tanks with that precious, hard-to-get liquid that they had taken for granted for so many years.

Petroleum is just one of the many different sources of energy we use to do work for us. The ten major energy sources we use today are classified into two broad groups—renewable and nonrenewable.

Nonrenewable energy sources are the kind we use most in the United States. Coal, petroleum, natural gas, propane, and uranium are nonrenewable energy sources. They are used to generate electricity, to heat our homes, to move our cars, and to manufacture all sorts of products from candy bars to CDs.

These energy sources are called nonrenewable because they cannot be replenished in a short period of time. Petroleum, for example, was formed millions of years ago from the remains of ancient sea life, so we can't make more quickly. We could run out of economically recoverable nonrenewable resources some day.

Renewable energy sources include biomass, geothermal, hydropower, solar and wind. They are called renewable energy sources because their supplies are replenishable 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.

Speaking of electricity, is it a renewable or nonrenewable source of energy? The answer is neither. Electricity is different from the other energy sources because it is a **secondary** source of energy. That means we have to use another energy source to make it. In the United States, coal is the number one fuel for generating electricity.

Measuring ENERGY

"You can't compare apples and oranges," the old saying goes. That holds true for energy sources. We buy gasoline in gallons, wood in cords, and natural gas in cubic feet. How can we compare them? With British thermal units (Btu's), that's how. The energy contained in gasoline, wood, or other energy sources can be measured by the amount of heat in Btu's it can produce.

One Btu is the amount of thermal energy needed to raise the temperature of one pound of water one degree Fahrenheit. A single Btu is quite small. A wooden kitchen match, if allowed to burn completely, would give off about one Btu of energy. One ounce of gasoline contains almost 1,000 Btu's of energy. Every day the average American uses about 890,000 Btu's. We use the term quad to measure very large quantities of energy. A quad is one quadrillion (1,000,000,000,000,000) Btu's. The United States uses about one quad of energy every 3.7 days. In 2004, the U.S. consumed 99.74 quads of energy, an all-time high.

Energy Use

Imagine how much energy you use every day. You wake up to an electric 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. And that's just some of the energy you use to get you through the first part of your day!

Every day, the average American uses about as much energy as is stored in seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to about 2,500 gallons of oil. This use of energy is called **energy consumption**.

Who Uses Energy?

The U.S. Department of Energy uses three categories to classify energy users—residential and commercial, industrial, and transportation. These categories are called the sectors of the economy.

Residential/Commercial

Residences are people's homes. Commercial buildings include office buildings, hospitals, stores, restaurants, and schools. Residential and commercial energy use are lumped together because homes and businesses use energy in the same ways—for heating, air conditioning, water heating, lighting, and operating appliances.

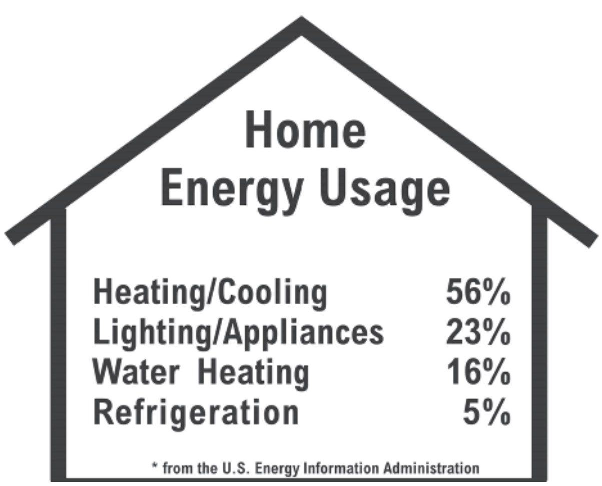
The residential/commercial sector of the economy consumed 38.8 percent of the total energy supply in 2004, more energy than either of the other sectors, with a total of 38.7 quads. The residential sector consumed 21.2 quads and the commercial sector consumed 17.5 quads.

Industrial

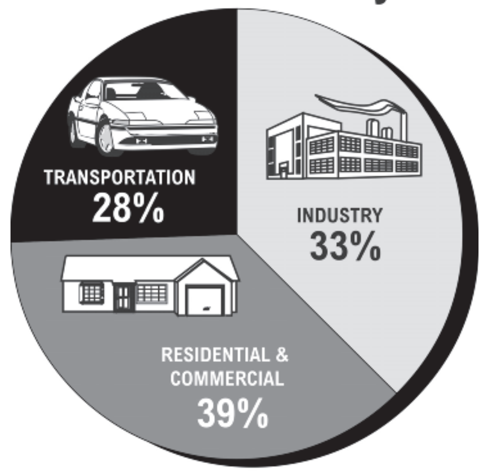
The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 33.25 quads of energy in 2004, which accounted for 33.3 percent of total consumption.

Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2004, the U.S. used large amounts of energy for transportation, 27.8 quads. More than 97 percent of this energy was supplied by petroleum products such as gasoline, diesel and jet fuel.



Energy Use By Sector Of The Economy



SOURCE: ENERGY INFORMATION ADMINISTRATION

Energy Use and Prices

In 1973, when Americans faced their first oil price shock, people didn't know how the country would react. How would Americans adjust to skyrocketing energy prices? How would manufacturers and industries respond? We didn't know the answers.

Now we know that Americans tend to use less energy when energy prices are high. We have the statistics to prove it. When energy prices increased sharply in the early 1970s, energy use dropped, creating a gap between actual energy use and how much the experts had thought Americans would be using.

The same thing happened when energy prices shot up again in 1979 and 1980—people used less energy. In 1985, when prices started to drop, energy use began to increase.

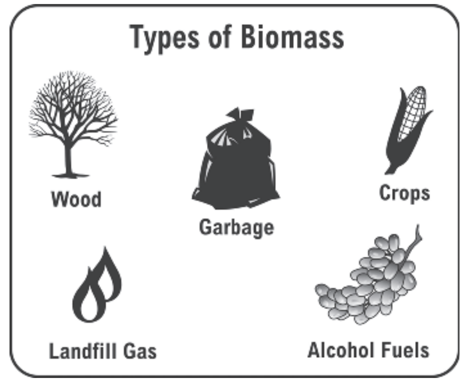
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

Most reductions in energy consumption in recent years are the result of improved technologies in industry, vehicles, and appliances. Without these energy conservation and efficiency technologies, we would be using much more energy today.

In 2004, the United States used 30-35 percent more energy than it did in the 1970s. That might sound like a lot, but the population increased by over 30 percent and the nation's **gross national product** (the total value of all the goods and services produced by a nation in one year) was more than 80 percent higher!

If every person in the United States consumed energy today at the rate we did in the 1970s, we would be using much more energy than we are today; perhaps as much as double the amount. Energy efficiency technologies have made a huge impact on overall consumption since the energy crisis of 1973.

Biomass



Biomass at a Glance

Classification: Renewable

U.S. Energy Production	2.85 Q	4.1 %
U.S. Energy Consumption	2.85 Q	2.9 %

Major Uses: electricity, transportation, heating
(Most electricity from biomass is for cogeneration, and is not included in these numbers.)

What Is Biomass?

Biomass is any organic matter—wood, crops, seaweed, animal wastes—that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food.

Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight gives plants the energy they need to convert water, carbon dioxide, and minerals into oxygen and sugars. The sugars, called **carbohydrates**, supply plants and the animals that eat plants with energy. Foods rich in carbohydrates are a good source of energy for the human body!

Biomass is a **renewable** energy source because its supplies are not limited. We can always grow trees and crops, and waste will always exist.

Types of Biomass

We use four types of biomass today—wood and agricultural products, solid waste, landfill gas and biogas, and alcohol fuels.

Wood and Agricultural Biomass

Most biomass used today is home grown energy. Wood—logs, chips, bark, and sawdust—accounts for about 71 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources include agricultural waste products like fruit pits and corncobs.

Wood and wood waste, along with agricultural waste, are used to generate electricity. Much of the electricity generated by biomass is used by the industries making the waste; it is not distributed by utilities, it is **co-generated**. Paper mills and saw mills, for example, use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they need to buy additional electricity from utilities.

Increasingly, timber companies and companies involved with wood products are seeing the benefits of using their lumber scrap and sawdust for power generation. This saves disposal costs and in some areas, may reduce the companies' utility bills. In fact, the pulp and paper industries rely on biomass to meet half of their energy needs. Other industries that use biomass include lumber producers, furniture manufacturers, agricultural businesses like nut and rice growers, and liquor producers.

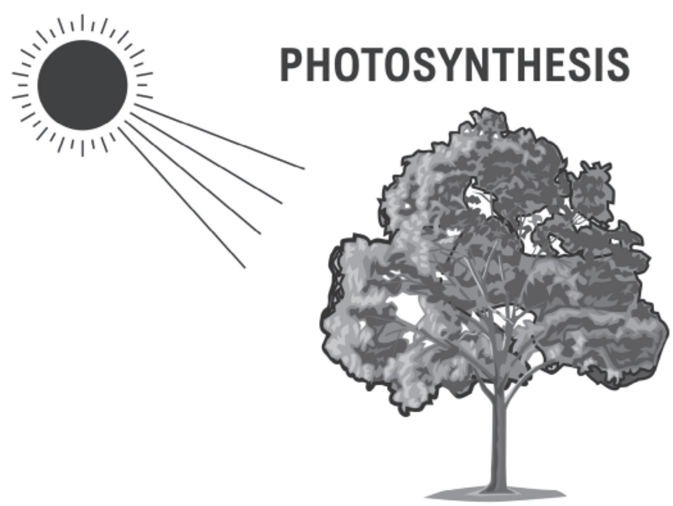
Solid Waste

There is nothing new about people burning trash. What's new is burning trash to generate electricity. This turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas.

Power plants that burn garbage for energy are called **waste-to-energy plants**. These plants generate electricity much as coal-fired plants do, except that combustible garbage—not coal—is the fuel used to fire their boilers. Making electricity from garbage costs more than making it from coal and other energy sources. The main advantage of burning solid waste is that it reduces the amount of garbage dumped in landfills by 60 to 90 percent, which in turn reduces the cost of landfill disposal. It also makes use of the energy in the garbage, rather than burying it in a landfill, where it remains unused.

Landfill Gas

Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting **cellulose** to sugars to feed itself. Although this process is slowed in a landfill, a substance called **methane gas** is still produced as the waste decays.



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

$$6\,H_2O + 6\,Co_2 + \text{radiant energy} \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

New regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless. The gas can cause fires or explosions if it seeps into nearby homes and is ignited. Landfills can collect the methane gas, purify it, and use it as fuel.

Methane, the main ingredient in natural gas, is a good energy source. Most gas furnaces and stoves use methane supplied by utility companies. In 2003, East Kentucky Power Cooperative began recovering methane from three landfills. The utility uses the gas to generate 8.8 megawatts of electricity—enough to power 7,500 to 8,000 homes.

Today, a small portion of landfill gas is used to provide energy. Most is burned off at the landfill. With today's low natural gas prices, this higher-priced **biogas** is rarely economical to collect. Methane, however, is a more powerful greenhouse gas than carbon dioxide. It is better to burn landfill methane and change it into carbon dioxide than release it into the atmosphere.

Methane can also be produced using energy from agricultural and human wastes. **Biogas digesters** are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen to produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting. It is a safe and clean-burning gas, producing little carbon monoxide and no smoke.

Biogas digesters are inexpensive to build and maintain. They can be built as family-sized or community-sized units. They need moderate temperatures and moisture for the fermentation process to occur. For developing countries, biogas digesters may be one of the best answers to many of their energy needs. They can help reverse the rampant deforestation caused by wood-burning, and can reduce air pollution, fertilize over-used fields, and produce clean, safe energy for rural communities.

Use of Biomass

Until the mid-1800s, wood gave Americans 90 percent of the energy used in the country. Today, biomass provides less than three percent of the energy we use. Biomass has largely been replaced by coal, natural gas, and petroleum.

U.S. BIOMASS USE

Nearly three-fourths of the biomass used today comes from burning wood and wood scraps such as saw dust. The rest comes from crops, garbage, landfill gas, and alcohol fuels. Industry is the biggest user of biomass. Sixty-one percent of biomass is used by industry. Electric utilities use biomass to produce electricity; 17 percent of biomass is used for power generation. Biomass produces two percent of the electricity we use. Homes are the next biggest users of biomass; 13 percent of biomass is used by the residential sector. About one-fifth of American homes burn wood for heating.

Biomass and the Environment

Environmentally, biomass has some advantages over fossil fuels such as coal and petroleum. Biomass contains little sulfur and nitrogen, so it does not produce the pollutants that can cause **acid rain**. Growing plants for use as biomass fuels may also help keep carbon dioxide levels balanced. Plants remove carbon dioxide—one of the **greenhouse gases**—from the atmosphere when they grow.

Using BIOMASS ENERGY

Usually we burn wood and use its energy for heating. Burning, however, is not the only way to convert biomass energy into a usable energy source. There are four ways:

FERMENTATION: There are several types of processes that can produce an alcohol (ethanol) from various plants, especially corn. The two most commonly used processes involve using yeast to ferment the starch in the plants to produce ethanol. One of the newest processes involves using enzymes to break down the cellulose in the plants' fibers, allowing more ethanol to be made from each plant, because all of the plant tissue is utilized, not just the starch.

BURNING: We can burn biomass in waste-to-energy plants to produce steam for making electricity, or we can burn it to provide heat for industries and homes.

BACTERIAL DECAY: Bacteria feed on dead plants and animals, producing methane. Methane is produced whenever organic material decays. Methane is the main ingredient in natural gas, the gas sold by natural gas utilities. Many landfills are recovering and using the methane gas produced by the garbage.

CONVERSION: Biomass can be converted into gas or liquid fuels by using chemicals or heat. In India, cow manure is converted to methane gas to produce electricity. Methane gas can also be converted to methanol, a liquid form of methane.

Biomass: Ethanol

What is Ethanol?

Ethanol is an alcohol fuel made by fermenting the sugars found in grains, such as corn and wheat, as well as potato wastes, cheese whey, corn fiber, rice straw, sawdust, urban wastes, and yard clippings.

There are several processes that can produce alcohol (ethanol) from the various plant forms of biomass. The two most commonly used processes involve using yeast to ferment the sugars and starch in the feedstock (corn or wheat) to create ethanol. This is how wine, beer, and liquor are made. Cider, for example, is made by fermenting apple juice.

A new process uses enzymes to break down the cellulose in woody fibers so that more of the plant waste can be used to make ethanol.

This new technology will soon make it possible to make ethanol from trees, grasses, and crop residues. Trees and grasses require less energy to produce than corn, which must be replanted and tended every year.

Scientists have developed fast-growing, hybrid trees that can be harvested in ten years or less. Many perennial grasses can be established in one year and can produce two harvests a year for many years. These new energy crops will not require constant tending or fertilizers, and their root systems will rebuild the soil. They will also prevent erosion and offer habitats for wild animals.

Soon, you may find yourself driving by huge farms that are not producing food or animal feed, but fuel for ethanol and power plants. These energy crops will be a boon to the American farmer. In recent years, advances in farming have allowed farmers to produce enough food for the country on much less land. In fact, American farmers export forty percent of the food they grow and still have plenty of land that is not under production. Energy crops will allow farmers to use more of their land productively.

History of Ethanol

Ethanol is not a new product. In the 1850s, nearly 90 million gallons were produced every year. At the beginning of the Civil War, a $2.08 per gallon tax was imposed on liquor to finance the war. Since ethanol is a product of fermentation, it was taxed as liquor.

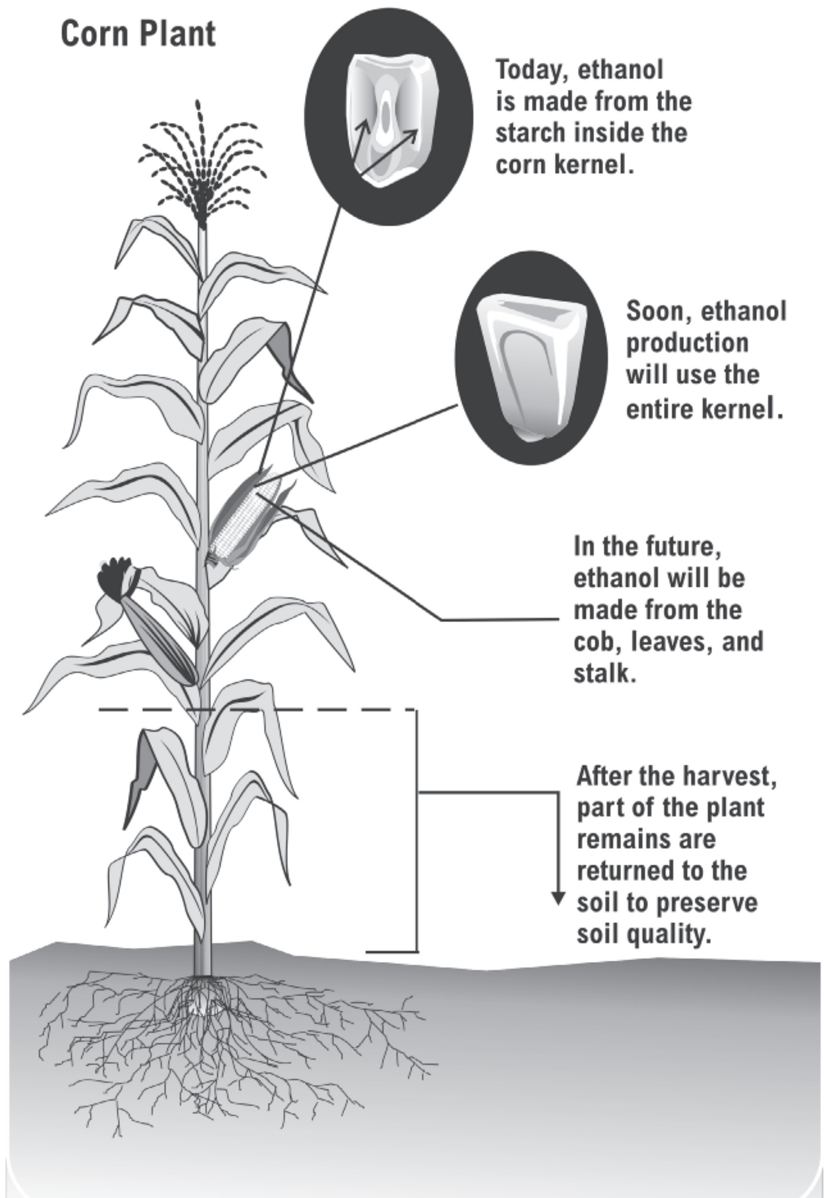
At the same time, competitors such as kerosene and methanol were taxed at only 10 cents a gallon. As a result, ethanol could not compete as a fuel and disappeared from the market.

In 1906, the federal liquor tax was repealed and ethanol became competitive as a fuel. In 1908, Henry Ford designed his Model T Ford to run on a mixture of gasoline and alcohol, calling it the fuel of the future.

During World War I, the use of ethanol increased rapidly and, by the end of the war, production had risen to 50 million gallons a year. It was used not only as a fuel, but in the manufacture of war materials as well.

In 1919, the ethanol industry received another blow when the era of Prohibition began. Since ethanol was considered liquor, it could only be sold when poisons were added to make it undrinkable. In a process called denaturing, ethanol was rendered poisonous by the addition of three–five percent petroleum components.

By the 1920s, ethanol was no longer thought of as an alternative to gasoline; it was considered a gasoline extender or octane enhancer that boosts the power of the car's engine. However, with the production of ethanol effectively banned by Prohibition, other products were used for that purpose.



With the end of Prohibition in 1933, interest in the use of ethanol as a fuel was revived. During World War II, production of ethanol rose dramatically to 600 million gallons a year. While some ethanol was used as fuel, most was used in the production of synthetic rubber, since supplies of natural rubber had been cut off by the war in Asia.

After the war, ethanol production again declined sharply. Not only were there no more government contracts to produce ethanol, but farmers were exporting much of their grain. At the same time, large supplies of cheap foreign oil made gasoline less expensive.

Ethanol Today

In the 1970s, embargoes by major oil producing countries curtailed gasoline supplies, which revived interest in ethanol as an alternative fuel. Today, 75 ethanol plants, mostly in the Midwest, produce about 3.5 billion gallons of ethanol a year. Many new plants are in the planning stages or actually under construction.

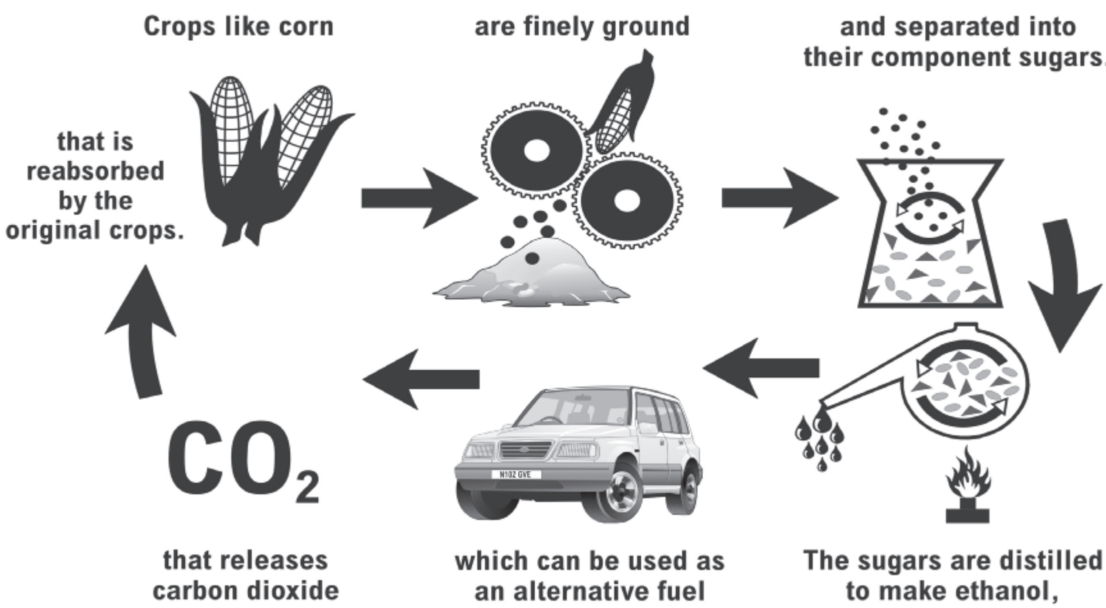
Another reason for the renewed interest in ethanol is its environmental benefit as a vehicle fuel. Since ethanol contains oxygen, using it as a fuel additive results in lower carbon monoxide emissions. Gasoline containing up to ten percent ethanol is widely used in urban areas that fail to meet standards for carbon monoxide and ozone. These ethanol blends, called E-2 to E-10 depending on the percentage of ethanol in the blend, result in up to 25 percent fewer carbon monoxide emissions than conventional gasoline.

Using ethanol can also reduce total carbon dioxide emissions. Ethanol is made from crops that absorb carbon dioxide and give off oxygen. This carbon cycle maintains the balance of carbon dioxide in the atmosphere when using ethanol as a fuel.

It costs more to produce ethanol than gasoline, but federal and state tax advantages make ethanol use competitive in the marketplace. As new technologies for producing ethanol from all parts of plants and trees become available and economical, the production and use of ethanol should increase dramatically.

ETHANOL VEHICLES IN USE TODAY

THE CARBON CYCLE



Coal

COAL at a Glance

Classification: Nonrenewable

U.S. Energy Production	22.69 Q	32.2 %
U.S. Energy Consumption	22.53 Q	22.6 %

Major Uses: electricity, industry

What Is Coal?

Coal is a fossil fuel created from the remains of plants that lived and died about 100 to 400 million years ago when parts of the earth were covered with huge swampy forests. Coal is classified as a nonrenewable energy source because it takes millions of years to form.

The energy we get from coal today comes from the energy that plants absorbed from the sun millions of years ago. All living plants store solar energy through a process known as photosynthesis. When plants die, this energy is usually released as the plants decay. Under conditions favorable to coal formation, however, the decay process is interrupted, preventing the release of the stored solar energy. The energy is locked into the coal.

Millions of years ago, dead plant matter fell into swampy water and over the years, 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.

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.

Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

History of Coal

North American Indians used coal long before the first settlers arrived in the New World. Hopi Indians, who lived in what is now Arizona, 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 at first. Instead, they relied on water wheels and 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 American Civil War, people also used coal to make iron and steel. And by the end of the 1800s, people even used coal to make electricity.

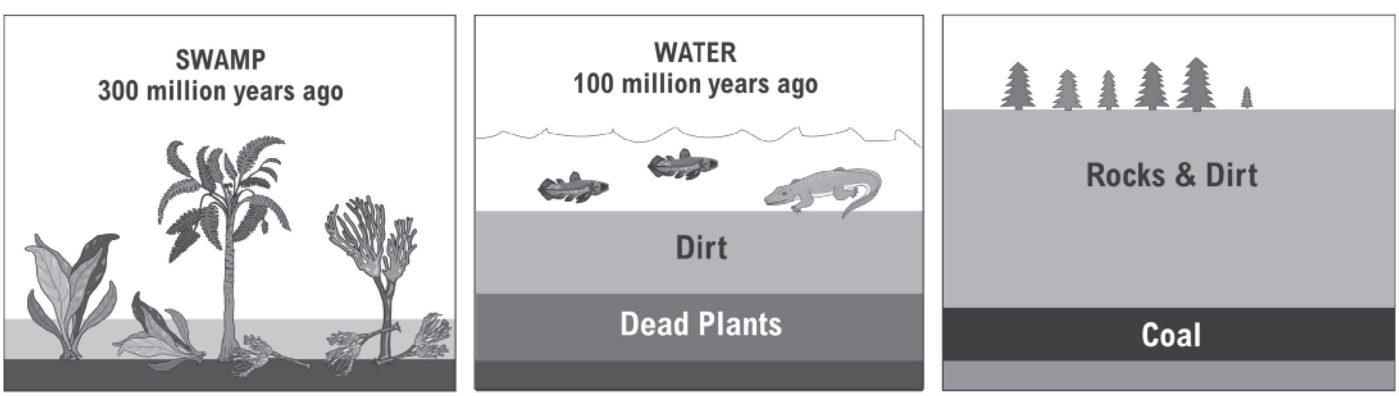
When America entered the 1900s, coal was the energy mainstay for the nation's businesses and industries. Coal stayed America's number one energy source until the demand for petroleum products pushed petroleum to the front. Automobiles needed gasoline. Trains switched from coal power to diesel fuel. Even homes that used to be heated by coal turned to oil or gas furnaces instead.

Coal production reached its low point in the early 1950s. Since 1973, coal production has increased by more than 80 percent, reaching record highs in 1998. Today, coal supplies almost 23 percent of the nation's total energy needs, mostly for electricity production.

Coal Mining

There are two ways to remove coal from the ground—surface and underground mining. **Surface mining** is used when a coal seam is relatively close to the surface, usually within 200 feet. The first step in surface mining is to remove and store the soil and rock covering the coal, called the **overburden**. Workers use a variety of equipment—draglines, power shovels, bulldozers, and front-end loaders—to expose the coal seam for mining.

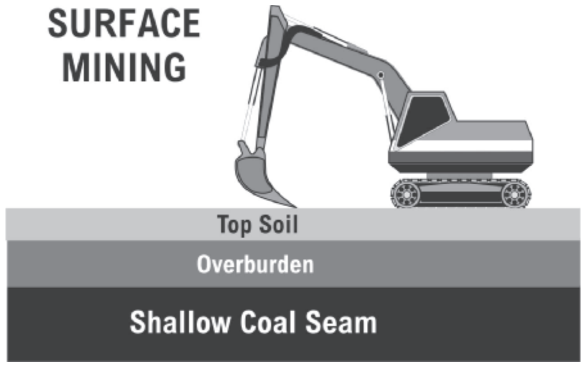
HOW COAL WAS FORMED



Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

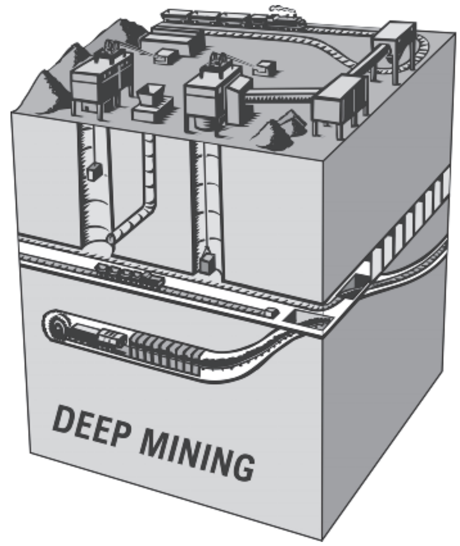


After surface mining, workers replace the overburden, grade it, cover it with topsoil, and fertilize and seed the area. This land **reclamation** is required by law and helps restore the biological balance of the area and prevent erosion. The land can then be used for croplands, wildlife habitats, recreation, or as sites for commercial development.

Although only about a third of the nation's coal can be extracted by surface mining, about two-thirds of all coal in the U.S. is mined using this method today. Why? Surface mining is typically much less expensive than underground mining. With new technologies, productivity has more than tripled since 1973.

Underground (or deep) mining is used when the coal seam is buried several hundred feet below the surface. In underground mining, workers and machinery go down a vertical shaft or a slanted tunnel called a slope to remove the coal. Mine shafts may sink as deep as 1,000 feet.

One method of underground mining is called **room-and-pillar mining**. With this method, much of the coal must be left behind to support the mine's roofs and walls. Sometimes as much as half the coal is left behind in large column formations to keep the mine from collapsing.



A more efficient and safer underground mining method, called **longwall mining**, uses a specially shielded machine that allows a mined-out area to collapse in a controlled manner. This method is called longwall mining because huge blocks of coal up to several hundred feet wide can be removed.

Processing and Transporting Coal

After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other impurities, increasing the heating value of the coal.

After the coal is mined and processed, it is ready to go to market. It is very important to consider transportation when comparing coal with other energy sources because sometimes transporting the coal can cost more than mining it.

Types of COAL

Coal is classified into four main types, depending on the amount of carbon, oxygen, and hydrogen present. The higher the carbon content, the more energy the coal contains.

LIGNITE is the lowest rank of coal, with a heating value of 4,000–8,300 British thermal units (Btu) per pound. Lignite is crumbly and has high moisture content. Most lignite mined in the United States comes from Texas. Lignite is mainly used to produce electricity. It contains 25–35 percent carbon. Less than eight percent of the coal mined in 2004 was lignite.

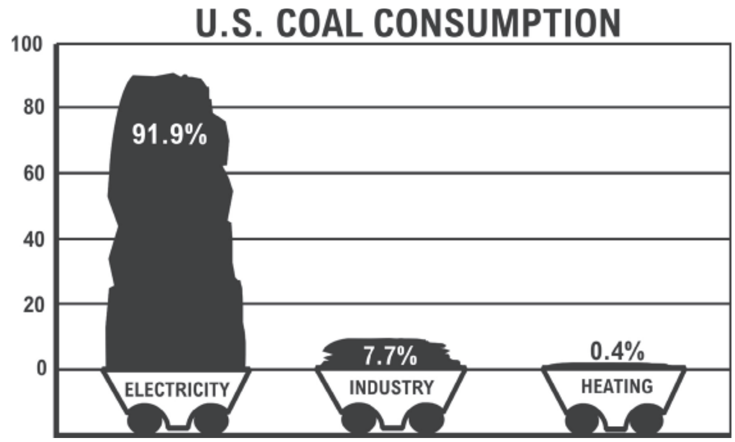
SUB-BITUMINOUS coal typically contains less heating value than bituminous coal (8,300–13,000 Btu per pound) and more moisture. It contains 35–45 percent carbon. Forty-three percent of the coal mined in 2004 in the U.S. was sub-bituminous.

BITUMINOUS coal was formed by added heat and pressure on lignite. Made of many tiny layers, bituminous coal looks smooth and sometimes shiny. It is the most abundant type of coal found in the United States and has two to three times the heating value of lignite. Bituminous coal contains 11,000–15,500 Btu per pound. Bituminous coal is used to generate electricity and is an important fuel for the steel and iron industries. It contains 45–86 percent carbon. Half of the coal mined in 2004 was bituminous coal.

ANTHRACITE was created where additional pressure combined with very high temperature inside the earth. It is deep black and looks almost metallic due to its glossy surface. It is found primarily in 11 northeastern counties of Pennsylvania. Like bituminous coal, anthracite coal is a big energy producer, containing nearly 15,000 Btu per pound. It contains 86–97 percent carbon.

Underground pipelines can easily move petroleum and natural gas to market. But that's not so for coal. Huge trains transport most coal (almost 60 percent) for at least part of its journey to market.

It is cheaper to transport coal on river barges, but this option isn't always available. Coal can also be moved by trucks and conveyors if the coal mine is close by. Ideally, coal-fired power plants are built near coal mines to minimize transportation costs.



Coal Reserves

When scientists estimate how much coal, petroleum, natural gas, or other energy sources there are in the United States, they use the term reserves. **Reserves** are deposits that can be harvested using today's methods and technology.

Experts estimate that the United States has about 269 billion tons of recoverable coal reserves. If we continue to use coal at the same rate as we do today, we will have enough coal to last about 270 years. This vast amount of coal makes the United States the world leader in known coal reserves.

Where is all this coal located? Coal deposits can be found in 38 states. Montana has the most coal—about 75 billion mineable tons. Other top coal states in order of known reserves are Illinois, Wyoming, West Virginia, Kentucky, Pennsylvania, Ohio, Colorado, Texas, and New Mexico. Western coal generally contains less sulfur than eastern coal. Low sulfur coal produces fewer pollutants.

The federal government is by far the largest owner of the nation's coalbeds. In the West, the federal government owns 60 percent of the coal and indirectly controls another 20 percent. Coal companies must lease the land from the federal government in order to mine this coal.

Coal Production

Coal production is the amount of coal mined and taken to market. Where does mining take place in the United States? Although coal is mined in 33 states, more coal is mined in western states than in eastern states, a marked change from the past when most coal came from eastern underground mines.

The West's share was just five percent of total production in 1968. In 2004, the West provided 56 percent of total production, and states east of the Mississippi River provided 44 percent.

Total U.S. production of coal was about a little more than one billion tons in 2004, a 60 percent increase since 1973. The leading coal producing states are Wyoming, West Virginia, Kentucky, Pennsylvania, Texas, Montana, and Colorado.

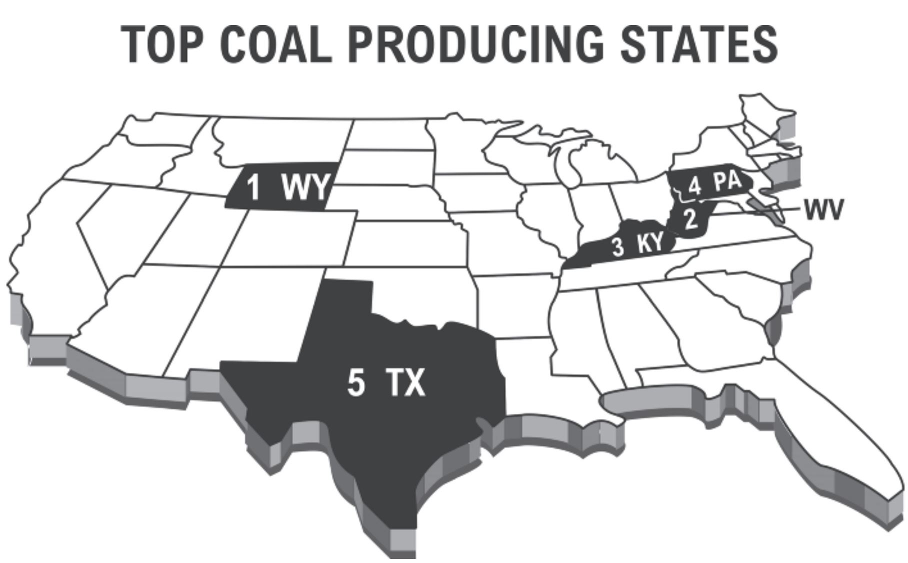
Some coal produced in the United States is exported to other countries. In 2004, foreign countries bought almost two percent of all the coal produced in the U.S. The five biggest foreign markets for U.S. coal are Canada, Japan, United Kingdom, Italy, and Brazil.

How Coal Is Used

The main use of coal in the United States is to generate electricity. Today, 91.9 percent of all the coal in the United States is used for electricity production. Coal generates half (50 percent) of the electricity used in the U.S. Other energy sources used to generate electricity include uranium (nuclear power), hydropower, natural gas, biomass, and wind.

Another major use of coal is in iron and steelmaking. The iron industry uses coke ovens to melt iron ore. **Coke**, an almost pure carbon residue of coal, is used as a fuel in smelting metals. The United States has the finest coking coals in the world. These coals are shipped around the world for use in coke ovens. Coal is also used by other industries. The paper, brick, limestone, and cement industries all use coal to make products.

Contrary to what many people think, coal is no longer a major energy source for heating American homes or other buildings. Less than half of one percent of the coal produced in the U.S. today is used for heating. Coal furnaces, which were popular years ago, have largely been replaced by oil or gas furnaces or by electric heat pumps.



Coal and the Environment

Eventually, as the effects of pollution became more noticeable, Americans decided it was time to balance the needs of industry and the environment.

Over a century ago, concern for the environment was not at the forefront of public attention. For years, smokestacks from electrical and industrial plants emitted pollutants into the air. Coal mining left some land areas barren and destroyed. Automobiles, coming on strong after World War II, contributed noxious gases to the air.

The Clean Air Act and the Clean Water Act require industries to reduce pollutants released into the air and the water. Laws also require companies to reclaim the land damaged by surface mining. Progress has been made toward cleaning and preserving the environment.

The coal industry's largest environmental challenge today is removing organic sulfur, a substance that is chemically bound to coal. All fossil fuels, such as coal, petroleum, and natural gas, contain sulfur.

When these fuels are burned, the organic sulfur is released and combines with oxygen to form sulfur dioxide. Sulfur dioxide is an invisible gas that has been shown to have adverse effects on air quality.

The coal industry is working to solve this problem. One method uses scrubbers to remove the sulfur in coal smoke. **Scrubbers** are installed at coal-fired electric and industrial plants where a water and limestone mixture reacts with sulfur dioxide to form sludge. Scrubbers eliminate up to 98 percent of the sulfur dioxide. Companies spend millions of dollars to install these scrubbers.

The coal industry has made significant improvements in reducing sulfur emissions. Since 1989, coal-fired plants in the United States have lowered sulfur dioxide emissions per ton by 25 percent and have increased efficiency significantly.

Coal plants also recycle millions of tons of fly ash (a coal by-product) into useful products like road building material, cement additives, and in some cases, pellets to be used in oyster beds.

Carbon dioxide is also released when coal is burned, just like it is released from the human body when we breathe. Carbon dioxide combines with other gases, such as those emitted from automobiles, to form a shield that allows the sun's light and heat in, but doesn't let the heat out. This phenomenon is called the greenhouse effect. Without this greenhouse effect, the earth would be too cold to support life.

Scientists and others are concerned that human activities are causing major changes in greenhouse gas levels in the earth's atmosphere that could cause a change in the earth's climate.

Many scientists believe the earth is already experiencing a warming trend due to the greenhouse effect. Other scientists believe the earth may actually be cooling. Long-term studies by many countries are being conducted to determine the effect of changing greenhouse gas levels in the atmosphere. Scientists are researching new technologies to help prevent changes to the global climate.

Many countries are making commitments to lower greenhouse gas emissions according to the Kyoto Protocol reached in 1997. The United States, however, is one of the few industrialized countries that has not signed on to the agreement because it will result in an increase in energy prices.

Clean COAL Technologies

Coal is the United States' most plentiful fossil fuel, but traditional methods of burning coal produce emissions that can reduce air and water quality. Using coal can help the United States achieve domestic energy security if we can develop methods to use coal that won't damage the environment.

The Clean Coal Technology Program is a government and industry funded program that was begun in 1986 in an effort to resolve U.S. and Canadian concern over acid rain. Clean coal technologies remove sulfur and nitrogen oxides before, during, and after coal is burned, or convert coal to a gas or liquid fuel. Clean coal technologies are also more efficient, using less coal to produce the same amount of electricity.

FLUIDIZED BED COMBUSTOR: One technique that cleans coal as it burns is a fluidized bed combustor. In this combustor, crushed coal is mixed with limestone and suspended on jets of air inside a boiler. The coal mixture floats in the boiler much like a boiling liquid. The limestone acts like a sponge by capturing 90 percent of the organic sulfur that is released when the coal is burned. The bubbling motion of the coal also enhances the burning process.

Combustion temperatures can be held to 1,500 degrees Fahrenheit, about half that of a conventional boiler. Since this temperature is below the threshold where nitrogen pollutants form, a fluidized bed combustor keeps both sulfur and nitrogen oxides in check.

COAL GASIFICATION: Another clean coal technology bypasses the conventional coal burning process altogether by converting coal into a gas. This method removes sulfur, nitrogen compounds, and particulates before the fuel is burned, making it as clean as natural gas.

Geothermal

GEOTHERMAL at a Glance

Classification: Renewable

U.S. Energy Production	0.34 Q	0.5 %
U.S. Energy Consumption	0.34 Q	0.3 %

Major Uses: electricity, heating

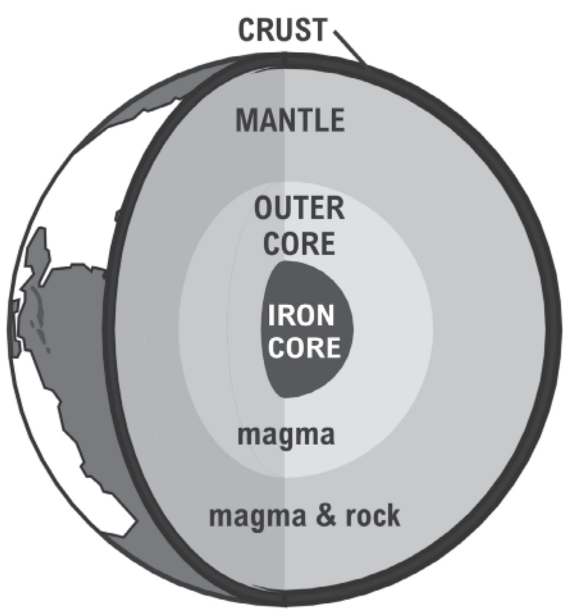
What Is Geothermal Energy?

Geothermal energy comes from the heat within the earth. The word geothermal comes from the Greek words *geo*, meaning *earth,* and *therme*, meaning *heat*. People around the world use geothermal energy to produce electricity, to heat homes and buildings, and provide hot water for a variety of uses.

The earth's core lies almost 4,000 miles beneath the earth's surface. The double-layered core is made up of very hot molten iron surrounding a solid iron center. Estimates of the temperature of the core range from 5,000 to 11,000 degrees Fahrenheit (°F).

Surrounding the earth's core is the mantle, thought to be partly rock and partly magma. The mantle is about 1,800 miles thick. The outermost layer of the earth, the insulating crust, is not one continuous sheet of rock, like the shell of an egg, but is broken into pieces called plates.

These slabs of continents and ocean floor drift apart and push against each other at the rate of about one inch per year in a process called **plate tectonics**. This process can cause the crust to become faulted (cracked), fractured or thinned, allowing plumes of magma to rise up into the crust.



THE EARTH'S INTERIOR

This magma can reach the surface and form volcanoes, but most remains underground where it can underlie regions as large as huge mountain ranges. The magma can take from 1,000 to 1,000,000 years to cool as its heat is transferred to surrounding rocks. In areas where there is underground water, the magma can fill rock fractures and porous rocks. The water becomes heated and can circulate back to the surface to create hot springs, mud pots and fumaroles, or it can become trapped underground, forming deep geothermal reservoirs.

Geothermal energy is called a **renewable** energy source because the water is replenished by rainfall, and the heat is continuously produced within the earth by the slow decay of radioactive particles that occurs naturally in all rocks.

History and Uses of Geothermal Energy

Many ancient peoples, including the Romans, Chinese, and Native Americans, used hot mineral springs for bathing, cooking, and heating. Water from hot springs is now used worldwide in spas, for heating buildings, and for agricultural and industrial uses. Many people believe hot mineral springs have natural healing powers.

Today, we drill wells into geothermal reservoirs deep underground and use the steam and heat to drive turbines in electric power plants. The hot water is also used directly to heat buildings, to increase the growth rate of fish in hatcheries and crops in greenhouses, to pasteurize milk, to dry foods products and lumber, and for mineral baths.

Where Is Geothermal Energy Found?

Geologists use many methods to find geothermal reservoirs. They study aerial photographs and geological maps. They analyze the chemistry of local water sources and the concentration of metals in the soil. They may measure variations in gravity and magnetic fields. Yet the only way they can be sure there is a geothermal reservoir is by drilling an exploratory well.

The hottest geothermal regions are found along major plate boundaries where earthquakes and volcanoes are concentrated. Most of the world's geothermal activity occurs in an area known as the **Ring of Fire**, which rims the Pacific Ocean and is bounded by Indonesia, the Philippines, Japan, the Aleutian Islands, North America, Central America, and South America.

High Temperature: Producing Electricity

When geothermal reservoirs are located near the surface, we can reach them by drilling wells. Some wells are more than two miles deep. Exploratory wells are drilled to search for reservoirs. Once a reservoir has been found, production wells are drilled. Hot water and steam—at temperatures of 250 to 700°F—are brought to the surface and used to generate electricity at power plants near the production wells. There are several different types of geothermal power plants:

Flashed Steam Plants: Most geothermal power plants are flashed steam plants. Hot water from production wells **flashes** (explosively boils) into steam when it is released from the underground pressure of the reservoir. The force of the steam is

used to spin the turbine generator. To conserve water and maintain the pressure in the reservoir, the steam is condensed into water and injected back into the reservoir to be reheated.

Dry Steam Plants: A few geothermal reservoirs produce mostly steam and very little water. In dry steam plants, the steam from the reservoir shoots directly through a **rock–catcher** into the turbine generator. The rock-catcher protects the turbine from small rocks that may be carried along with the steam from the reservoir.

The first geothermal power plant was a dry steam plant built at Larderello in Tuscany, Italy, in 1904. The original buildings were destroyed during World War II, but they have since been rebuilt and expanded. The Larderello field is still producing electricity today.

The Geysers dry steam reservoir in northern California has been producing electricity since 1960. It is the largest known dry steam field in the world and, after 40 years, still produces enough electricity to supply a city the size of San Francisco.

Binary Power Plants: Binary power plants transfer the heat from geothermal hot water to other liquids to produce electricity. The geothermal water is passed through a **heat exchanger** in a closed pipe system, and then reinjected into the reservoir. The heat exchanger transfers the heat to a working fluid—usually isobutane or isopentane—which boils at a lower temperature than water. The vapor from the working fluid is used to turn the turbines.

Binary systems can, therefore, generate electricity from reservoirs with lower temperatures. Since the system is closed, there is little heat loss and almost no water loss, and virtually no emissions.

Hybrid Power Plants: In some power plants, flash and binary systems are combined to make use of both the steam and the hot water. A hybrid system provides about 25 percent of the electricity to the big island of Hawaii.

Low Temperature: Direct Use or Heating

Only in the last century have we used geothermal energy to produce electricity, but people have used it to make their lives more comfortable since the dawn of mankind.

Hot Spring Bathing & Spas: For centuries, people have used hot springs for cooking and bathing. The early Romans used geothermal water to treat eye and skin diseases and, at Pompeii, to heat buildings. Medieval wars were even fought over lands for their hot springs.

Today, many hot springs are still used for bathing. And around the world, millions of people visit health spas to soak in the mineral–rich water.

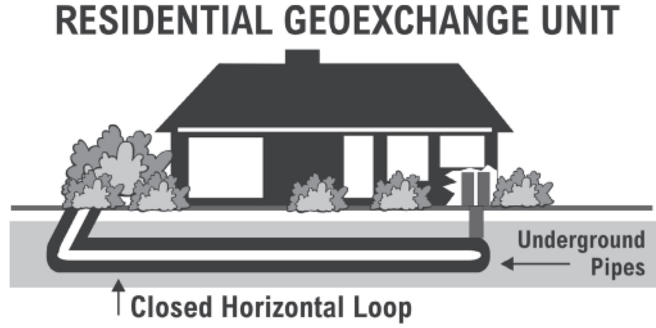
Agriculture & Aquaculture: Water from geothermal reservoirs is used in many places to warm greenhouses that grow flowers, vegetables, and other crops. Natural warm water can also speed the growth of fish, shellfish, reptiles and amphibians. In Japan, aqua-farms grow eels and alligators. In the U.S., aqua-farmers grow tropical fish for pet shops. Iceland hopes to raise two million abalone, a shellfish delicacy, a year through aquaculture.

Industry: The heat from geothermal water is used worldwide for dying cloth, drying fruits and vegetables, washing wool, manufacturing paper, pasteurizing milk, and drying timber products. It is also used to help extract gold and silver from ore. In Klamath Falls, Oregon, hot water is piped under sidewalks and roads to keep them from freezing in winter.

Heating: The most widespread use of geothermal resources—after bathing—is to heat buildings. In the Paris basin in France, geothermal water from shallow wells was used to heat homes 600 years ago. More than 500,000 people in France now use geothermal heat in their homes and buildings.

Geothermal **district systems** pump hot water from a reservoir through a **heat exchanger** that transfers the heat to separate water pipes that go to many buildings. The geothermal water is then reinjected into the reservoir to be reheated.

The first district heating system in the U.S. was built in 1893 in Boise, Idaho, where it is still in use. There are many other systems in use in the country today. Because it is clean and economical, district heating is becoming increasingly popular. In Reykjavik, Iceland, 95 percent of the buildings use geothermal energy for heat.



GeoExchange Systems: Heating and Cooling

Once you go about twenty feet below the Earth's surface, the temperature is remarkably constant year round. In temperate regions, the temperature stays about 52 degrees Fahrenheit. In tropical regions, it can range as high as 65-70 degrees, while certain arctic regions stay near freezing all year.

For most areas, this means that soil temperatures are usually warmer than the air in winter and cooler than the air in summer. Geothermal exchange systems use the Earth's constant temperatures to heat and cool buildings. These heat pumps transfer heat from the ground into buildings in winter and reverse the process in the summer.

A geothermal exchange system doesn't look like a traditional furnace or air conditioner. For one thing, most of the equipment is underground. A liquid—usually a mixture of water and antifreeze—circulates through a long loop of plastic pipe buried in the ground. This liquid absorbs heat and carries it either into or out of the building.

One advantage of a geothermal exchange system is that it doesn't have to manufacture heat. The heat is free, renewable, and readily available in the ground. The only energy this system needs is the electricity to pump the liquid through the pipes and deliver the conditioned air to the building. The pump itself is usually a small unit located inside the building.

The geothermal exchange pipes can be buried in several ways. If space is limited, holes for the pipe can be dug straight into the ground as far down as 300 feet. In very rocky areas, this method might not be an option.

If there is land available, the pipes can be buried horizontally in shallow trenches four to six feet underground, where the ground remains at approximately the same temperature all of the year. Once the pipes are in place, the surface can be used as a front lawn, football field, or parking lot. The pipes are very durable and should last up to 50 years without maintenance.

If a large lake or pond is nearby, the pipes can be buried in the water. The water must be at least six feet deep, though, or the temperature of the water will change too much. Deep, flowing water provides especially good heat exchange for a geothermal system.

Geothermal systems cost more to install than conventional heating and cooling systems. Over the life of the system, however, they can produce significant cost savings. They can reduce heating costs by 50–70 percent, and cooling costs by 20–40 percent. If the cost of the installation is spread out over several years, users see savings from the day they begin using the system. Over the life of the system, the average homeowner can anticipate saving about $20,000.

In addition, geothermal systems are low maintenance and should last twice as long as conventional systems. The pumps should last 20 years, since they are located inside, away from the weather. And most of the energy they use is free. Electricity is used only to move the heat, not to produce it.

Today, more than 300,000 homes and buildings in the United States use geothermal heat exchange systems. They are an

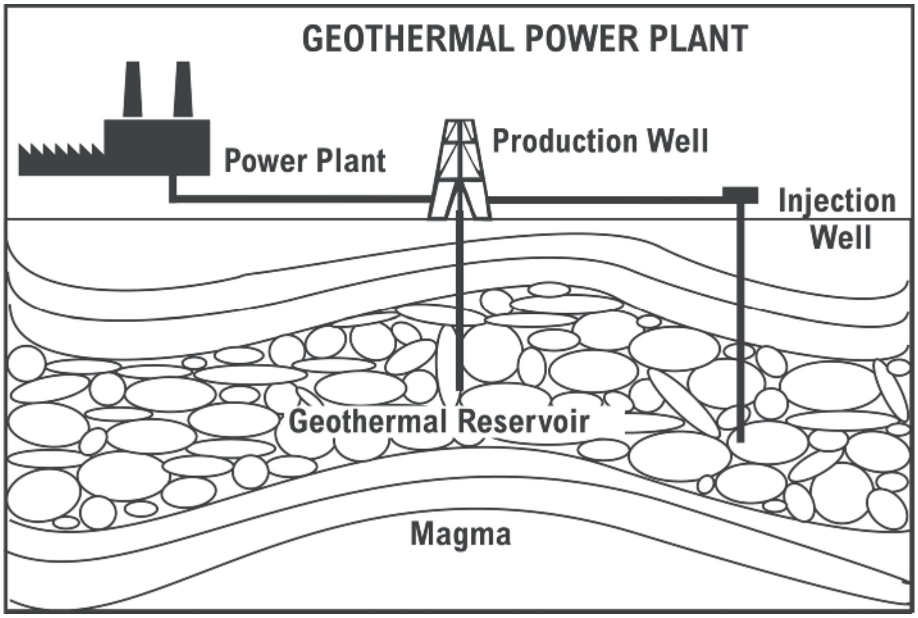
Future GEOTHERMAL Resources

Today, geothermal power plants use hydrothermal resources *(hydro = water, therme = heat)*. Three other kinds of geothermal resources—hot dry rock, magma, and geopressured—are often called near-future geothermal resources. Researchers from the U.S. Department of Energy are studying ways to develop these resources for electricity production.

HOT DRY ROCK GEOTHERMAL RESOURCES underlie much of the world's surface. The U.S. is especially rich in these resources. Some scientists believe the resource base of hot dry rock in the U.S. far exceeds worldwide fossil fuel resources. Using hot dry rock resources to produce electricity requires drilling holes deep into the rock, pumping in cold water at high pressure to fracture the rock, and then accessing the heated water and steam from an adjacent well. The water can be used repeatedly, and there are no emissions into the air. This process has been successfully demonstrated by research projects in the United States, Japan, and Europe.

MAGMA GEOTHERMAL ENERGY has been called the ultimate energy source. A magma power plant would use a process similar to hot dry rock—water would be injected directly into the magma, cooling and hardening the rock around the well. The resulting steam would be pumped out through a pipe in the well.

GEOPRESSURED RESOURCES are reservoirs of hot water and natural gas (primarily methane) locked in deep sedimentary rocks, under great pressure from the overlying sediments. The heat, pressure, and natural gas can be used to produce electricity. In the U.S., geopressured resources occur along the Texas and Louisiana coasts.



efficient, economical alternative to conventional heating and cooling systems. The U.S. Environmental Protection Agency has rated geothermal heat pump systems among the most efficient heating and cooling technologies.

Geothermal Production

Geothermal energy is put to work in many places around the world. The best-known geothermal energy sources in the United States are located in western states and Hawaii. Some moderately hot geothermal resources also exist in the Dakotas, along the Atlantic coast, and in Arkansas and Texas.

Geothermal power plants operate in California, Nevada, Utah, and Hawaii. Today, the total installed capacity of geothermal power plants in the United States is almost 3,000 megawatts (MW), the equivalent of three nuclear power plants.

In 2004, geothermal energy produced about 19 billion kilowatt hours (kWh) of electricity, or 0.5 percent of the electricity used in this country. This is enough to serve the electricity needs of three million households. California gets more electricity from geothermal energy than any other state.

Geothermal Economics

Geothermal power plants can produce electricity as cheaply as many conventional power plants. It costs 4.5 to seven cents per kWh to produce electricity from the average geothermal system. In comparison, new coal-fired and natural gas plants produce electricity at about four cents per kWh.

Initial construction costs for geothermal power plants are high because geothermal wells and power plants must be constructed at the same time. But the cost of producing electricity over time is lower because the price and availability of the fuel is stable and predictable. The fuel does not have to be imported or transported to the power plant. The power plant literally sits on top of its fuel source.

Geothermal power plants are excellent sources of **baseload power**. Baseload power is power that electric utility companies must deliver all day long. Baseload geothermal plants sell electricity all the time.

Geothermal Energy and the Environment

Geothermal energy is a renewable energy source that does little damage to the environment. Geothermal steam and hot water do contain naturally occurring traces of hydrogen sulfide (a gas that smells like rotten eggs) and other gases and chemicals that can be harmful in high concentrations.

Geothermal power plants use **scrubber systems** to clean the air of hydrogen sulfide and the other gases. Sometimes the gases are converted into marketable products, such as liquid fertilizer.

Geothermal power plants do not burn fuel to generate electricity, so their emission levels are very low. They release about one percent of the carbon dioxide emitted by comparable fossil fuel plants.

Emissions of sulfur compounds from vehicles and fossil fuel plants also contribute to acid rain. Geothermal power plants, on the other hand, emit only one to three percent of the sulfur compounds that coal and oil-fired power plants do. Well-designed **binary cycle power plants** have no emissions at all.

Geothermal power plants are compatible with many environments. They have been built in deserts, in the middle of crops, and in mountain forests. Development is often allowed on federal lands because it does not significantly harm the environment. Geothermal features in national parks, such as geysers and fumaroles in Yellowstone and Lassen Volcanic National Parks, are protected by law, so geothermal reservoirs are not tapped in these areas.

Geothermal Reserves

The earth has no shortage of geothermal activity, but not all geothermal resources are easy or economical to use. Geothermal energy comprises four percent of the total U.S. domestic energy reserves, an amount exceeded only by coal (83 percent) and biomass (five percent).

Because energy sources are considered energy reserves only when they are economical to develop, the amount of geothermal reserves will increase as the price of other fuels increases. Improvements in technology will make it easier to capture geothermal resources. This will also bring costs down and increase geothermal reserves.

Today, there are geothermal power plants in many countries, supplying electricity to millions of people. Direct uses of geothermal reservoirs amount to over 11,000 megawatts of thermal energy in 35 countries. An additional 40 countries use hot springs and spas, but have not yet commercially developed their geothermal reservoirs.

Hydropower

HYDROPOWER at a Glance

Classification: Renewable

U.S. Energy Production	2.73 Q	3.9 %
U.S. Energy Consumption	2.72 Q	2.7 %

Major Use: electricity

What Is Hydropower?

Hydropower (from *hydro* meaning water) is energy that comes from the force of moving water. The fall and flow of water is part of a continuous natural cycle called the water cycle.

Energy from the sun evaporates water in the earth's oceans and rivers and draws it upward as water vapor. When the water vapor reaches the cooler air in the atmosphere, it condenses and forms clouds. The moisture eventually falls to the earth as rain or snow, replenishing the water in the oceans and rivers. Gravity drives the water, moving it from high ground to low ground. The force of moving water can be extremely powerful.

Hydropower is called a **renewable** energy source because the water on the earth is continuously replenished by precipitation. As long as the water cycle continues, we won't run out of this energy source.

History of Hydropower

Hydropower has been used 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 the water wheel to power machines.

The water wheel is a simple machine. The water wheel is located below a source of flowing water. It captures the water in buckets attached to the wheel and the weight of the water causes the wheel to turn. Water wheels convert the potential energy (gravitational energy) of the water into motion. That energy can then be used to grind grain, drive sawmills, or pump water.

In the late 19th century, the force of falling water was used to generate electricity. The first hydroelectric power plant was built at Niagara Falls in 1879. In the following decades, many more hydroelectric plants were built. At its height in the early 1940s, hydropower provided 33 percent of this country's electricity.

By the late 1940s, the best sites for big dams had been developed. Inexpensive fossil fuel plants also entered the picture. At that time, plants burning coal or oil could make electricity more cheaply than hydro plants. Soon they began to underprice the smaller hydroelectric plants. It wasn't until the oil shocks of the 1970s that people showed a renewed interest in hydropower.

Hydro Dams

It's easier to build a hydro plant where there is a natural waterfall. That's why the first hydro plant was built at Niagara Falls. Dams, which are artificial waterfalls, are the next best way.

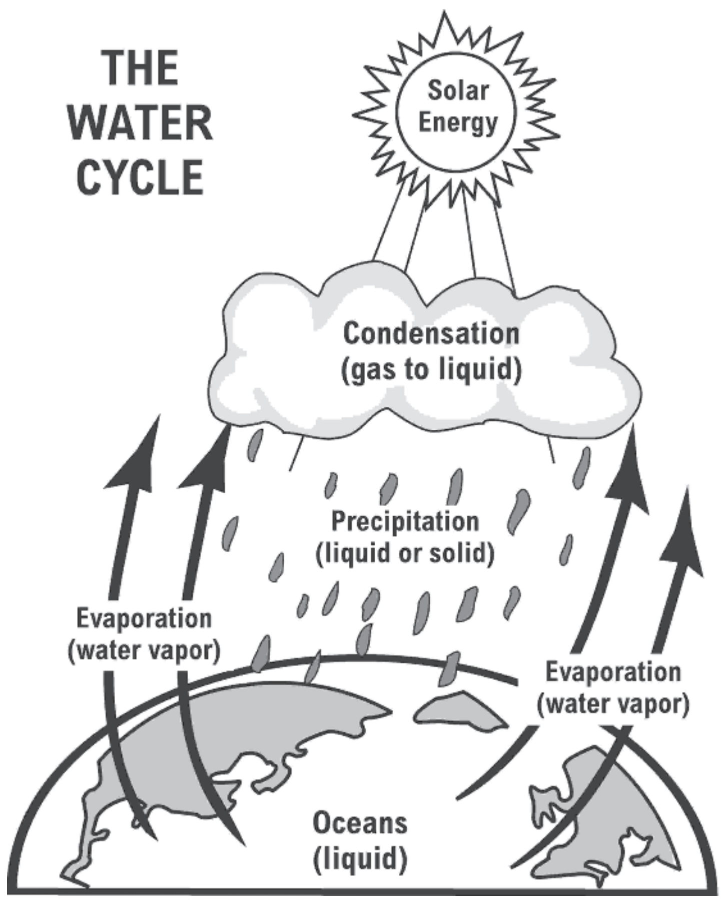
Dams are built on rivers where the terrain will produce an artificial lake or **reservoir** above the dam. Today there are about 80,000 dams in the United States, but only three percent have power-generating hydro plants. Most dams are built for flood control and irrigation, not electric power generation.

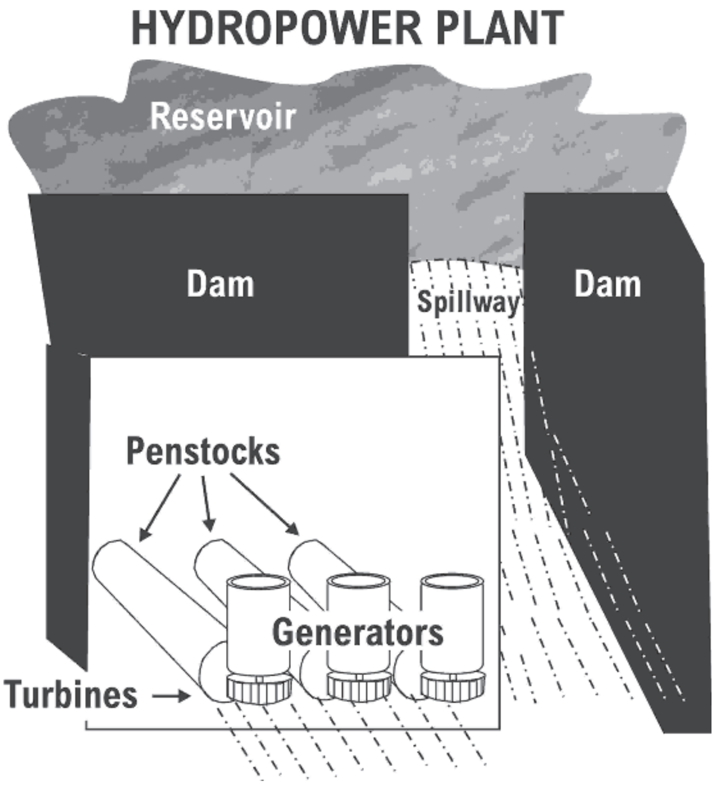
A dam serves two purposes at a hydro plant. First, a dam increases the **head** or height of a waterfall. Second, it controls the flow of water. Dams release water when it is needed for electricity production. Special gates called **spillway gates** release excess water from the reservoir during heavy rainfalls.

Hydropower Plants

As people discovered centuries ago, the flow of water represents a huge supply of kinetic energy that can be put to work. Water wheels are useful for generating mechanical energy to grind grain or saw wood, but they are not practical for generating electricity. Water wheels are too bulky and slow.

Hydroelectric plants are different. They use modern turbine generators to produce electricity, just as thermal (coal, oil, nuclear) power plants do.





How a Hydro Plant Works

A typical hydro plant is a system with three parts:

– an electric plant where the electricity is produced.

– a dam that can be opened or closed to control water flow.

– a reservoir (artificial lake) where water can be stored.

To make electricity, a dam opens its gates to allow water from the reservoir above to flow down through a large tube called a **penstock**. At the bottom of the penstock, the fast-moving water spins the blades of a turbine. The turbine is connected to a generator to produce electricity. The electricity is then transported via huge transmission lines to a local utility company.

Head and Flow

The amount of electricity that can be generated at a hydro plant is determined by two factors: head and flow. **Head** is how far the water drops. It is the distance from the highest level of the dammed water to the point where it goes through the power-producing turbine.

Flow is how much water moves through the system - the more water that moves through a system, the higher the flow. Generally, a **high-head plant** needs less water flow than a **low-head plant** to produce the same amount of electricity.

Storing Energy

One of the biggest advantages of a hydropower plant is its ability to store energy. The water in a reservoir is, after all, stored energy. Water can be stored in a reservoir and released when needed for electricity production.

During the day when people use more electricity, water can flow through a plant to generate electricity. Then, during the night when people use less electricity, water can be held back in the reservoir.

Storage also makes it possible to save water from winter rains for summer generating power, or to save water from wet years for generating electricity during dry years.

Pumped Storage Systems

Some hydro plants use pumped storage systems. A pumped storage system operates much as a public fountain does. The same water is used again and again.

At a pumped storage hydro plant, flowing water is used to make electricity and then stored in a lower pool. Depending on how much electricity is needed, the water may be pumped back to an upper pool. Pumping water to the upper pool requires electricity so hydro plants usually use pumped storage systems only when there is a big demand for electricity.

Pumped hydro is the most reliable energy storage system used by American electric utilities. Coal and nuclear power plants have no energy storage systems. They must turn to expensive gas and oil-fired generators when people demand lots of electricity. They also have no way to store any extra energy they might produce during normal generating periods.

Hydropower Production

How much electricity do we get from hydropower today? Depending on the amount of rainfall, hydro plants produce from five to ten percent of the electricity produced in this country (10 percent in 1997, 5.6 percent during the protracted drought of 2001). In Oregon and Washington, hydropower supplies over 85 percent of the electricity each year.

Today, there are about 75 million kilowatts of hydro generating capacity in the United States. That's equivalent to the generating capacity of 70 large nuclear power plants. The biggest hydro plant in the U.S. is located at the Grand Coulee Dam on the Columbia River in northern Washington State. The United States also gets some hydropower production from Canada. Some New England utilities buy this imported electricity.

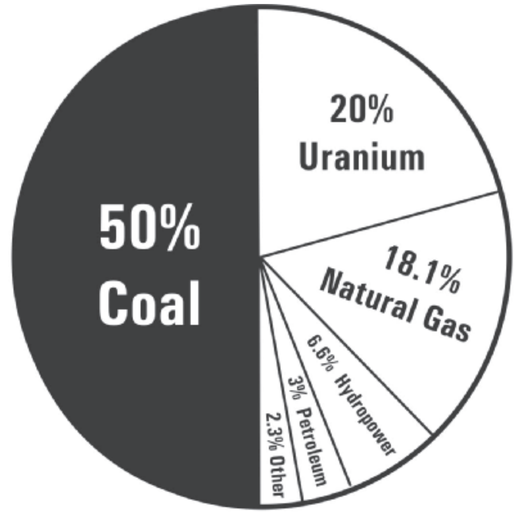
What does the future look like for hydropower? The best sites for hydropower dams have already been developed so the development of big hydro plants is unlikely.

Existing plants could be enlarged to provide additional generating capacity. Plus, many flood-control dams not equipped for electricity production could be outfitted with generating equipment. The Federal Energy Regulatory Commission estimates 60 thousand megawatts of additional generating capacity could be developed in the United States.

Hydropower for Baseload Power

Demand for electricity is not steady; it goes up and down. People use more electricity during the day when they are awake and using electrical appliances, and less at night when they are asleep. People also use more electricity when the weather is very cold or very hot.

Electric utility companies have to produce electricity to meet these changing demands. Baseload power is the electricity that utilities have to generate all the time. For that reason, baseload power should be cheap and reliable. Hydropower meets both these requirements. Generating electricity with hydropower is the cheapest way to generate electricity in the U.S., and the fuel supply—flowing water—is always available.



U.S. ELECTRICITY PRODUCTION

Hydro plants are more energy efficient than most thermal power plants, too. That means they waste less energy to produce electricity. In thermal power plants, a lot of energy is lost as heat. Hydro plants also run 85 percent of the time, about 50 percent more than thermal plants.

Economics of Hydropower

Hydropower is the cheapest way to generate electricity today. No other energy source, renewable or nonrenewable, can match it. Today, it costs about one cent per kWh (kilowatt-hour) to produce electricity at a typical hydro plant. In comparison, it costs coal plants about four cents per kWh and nuclear plants about two cents per kWh to generate electricity.

Producing electricity from hydropower is cheap because, once a dam has been built and the equipment installed, the energy source—flowing water—is free.

Hydropower plants also produce power cheaply due to their sturdy structures and simple equipment. Hydro plants are dependable and long-lived, and their maintenance costs are low compared to coal or nuclear plants.

One requirement may increase hydropower's costs in the future. The procedure for licensing a dam has become a lengthy and expensive process. Many environmental impact studies must be undertaken and as many as 13 state and federal agencies must be consulted. It takes anywhere from five to seven years to get a license to build a hydroelectric dam.

Hydropower and the Environment

Hydropower dams can cause several environmental problems, even though they burn no fuel. Damming rivers may destroy or disrupt wildlife and natural resources. Fish, for one, may no longer be able to swim upstream.

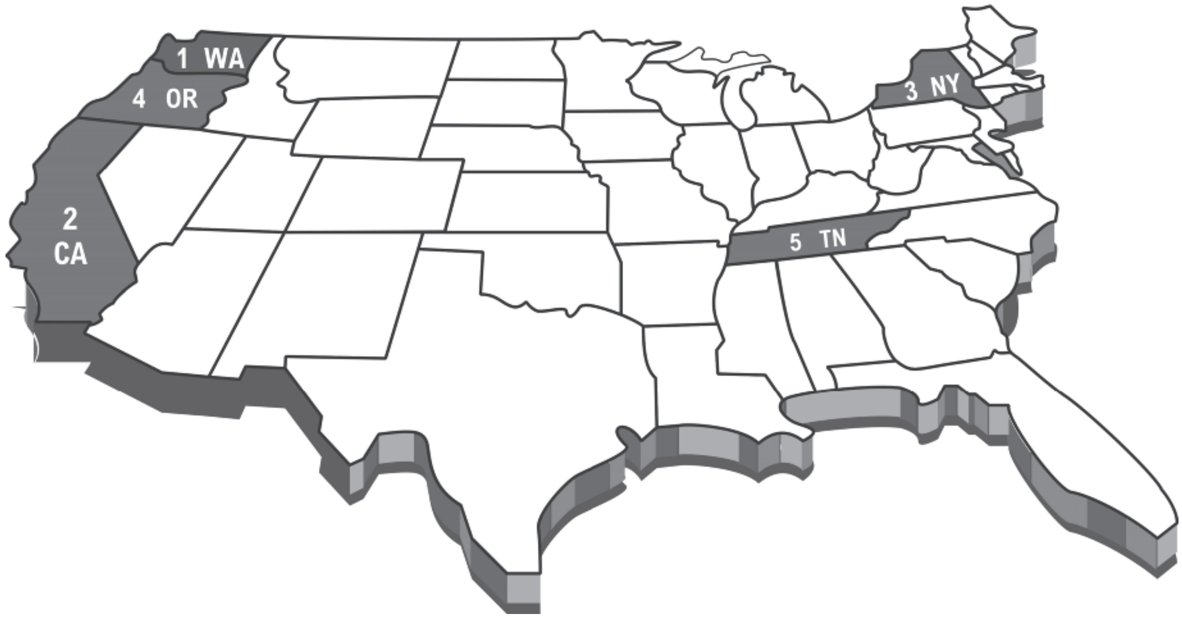
Hydro plant operations may also affect water quality by churning up dissolved metals that may have been deposited by industry long ago. Hydropower operations may increase silting, change water temperatures, and lower the levels of dissolved oxygen.

Some of these problems can be managed by constructing fish ladders, dredging the silt, and carefully regulating plant operations.

Hydropower has advantages, too. Hydropower's fuel supply (flowing water) is clean and is renewed yearly by snow and rainfall. Furthermore, hydro plants do not emit pollutants into the air because they burn no fuel. With growing concern over greenhouse gas emissions and increased demand for electricity, hydropower may become more important in the future.

Hydropower facilities offer a range of additional benefits. Many dams are used to control flooding and regulate water supply, and reservoirs provide lakes for recreational purposes, such as boating and fishing.

TOP HYDROPOWER PRODUCING STATES



Other Hydro Resources

Tidal Energy

The tides rise and fall in eternal cycles. The waters of the oceans are in constant motion. We can use some of the ocean's energy, but most of it is out of reach. The problem isn't harnessing the energy as much as transporting it. Generating electricity in the middle of the ocean just doesn't make sense—there's no one there to use it. We can only use the energy near shore, where people need it.

Tidal energy is the most promising source of ocean energy for today and the near future. Tides are changes in the level of the oceans caused by the rotation of the earth and the gravitational pull of the moon and sun. Near shore water levels can vary up to 40 feet, depending on the season and local factors. Only about 20 locations have good inlets and a large enough tidal range—about 10 feet—to produce energy economically.

Tidal energy plants capture the energy in the changing tides. A low dam, called a **barrage**, is built across an inlet. The barrage has one-way gates (**sluices**) that allow the incoming flood tide to pass into the inlet. When the tide turns, the water flows out of the inlet through huge turbines built into the barrage, producing electricity. The oldest and largest tidal plant—La Rance in France—has been successfully producing electricity since 1968.

Today, the electricity from tidal plants costs more than from conventional power plants. It is very expensive and takes a long time to build the barrages, which can be several miles long. Also, tidal plants produce electricity less than half of the time. The seasons and cycles of the moon affect the level—and the energy—of the tides. The tides are very predictable, but not controllable.

On the other hand, the fuel is free and non-polluting, and the plants are easy to maintain. Only two operators are needed to run the La Rance plant at night and on weekends. And the plants should run for a hundred years with little up-keep.

Tidal power is a renewable energy source. The plants do affect the environment, though they produce no air pollution. During construction, there are major short-term changes to the ecology of the inlet. Once the plants go into operation, there can be long-term changes to water levels and currents. The plants in operation have reported no major environmental problems.

The United States has no tidal plants and only a few sites where tidal energy could be produced economically. France, England, Canada and Russia have much more potential. The keys are to lower construction costs, increase output, and protect the environment.

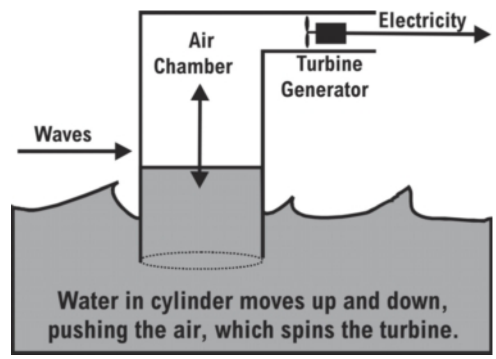
Wave Energy

There is also tremendous energy in waves. Waves are caused by the wind blowing over the surface of the ocean. In many areas of the world, the wind blows with enough consistency and force to provide continuous waves. The west coasts of the United States and Europe and the coasts of Japan and New Zealand are good sites for harnessing wave energy.

There are several ways to harness wave energy. The motion of the waves can be used to push and pull air through a pipe. The air spins a turbine in the pipe, producing electricity. In Norway, a demonstration tower built into a cliff produces electricity for about four cents a kWh using this method. The wail of the fast-spinning turbines, however, can be heard for miles.

Another way to produce energy is to bend or focus the waves into a narrow channel, increasing their power and size. The waves then can be channeled into a catch basin, like tidal plants, or used directly to spin turbines.

There aren't any big commercial wave energy plants, but there are a few small ones. There are wave-energy devices that power the lights and whistles on buoys. Small, on-shore sites have the best potential for the immediate future, especially if they can also be used to protect beaches and harbors. They could produce enough energy to power local communities. Japan, which must import almost all of its fuel, has an active wave-energy program.



OTEC

The energy from the sun heats the surface water of the ocean. In tropical regions, the surface water can be 40 or more degrees warmer than the deep water. This difference can be used to produce electricity. **Ocean Thermal Energy Conversion**, or **OTEC**, has the potential to produce more energy than tidal, wave, and wind energy combined, but it is a technology for the future. There are no large-scale OTEC power plants in use today.

The warm surface water is turned into steam under pressure, or used to heat another fluid into a vapor. This steam or vapor spins a turbine to produce electricity. Pumps bring cold deep water to the surface through huge pipes. The cold water cools the steam or vapor, turning it back into liquid form, and the closed cycle begins again. In an open system design, the steam is turned into fresh water, and new surface water is added to the system.

An OTEC system is only about 2.5 percent efficient. Pumping the water is a giant engineering challenge. In addition, the electricity must be transported to land. OTEC systems must have a temperature difference of at least 38 degrees Fahrenheit to operate. This limits OTEC's use to tropical regions where the surface waters are very warm. Hawaii, with its tropical climate, has experimented with OTEC systems since the 1970s.

Today, there are several experimental OTEC plants, but no big operations. It will probably be 15 to 20 years before the technology is available to produce energy economically from OTEC systems. OTEC will have the potential to produce non-polluting, renewable energy.

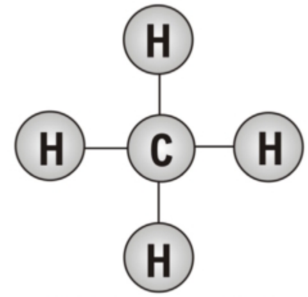
Natural Gas

NATURAL GAS at a Glance

Classification: Nonrenewable

U.S. Energy Production	19.34 Q	27.5 %
U.S. Energy Consumption	22.99 Q	23.1 %

Major Uses: heating, industry, electricity



Methane = CH_4

What Is Natural Gas?

Natural gas is generally considered a nonrenewable fossil fuel. *(There are some renewable sources of methane, the main ingredient in natural gas, also discussed in this factsheet.)* Natural gas is considered a fossil fuel because most scientists believe that natural gas was formed from the remains of tiny sea animals and plants that died 200-400 million years ago.

When these tiny sea animals and plants died, they sank to the bottom of the oceans where they were buried by layers of sediment that turned into rock. Over the years, the layers of sedimentary rock became thousands of feet thick, subjecting the energy-rich plant and animal remains to enormous pressure. Most scientists believe that the pressure, combined with the heat of the earth, changed this organic mixture into petroleum and natural gas. Eventually, concentrations of natural gas became trapped in the rock layers like a wet sponge traps water.

Raw natural gas is a mixture of different gases. The main ingredient is methane, a natural compound that is formed whenever plant and animal matter decays. By itself, methane is odorless, colorless, and tasteless. As a safety measure, natural gas companies add a chemical odorant called **mercaptan** (it smells like rotten eggs) so escaping gas can be detected. Natural gas should not be confused with gasoline, which is made from petroleum.

History of Natural Gas

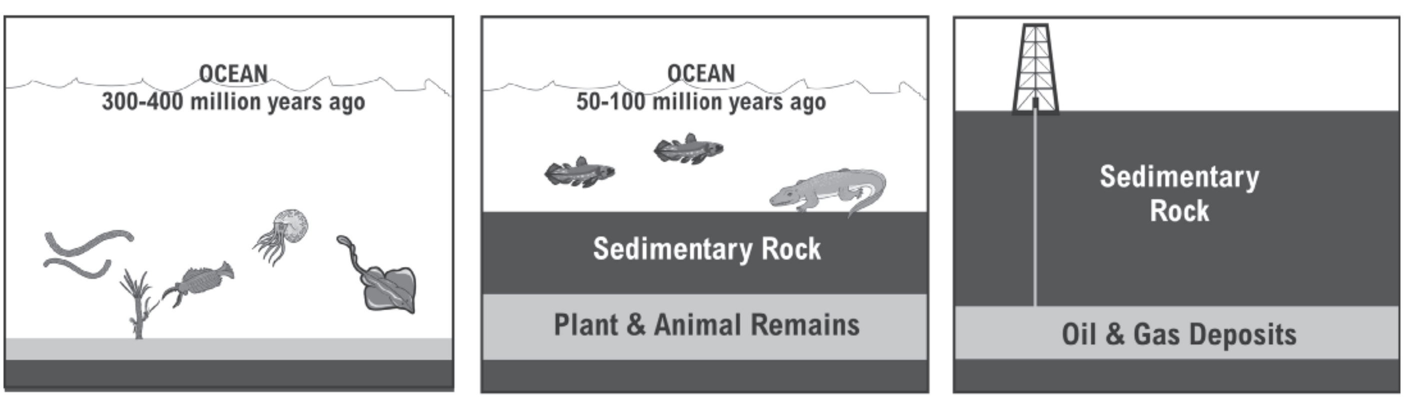
The ancient peoples of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeping from cracks in the ground was ignited by lightning. They sometimes built temples around these eternal flames so they could worship 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 seawater for salt.

Natural gas was first used in America to illuminate the streets of Baltimore in 1816. Soon after, in 1821, William Hart dug the first successful American natural gas well in Fredonia, New York. His well was 27 feet deep, quite shallow compared to today's wells. The Fredonia Gas Light Company opened its doors in 1858 as the nation's first natural gas company.

By 1900, natural gas had been discovered in 17 states. In the past 40 years, the use of natural gas has grown. Today, natural gas accounts for 23 percent of the energy we use.

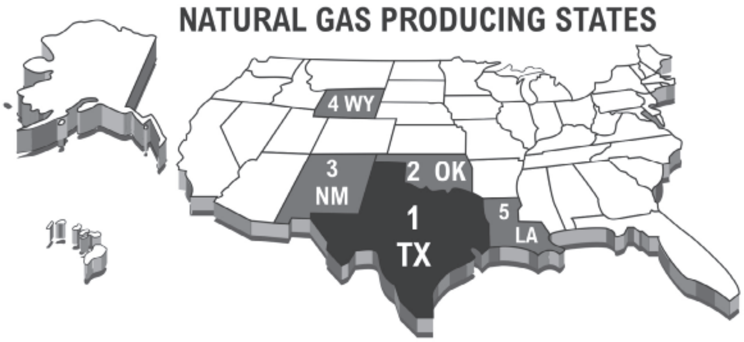
OIL & NATURAL GAS FORMATION



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary 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 layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.



Producing Natural Gas

Natural gas can be hard to find since it can be trapped in porous rocks deep underground. Geologists 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 and record the sound waves as they bounce back from the sedimentary rock layers underground. They also may measure the gravitational pull of rock masses deep within the earth.

If test results are promising, the scientists may recommend drilling to find the natural gas deposits. Natural gas wells average 6,100 feet deep and can cost a hundred dollars per foot to drill, so it's important to choose sites carefully.

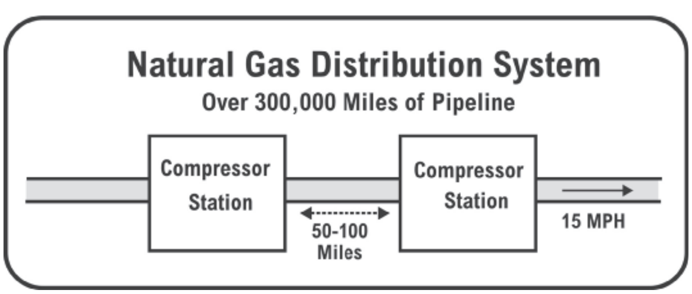
Only about 48 percent of the exploratory wells produce gas. The others come up dry. The odds are better for developmental wells—wells drilled on known gas fields. On average, 85 percent of the developmental wells yield gas. Natural gas can be found in pockets by itself or in petroleum deposits.

After natural gas comes out of the ground, it goes to a processing plant where it is cleaned of impurities and separated into its various components. Approximately 90 percent of natural gas is composed of methane, but it also contains other gases such as propane and butane.

Natural gas may also come from several other sources. One source is **coalbed methane**, natural gas found in coalbeds. Until recently, coalbed gas was just considered a safety hazard to miners, but now it is a valuable source of natural gas.

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 decaying garbage. The gas from coalbeds and landfills accounts for almost 10 percent of the total gas supply today, and experts predict this figure will increase. The gas recovered from landfills is usually burned on the landfill site to generate electricity for the facility itself.

Today, natural gas is produced in 32 states, but the top five states—Texas, Oklahoma, New Mexico, Wyoming, and Louisiana—produce 59 percent of the total. Altogether, the U.S. produces about a fourth of the world's natural gas each year.



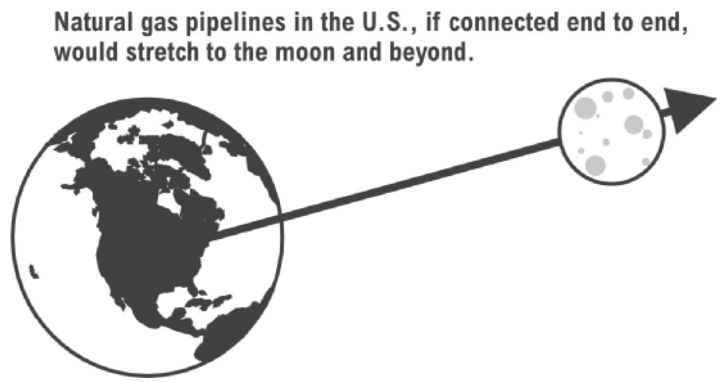
Transporting and Storing Natural Gas

How does natural gas get to you? Usually by pipeline. Approximately 300,000 miles of underground pipelines link natural gas wells to cleaning plants to major cities across the United States. Natural gas is sometimes transported thousands of miles by pipeline to its final destination.

A machine called a **compressor** increases the pressure of the gas, forcing the gas to move along the pipelines. Compressor stations, which are spaced about 50 to 100 miles apart, move the gas along the pipelines at about 15 miles per hour.

Some gas moved along this subterranean highway is temporarily stored in huge underground reservoirs. The underground reservoirs are typically filled in the summer so there will be enough natural gas during the winter heating season.

Eventually, the gas reaches the city gate of a local gas utility. The pressure is reduced and an odorant is added so leaking gas can be detected. Local gas companies use smaller pipes to carry gas the last few miles to homes and businesses. A gas meter measures the volume of gas a consumer uses.



Natural Gas Use

Just about everyone in the United States uses natural gas. Natural gas ranks number two in energy consumption, after petroleum, which provides more than 38 percent of our total energy demand. About 23 percent of the energy we use in the United States comes from natural gas.

Industry is the biggest consumer of natural gas, using it mainly as a heat source to manufacture goods. Industry also uses natural gas as an ingredient in fertilizer, photographic film, ink, glue, paint, plastics, laundry detergent, and insect repellents. Synthetic rubber and man-made fibers like nylon also could not be made without the chemicals derived from natural gas.

Residences—people's homes—are the second biggest users of natural gas. Six in ten homes use natural gas for heating. Many homes also use gas water heaters, stoves, and clothes dryers. Natural gas is used so often in homes because it is clean burning.

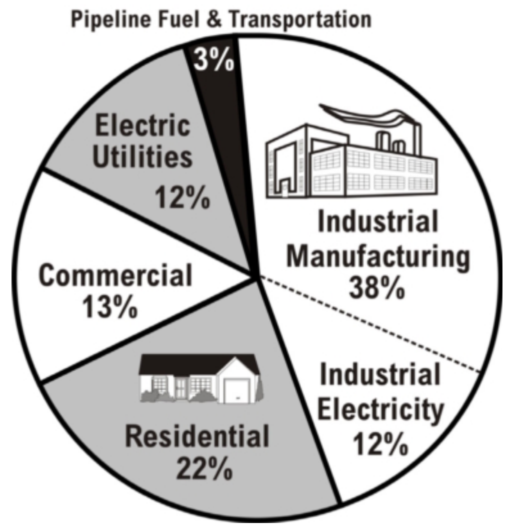
Like residences, commercial use of natural gas is mostly for indoor space heating of stores, office buildings, schools, churches, and hospitals.

Natural gas is also used to make electricity—it is the third largest producer of electricity after coal and uranium. Many people in the energy industry believe natural gas will play a bigger role in electricity production as the demand for electricity increases in the future.

Natural gas power plants are cleaner than coal plants and can be brought on-line very quickly. Natural gas plants produce electricity more efficiently than new coal plants and produce it with fewer emissions. Today, natural gas generates 18 percent of the electricity in the U.S.

To a lesser degree, natural gas is becoming popular as a transportation fuel. Natural gas can be used in any vehicle with a regular internal combustion engine, although the vehicle must be outfitted with a special carburetor and fuel tank. Natural gas is cleaner burning than gasoline, costs less, and has a higher octane (power boosting) rating. In 2004, more than 150,000 vehicles ran on natural gas in the United States.

NATURAL GAS USE



Natural Gas Reserves

People in the energy industry use two special terms when they talk about how much natural gas there is—resources and reserves. Natural gas resources include all the deposits of gas that are still in the ground waiting to be tapped. Natural gas reserves are only those gas deposits that geologists know, or strongly believe, can be recovered given today's prices and drilling technology. In other words, when geologists estimate the amount of known gas reserves, they do not include gas deposits that may be discovered in the future or gas deposits that are not economical to produce given today's prices.

The United States has large reserves of natural gas. Most reserves are in the Gulf of Mexico and in the following states: Texas, Louisiana, Oklahoma, New Mexico, Wyoming, Kansas, and Alaska. If we continue to use natural gas at the same rate as we use it today, the United States has about a 30-50 year supply of natural gas, though another 200 years of gas supplies could be produced if people are willing to pay more for the gas they use.

Natural Gas Prices

Since 1985, natural gas prices have been set by the market. The federal government sets the price of transportation for gas that crosses state lines. State public utility commissions will continue to regulate natural gas utility companies—just as they regulate electric utilities. These commissions regulate how much utilities may charge and monitor the utilities' policies.

How much does it cost to heat your home with natural gas? Compared to other energy sources, natural gas is an economical choice, though the price is increasing with demand. It is about three times cheaper than electricity when you use resistance heat and also less expensive than electric heat pumps.

Natural Gas and the Environment

All the fossil fuels—coal, petroleum, and natural gas—release pollutants into the atmosphere when burned. The good news is that natural gas is the most environmentally friendly fossil fuel.

Burning natural gas produces less sulfur, carbon, and nitrogen than burning other fossil fuels. Natural gas also emits little ash particulate into the air when it is burned.

Like all fossil fuels, burning natural gas produces carbon dioxide, a greenhouse gas. Many scientists believe that increasing levels of carbon dioxide in the atmosphere, caused in large part by fossil fuel use, could have long-term effects on global climate.

In 1997, the United States and many other industrialized countries agreed upon a plan to reduce emissions of greenhouse gases. This treaty, called the Kyoto Protocol, has been signed by the United States, but not approved by the Senate. President Bush has announced he will not approve the treaty in its present form because it exempts emerging countries such as China, which will soon surpass the U.S. as the top emitter of greenhouse gases.

Measuring NATURAL GAS

Gasoline is sold in gallons, coal in pounds, and wood in cords. Natural gas is sold in cubic feet. We can measure the heat contained in all these energy sources by one common unit of measure. The heat stored in a gallon of gasoline, a pound of coal, or a cubic foot of natural gas can all be measured in British thermal units or Btu's.

One Btu is the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit. One candy bar (an energy source for the human body) has about 1,000 Btu. One cubic foot of natural gas has about 1,031 Btu. Natural gas is usually sold to pipeline companies in standard measurements of thousands of cubic feet (Mcf). One thousand cubic feet of natural gas would fit into a box that is 10 feet deep, 10 feet long, and 10 feet wide. Most residential customers are billed by the number of therms of natural gas they use each month. A therm is a measure of the thermal energy in the gas and is equal to about 97 cubic feet.

Future of Natural Gas

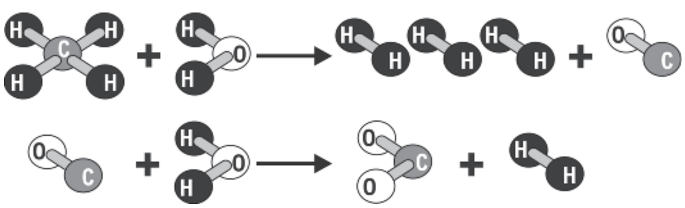
Fuel Cells

Many scientists are interested in using natural gas to generate electricity without combustion using a fuel cell. A fuel cell is similar to a battery. It uses a chemical process rather than combustion to convert the energy content of a fuel into electricity.

Most fuel cells in production and development today use hydrogen as a fuel. Since hydrogen gas is not found naturally on earth, it must be manufactured. There are many ways to do this. The fact that hydrogen can be produced using so many different domestic resources is an important reason why it is a promising energy carrier. In a hydrogen economy, we will not need to rely on a single resource or technology to meet our energy needs.

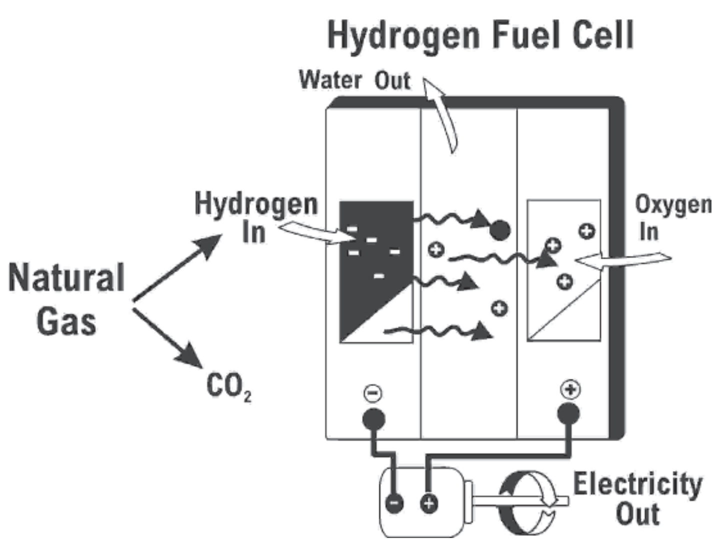
Industry produces hydrogen by steam reforming, a two-part process in which high-temperature steam separates the hydrogen atoms from the carbon atoms in methane (CH_4), as shown below.

$$CH_4 + H_2O\text{ (steam)} \rightarrow 3H_2 + CO$$
$$CO + H_2O\text{ (steam)} \rightarrow CO_2 + H_2$$



Today, most of the hydrogen produced by steam reforming isn't used as fuel for fuel cell applications but in industrial processes. Steam reforming is the most cost-effective way to produce hydrogen today and accounts for about 95 percent of the hydrogen produced in the U.S. Fuel cells today are expensive; the technology to generate electricity from fuel cells must be improved if they are to be commercially successful.

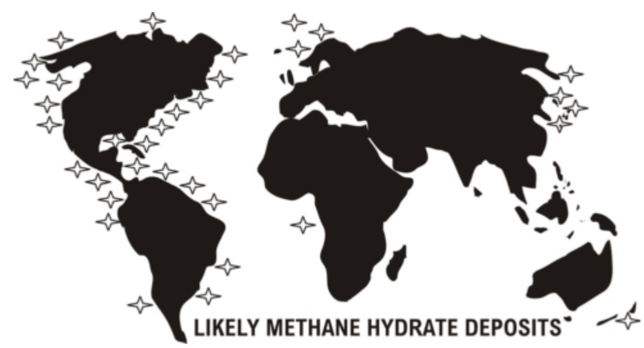
The chemical process of producing electricity from natural gas is much more energy-efficient than combustion, and it emits no air pollutants.



Methane Hydrates

Buried in the sediments of the ocean floor is a reserve of methane so vast it could possibly fuel the entire world. In sediments on the ocean floor, tiny bacteria continuously break down the remains of sea animals and plants, producing methane gas. Under the enormous pressures and cold temperatures at the bottom of the sea, this methane gas dissolves and becomes locked in water molecules to form crystals. These crystals cement together the ocean sediments into solid layers—called methane hydrates—that can extend down into the sea floor.

Scientists also suspect that huge deposits of free methane gas are trapped beneath the hydrate layer. Researchers estimate there is more carbon trapped in hydrates than in all the fossil fuels. They aren't sure how to capture this methane. When a hydrate breaks down, it loses its solidity and turns to mush, causing major landslides and other disturbances to the ocean floor, as well as an increase in methane escaping into the atmosphere.



Biomass

Scientists are also researching new ways to obtain natural (methane) gas from biomass—a fuel source derived from plant and animal wastes. Methane gas is naturally produced whenever organic matter decays.

Today, we can drill shallow wells into landfills to recover the methane gas. Landfills are already required to collect methane gas as a safety measure. Typically, landfills collect the gas and burn it to get rid of it. But the gas can be put to work. Last year, over four billion cubic feet of landfill methane gas was used for heating and electricity production. There are other ways to convert biomass into natural gas. One method converts aquatic plants, such as sea kelp, into methane gas. In the future, huge kelp farms could also produce renewable gas energy.

Liquefied Natural Gas

Another successful development has been the conversion of natural gas into a liquid. As a liquid, natural gas is called LNG, or liquefied natural gas. LNG is made by cooling natural gas to a temperature of minus 259^{O}F. At that temperature, natural gas becomes a liquid and its volume is reduced 600 times. Liquefied natural gas is easier to store than the gaseous form since it takes up much less space. LNG is also easier to transport. People can put LNG in special tanks and transport it on trucks or ships. Today, more than 100 LNG storage facilities are operating in the United States.

Petroleum

PETROLEUM at a Glance

Classification: Nonrenewable

U.S. Energy Production	12.18 Q	17.3 %
U.S. Energy Consumption	38.23 Q	38.4 %

Major Uses: transportation, industry

What Is Petroleum?

Petroleum is a **fossil fuel**. 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. They were buried by thousands of feet of sediment and sand that turned into rock.

Over time, this organic mixture was subjected to enormous pressure and heat as the layers increased. The mixture changed chemically, breaking down into compounds made of hydrogen and carbon atoms—hydrocarbons. Finally, an oil-saturated rock—much like a wet household sponge—was formed.

All organic material does not turn into oil. Certain geological conditions must exist within the oil-rich rocks. First, there must be a trap of non-porous rock that prevents the oil from seeping out, and a seal (such as salt or clay) that keeps the oil from rising to the surface. Even under these conditions, only about two percent of the organic material is transformed into oil.

A typical petroleum reservoir is mostly sandstone or limestone in which oil is trapped. The oil in it may be as thin as gasoline or as thick as tar. It may be almost clear or black.

Petroleum is called a **nonrenewable** energy source because it takes millions of years to form. We cannot make more oil in a short time.

History of Oil

People have used naturally available crude oil for thousands of years; the ancient Chinese and Egyptians, for example, burned oil to produce light.

Before the 1850s, Americans often used whale oil for light. When whale oil became scarce, people began looking for other oil sources. In some places, oil seeped naturally to the surface of ponds and streams. People skimmed this oil and made it into kerosene. Kerosene was commonly used to light America's homes before the arrival of the electric light bulb.

As demand for kerosene grew, a group of businessmen hired Edwin Drake to drill for oil in Titusville, Pennsylvania. After much hard work and slow progress, he discovered oil in 1859. Drake's well was 69.5 feet deep, very shallow compared to today's wells.

Drake refined the oil from his well into kerosene for lighting. Gasoline and other products made during refining were simply thrown away because people had no use for them.

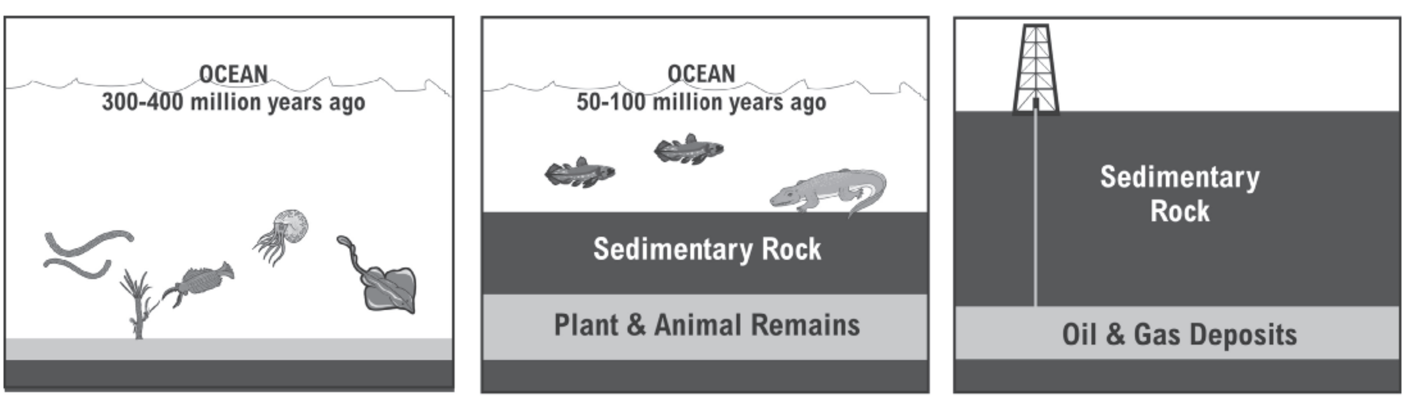
In 1892, the horseless carriage, or automobile, solved this problem since it required gasoline. By 1920, there were nine million motor vehicles in this country and gas stations were opening everywhere.

Producing Oil

Although research has improved the odds since Edwin Drake's days, petroleum exploration today is still a risky business. Geologists study underground rock formations to find areas that might yield oil. Even with advanced methods, only about 44 of every 100 exploratory wells find oil, and only 10 of those are profitable.

When the potential for oil production is found, a petroleum company brings in a 50 to 100-foot drilling rig and raises a **derrick** that houses the drilling tools. Today's oil wells average 6,000 feet deep and may sink below 20,000 feet. The average well produces about 11 barrels of oil a day.

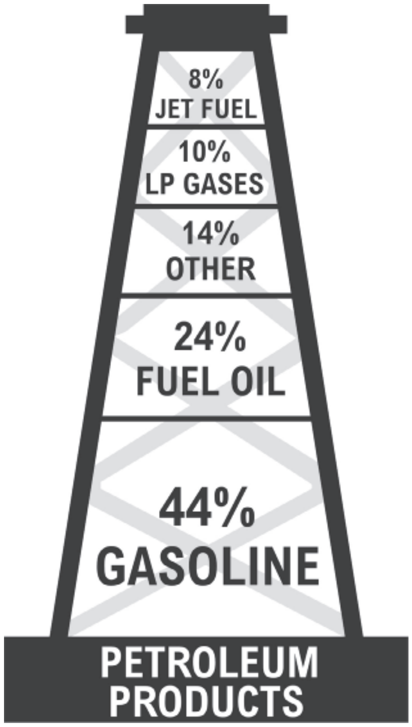
OIL & NATURAL GAS FORMATION



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary 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 layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.



To safeguard the environment, oil drilling and oil production are regulated by state and federal governments. Oil companies must get permission to explore for oil on new lands. Many experts believe that 85 percent of our remaining oil reserves are on land owned by the federal government. Oil companies lease the mineral rights from the federal government, which, in return, receives rental payments for the mineral rights as well as percentage payments from each barrel of oil.

Texas produces more oil than any other state. The other top producing states are Alaska, California, Louisiana, New Mexico, and Oklahoma. In all, 31 states produce petroleum.

From Well to Market

We cannot use crude oil in the state it's in when it comes out of the ground. The process is a little more complicated than that. So, how does thick, black crude oil come out of the ground and eventually get into your car as a thin, amber-colored liquid called gasoline?

Oil's first stop after being pumped from a well is an oil refinery. A **refinery** is a plant where crude oil is processed. Sometimes, refineries are located near oil wells, but usually the crude oil has to be delivered to the refinery by ship, barge, pipeline, truck, or train.

After the crude oil has reached the refinery, huge round tanks store the oil until it is ready to be processed. Tank farms are sites with many storage tanks.

An oil refinery cleans and separates the crude oil into various fuels and by-products. The most important one is gasoline. Some other petroleum products are diesel fuel, heating oil, and jet fuel.

Refineries use many different methods to make these products. One method is a heating process called **distillation**. Since oil products have different boiling points, the end products can be distilled or separated. Asphalts have a higher boiling point than gasolines, allowing the two to be separated.

Refineries have another job. They remove contaminants from the oil. A refinery removes sulfur from gasoline, for example, to increase its efficiency and to reduce air pollution. Nine percent of the energy in the crude oil is used to operate the refineries.

Shipping Oil Products

After processing at the refinery, gasoline and other petroleum products are usually shipped across the country through pipelines. There are about 230,000 miles of pipelines in the United States. Pipelines are the safest and cheapest way to move large quantities of petroleum across land.

Pump stations, which are spaced 20 to 100 miles apart along the underground pipelines, keep the petroleum products moving at a speed of about five miles per hour. At this rate, it takes 15 days to move a shipment of gasoline from Houston, Texas to New York City.

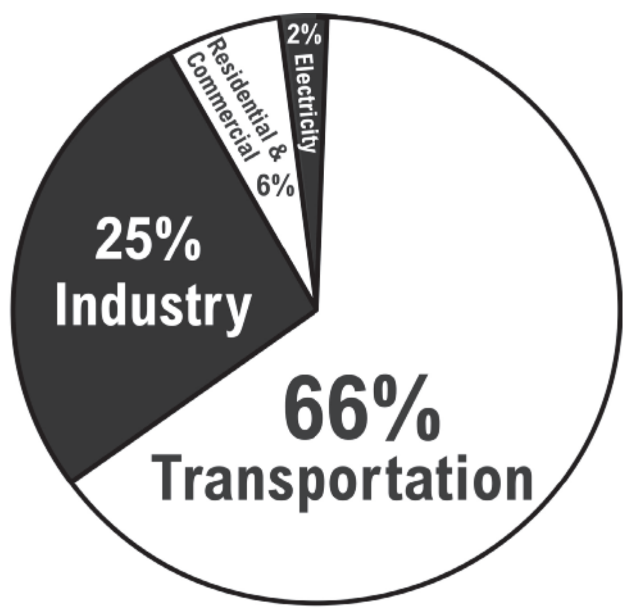
Distribution

Companies called **jobbers** handle the wholesale distribution of oil. There are 15,000 jobbers in the U.S., and they sell just about everything that comes out of a barrel of crude oil. Jobbers fill bulk orders for petroleum products from gasoline stations, industries, utility companies, farmers, and other consumers.

The retailer is the next link in the chain. A retailer may be a gasoline station or a home heating oil company. The last link is when you pump gasoline into your car, and the engine converts the gasoline's chemical energy into motion to move your car!

Demand for Oil

Since World War II, petroleum has replaced coal as the leading source of energy in the United States. Petroleum supplies 38.3 percent of the total energy demand. Coal supplies 22.6 percent and natural gas supplies 23.1 percent of our total energy needs.



PETROLEUM CONSUMPTION BY SECTOR OF THE ECONOMY

Americans use about 20 million barrels of oil (more than 880 million gallons) every day of the year. And experts say we will be using more oil, especially for transportation, in the coming years.

Even now, we use about a third more oil for transportation than we did in 1973, when the first oil crisis hit the U.S. This is true even though today's automobiles get almost twice as many miles to the gallon as their 1970s counterparts, because there are two-thirds more vehicles on the road today than in 1973. Today, we use about two out of every three barrels of oil to keep us on the move.

Imported Oil

To satisfy our appetite for petroleum, the United States has become increasingly dependent upon other countries for petroleum. Today, we import about two-thirds of our petroleum from other countries.

Americans know this dependence is problematic. We were first alerted to that reality in 1973 when some Arab countries stopped shipping oil (called an embargo) to the United States. These countries belonged to an international trade group called the Organization of Petroleum Exporting Countries or OPEC for short.

OPEC members try to set production levels for petroleum. As a rule, the less oil they produce, the higher the price of oil on the world market. The OPEC countries don't always agree. Some OPEC countries want to produce less oil to raise prices. Other OPEC countries want to flood the market with petroleum to reap immediate returns.

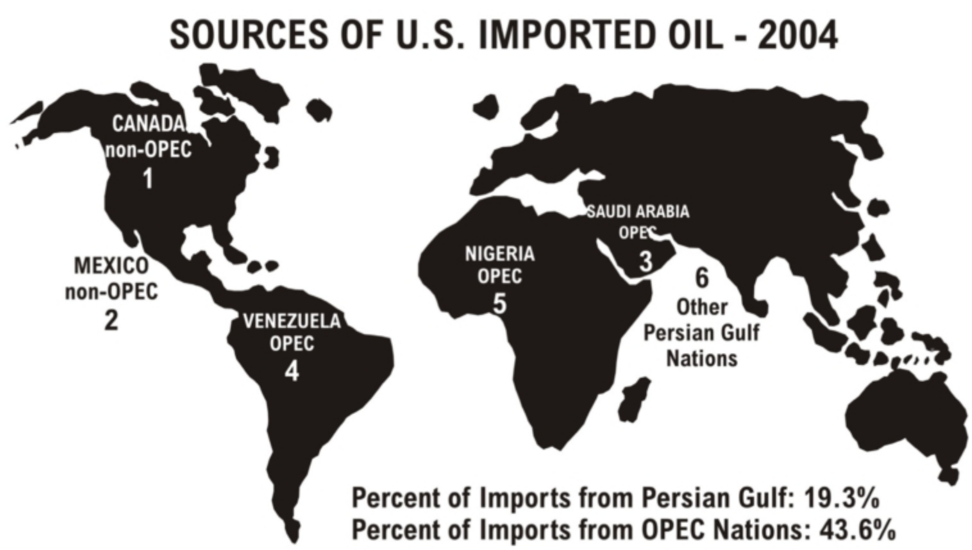
The next shock came in 1978-79 when the Iranian Revolution cut off oil production. Again, world oil prices raced up. Other recent crises were the Persian Gulf War and the U.S. invasion of Iraq. Current unrest in Nigeria is also causing concern over the stability of crude oil supplies. The U.S. has taken some steps to prevent another big oil crisis. For one thing, the U.S. has about a three-month supply of oil tucked away in the **Strategic Petroleum Reserve (SPR)**. Established in 1975, the SPR is only to be tapped during an energy emergency. The SPR was first used in January 1991, during the Persian Gulf Crisis.

The United States has also turned to non-Arab and non-OPEC countries for oil imports. Today, we import much of our oil from Canada and Mexico. This is good for us because we have friendly relations with our neighbors, and because the oil doesn't have to be shipped so far. Still, the amount of oil that we can import from Canada and Mexico is limited. By law, Mexico can only export half of the oil it produces to the United States.

Even with the SPR and imports from friendly, non-OPEC countries, U.S. oil supply is not totally secure. We buy over forty percent of our imported oil from OPEC countries, a fifth from Persian Gulf countries.

Some economists believe the United States is setting itself up for another oil crisis. Other analysts say a true oil shock—like those of the 1970s—is unlikely because the producing nations don't want to drive their customers away or encourage a shift to other forms of energy.

Still, there are more steps we can take to help ensure our energy security. Depending on whom you talk to—whether an oil company representative or an environmentalist—opinions vary on the one or more steps we should take. Some experts believe we should decrease our demand for oil through increased conservation. Others say we should increase oil production and exploration in the United States, particularly in the Arctic National Wildlife Refuge (ANWR) in northern Alaska. Others say we should use alternative fuels, especially for transportation. Some experts believe we will need to do all three to avert another oil crisis.



Offshore Oil Reserves

There are rich deposits of petroleum and natural gas on the outer continental shelf (OCS), especially off the Pacific coasts of California and Alaska and in the Gulf of Mexico. Thirty basins have been identified that could contain enormous oil and gas reserves. It is estimated that 30 percent of undiscovered U.S. gas and oil reserves are contained in the OCS.

Today, there are more than 4,000 drilling platforms, servicing thousands of wells. OCS production supplies approximately 30 percent of the nation's natural gas production and 24 percent of its oil production. Most of the active wells are in the Central and Western Gulf of Mexico, with additional wells off the coast of California.

Although there are no producing wells in other areas, there is believed to be significant oil potential in the Beaufort Sea off Alaska, as well as natural gas potential in the Eastern Gulf of Mexico and in certain basins off the Atlantic Coast.

On December 31, 1997, President Clinton excluded the Pacific OCS, the North Atlantic and North Aleutian areas, and parts of the Eastern Gulf of Mexico from energy development until 2007.

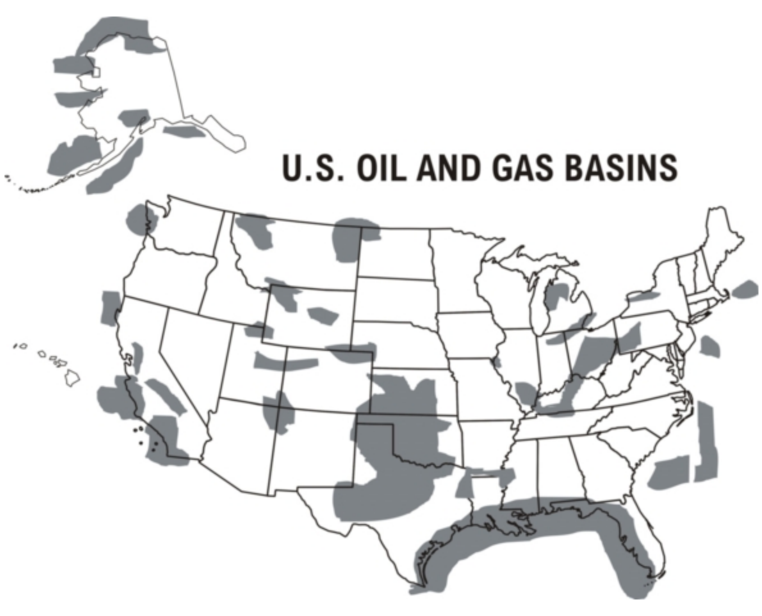
Offshore Production

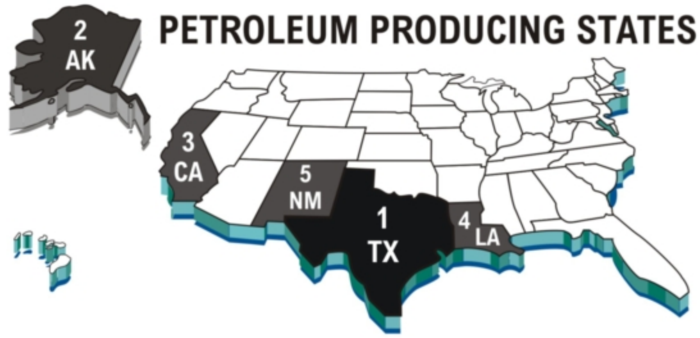
Offshore production is costly—many times more expensive than land-based production. To reach oil buried in shallow water, drilling platforms stand on stilt-like legs that are imbedded in the ocean floor. These huge platforms hold all the drilling equipment needed, as well as housing and storage areas for the work crews. Once the well has been drilled, the platforms also hold the production equipment.

Floating platforms are used for drilling in deeper waters. These self-propelled vessels are anchored to the ocean bottom with huge cables. Once the wells have been drilled from these platforms, the production equipment is lowered to the ocean floor and sealed to the well casings to prevent leakage. Wells have been drilled in 10,000 feet of water using these floating rigs.

Oil Prices

Most of the world moves on petroleum—gasoline for cars, jet fuel for planes, and diesel fuel for trucks. Then there are the petroleum products needed to run factories and manufacture goods. That's why the price of oil is so important. In 1998, the average price of a barrel of oil dropped as low as $8 a barrel; in the spring of 2006, the price shot up to over $75, the highest price in history.





Low oil prices are good for the consumer and the economy, acting as a check on inflation. The oil industry, however, does not prosper during periods of low oil prices. Oil industry workers lose their jobs, many small wells are permanently sealed, and the exploration for new oil sources drops off. Low oil prices have another side effect. People use more petroleum products when crude oil is cheap. They buy bigger cars and drive more miles. Urban air quality suffers. With the recent return of high oil prices, the sale of large cars and SUVs has decreased dramatically.

Oil & the Environment

In the United States, we use more petroleum than any other energy source. Petroleum products—gasoline, fertilizers, plastics, medicines—have brought untold benefits to Americans and the rest of the world. We depend on these products, and, as consumers, we demand them. But there is a flipside—petroleum production, distribution and consumption can contribute to air and water pollution.

Drilling for oil can disturb fragile ecosystems. 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.

Many advances have been made in protecting the environment since the passage of the Clean Air Act in 1970. Oil companies have redesigned their refineries to reduce emissions into the air and water. Gasolines have been reformulated to burn cleaner, dramatically cutting the levels of lead, nitrogen oxide, carbon monoxide, and hydrocarbons released into the air.

The production, transportation, distribution, and consumption of petroleum are strictly regulated to minimize the negative effects on the environment. Our increasing dependence on petroleum presents a continuing challenge. The future must balance the growing demand for petroleum products with protection of the global environment.

Propane

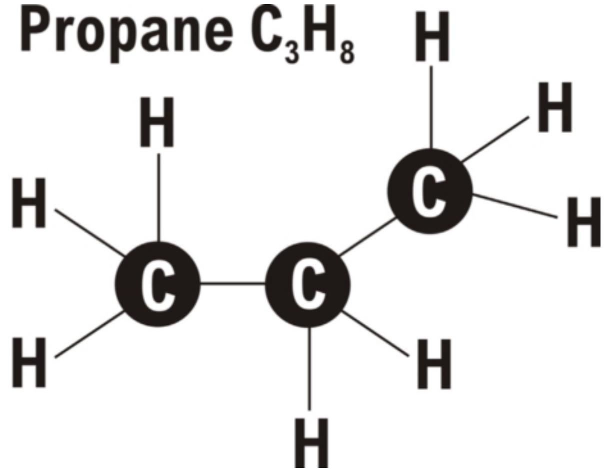
PROPANE at a Glance

Classification: Nonrenewable

U.S. Energy Production	1.80 Q	2.6 %
U.S. Energy Consumption	1.90 Q	1.9 %

Major Uses: industry, heating, transportation

Propane C_3H_8



What Is Propane?

Propane is a gas derived from natural gas and petroleum. It is found mixed with natural gas and petroleum deposits. 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 and were buried by layers of sediment and sand that turned into rock. Over time, the layers became thousands of feet thick.

The layers were subjected to enormous heat and pressure, changing the energy-rich remains into petroleum and natural gas deposits. Eventually, pockets of these fossil fuels became trapped in rocks, much as a wet sponge holds water.

Propane is one of the many fossil fuels included in the **liquefied petroleum (LP)** gas family. Because propane is the type of LP-gas most commonly used in the United States, propane and LP-gas are often used synonymously. Butane is another LP-gas often used in lighters. The chemical formula for propane is C_3H_8.

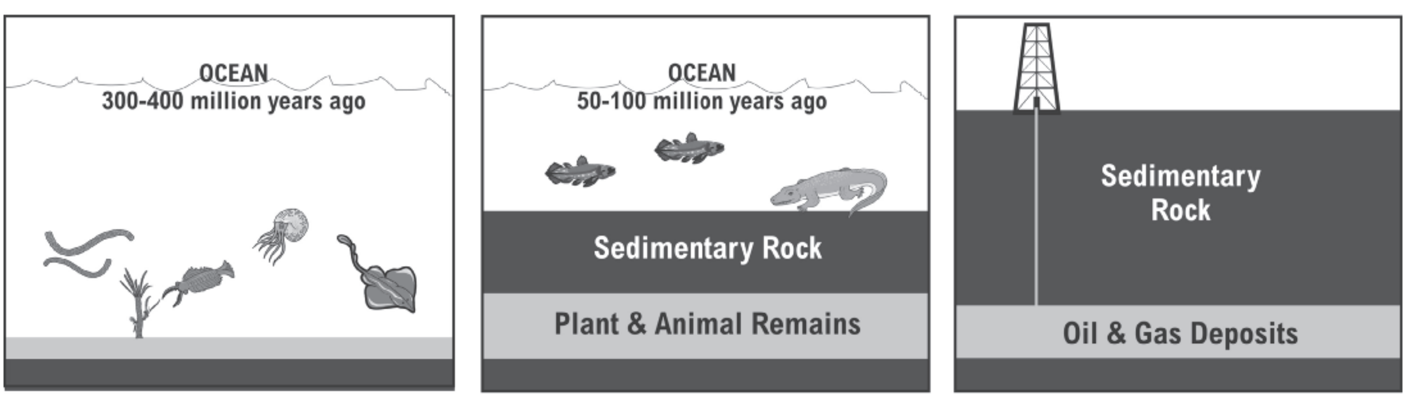
Just as water can change its physical state and become a liquid or a gas (steam vapor), so can propane. Under normal atmospheric pressure and temperature, propane is a gas. Under moderate pressure and/or lower temperatures, however, propane changes into a liquid. Propane is easily stored as a liquid in pressurized tanks. Think of the small tanks you see attached to a gas barbecue grill, for example.

Propane takes up much less space in its liquid form. It is 270 times more compact in its liquid state than it is as a gas. A thousand gallon tank holding gaseous propane would provide a family enough cooking fuel for one week. A thousand gallon tank holding liquid propane would provide enough cooking fuel for more than five years!

When propane vapor (gas) is drawn from a tank, some of the liquid in the tank instantly vaporizes to replace the vapor that was removed. Propane is nicknamed the portable gas because it is easier to store and transport than natural gas, which requires pipelines.

Like natural gas, propane is colorless and odorless. An odorant called mercaptan is added to propane (as it is to natural gas) to serve as a warning agent for escaping gas. And, like all fossil fuels, propane is a **nonrenewable** energy source. We can't make more propane in a short period of time.

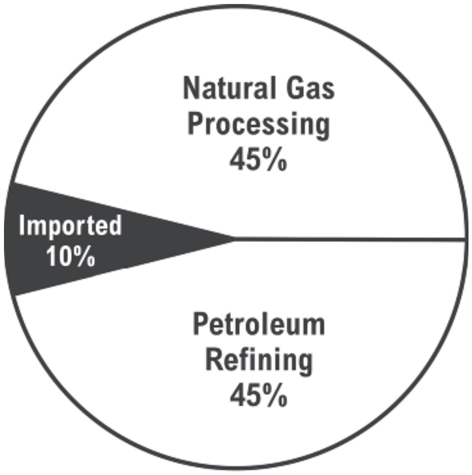
OIL & NATURAL GAS FORMATION



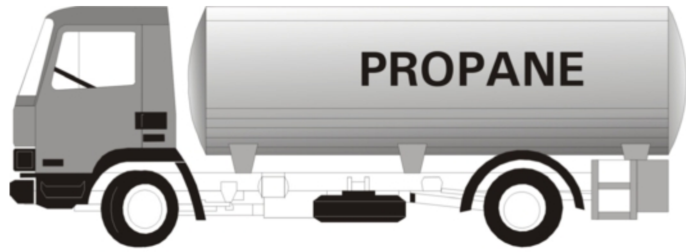
Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary rock.

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 layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.



Sources of U.S. Propane



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

History of Propane

Propane does not have a long history. It wasn't discovered until 1912 when people were trying to find a way to store gasoline. The problem with gasoline was that it evaporated when stored under normal conditions.

Dr. Walter Snelling, directing a series of experiments for the U.S. Bureau of Mines, discovered that several evaporating gases could be changed into liquids and stored at moderate pressure. The most plentiful of those gases was propane. Dr. Snelling developed a way to bottle the liquid gas. One year later, the propane industry began heating American homes. By 1915, propane was being used in torches to cut through metal.

Producing Propane

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

Forty-five percent of the propane is extracted from crude petroleum. Petroleum is separated into its various products at a processing plant called a refinery. The other ten percent of the propane we use in the U.S. is imported from other countries, mostly from Canada and Mexico.

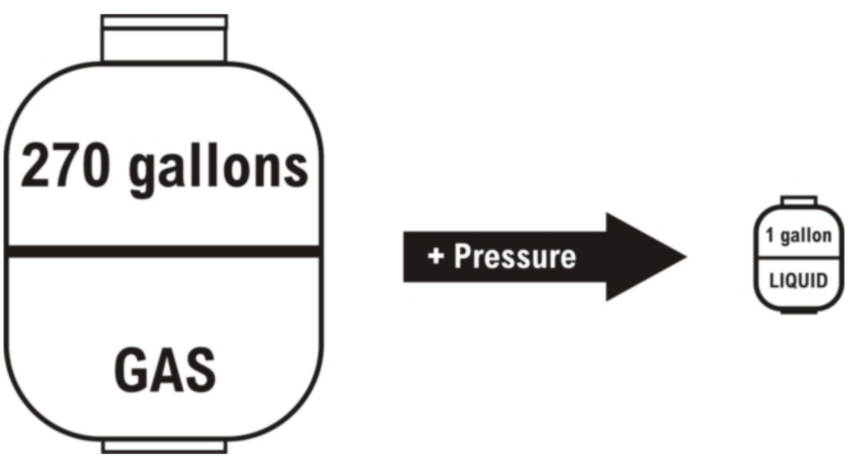
Transporting Propane

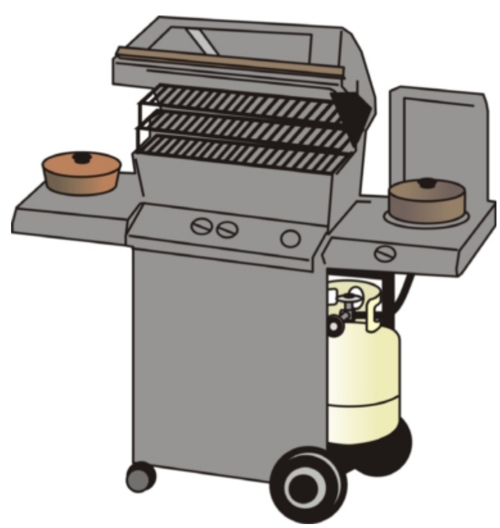
How does propane get from natural gas processing plants and oil refineries to the consumer? Usually, propane first moves through underground pipelines to distribution terminals across the nation. There are about 70,000 miles of pipeline in the United States moving propane to 13,500 bulk storage and distribution terminals.

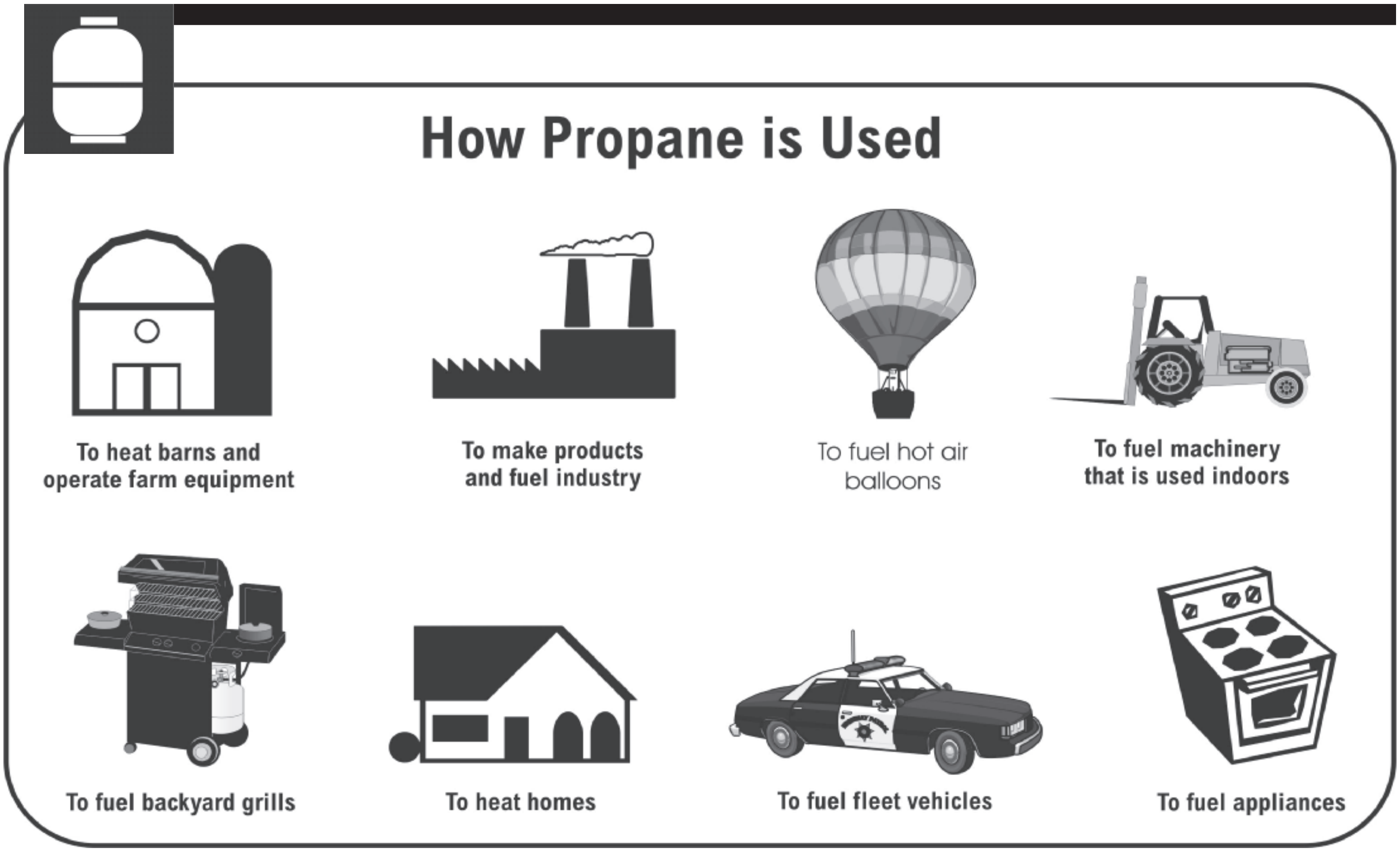
Distribution terminals, which are operated by propane companies, function like warehouses that store merchandise before shipping it to stores and shops. Sometimes, especially in the summer when less energy is needed for heating, propane is stored in large underground storage caverns.

After storage at distribution terminals, propane is transported by railroad tank cars, transport trucks, barges, and tanker ships to bulk plants. A **bulk plant** is where local propane dealers fill their small tank trucks, called bobtails.

People who use very little propane—backyard barbecuers, for example—must bring their propane cylinders to a dealer to be filled. There are about 165,000 propane dealers, such as hardware stores and gas stations, in the U.S. today.







How Propane Is Used

Propane is a clean–burning, versatile fuel. It is used by nearly everyone in the United States—in homes, on farms, by business, and in industry—mostly for producing heat and operating equipment.

Homes

Homes and businesses use about one–third of the propane consumed in the U.S. Propane is used mostly in homes in rural areas that do not have natural gas service, as well as in manufactured (mobile) homes. More than 14 million households use propane to meet some of their energy needs. Nearly a million households use propane as their main heating source. About one-fourth of mobile homes use propane for heating.

Propane is also used in homes for air conditioning, heating water, cooking and refrigerating foods, drying clothes, lighting, and fueling fireplaces.

Homes that use propane as a main energy source usually have a large propane tank outside of the house that stores propane under pressure as a liquid.

Propane dealers deliver propane to the residences in trucks, filling the tanks several times a year as needed. The average residential propane tank holds between 500–1,000 gallons of liquid fuel.

Millions of backyard cooks use propane–powered gas grills for cooking. And recreational vehicles (RV's) usually have propane-fueled appliances, giving them a portable source of energy for cooking, hot water, and refrigeration.

Farms

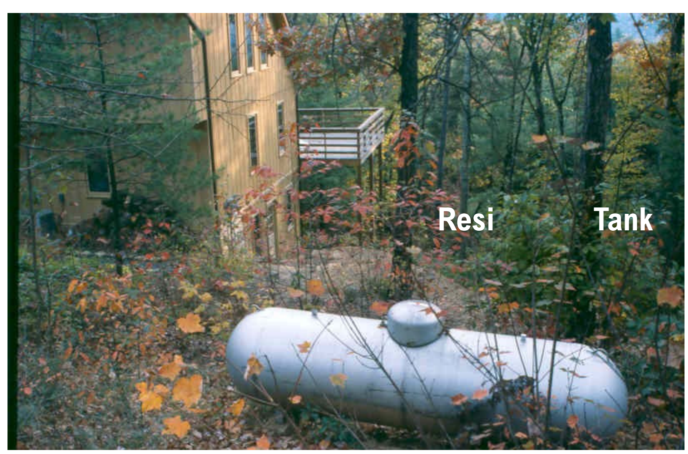
Half of America's farms—nearly 700,000—use propane to help meet their energy needs. Farmers use propane to dry crops such as corn, soybeans, grains, tobacco, apples, peanuts, and onions. Propane is also used to ripen fruit, heat water, and refrigerate foods.

Propane flamethrowers are used to control weeds. Propane is also used to heat barns, chicken houses, stock tanks, nurseries, greenhouses, orchards, and incubators.

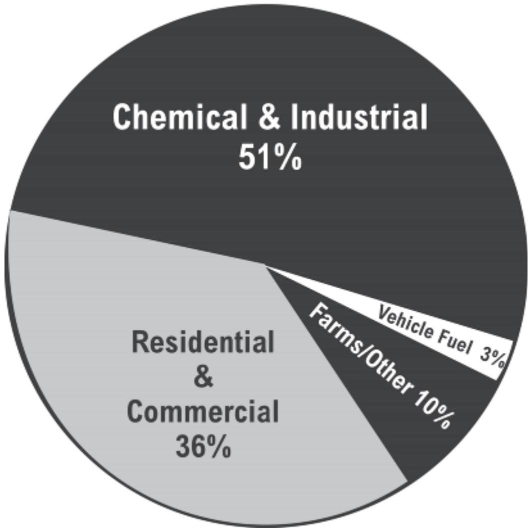
Propane is one fuel farmers use to operate a variety of farm equipment, including tractors, weeders, irrigation pumps, stand-by generators, and seedling planters.

*Business*s

More than one million business and commercial establishments—such as hotels, schools, hospitals, restaurants, and laudromats—use propane for heating and cooling air, cooking and refrigerating food, heating water, and lighting.



PROPANE CONSUMPTION



Industry

Industry uses more than half of the propane consumed in the U.S. Some industries find propane well suited to their special needs. Metal workers use propane tanks to fuel their cutting torches and other equipment. Industries also use propane for soldering, vulcanizing, and other processes that need a ready heat source. More than 350,000 industrial sites use propane as fuel.

Portable propane heaters provide a convenient source of heat for construction and road workers in cold weather. Propane also is used to heat asphalt for highway construction and repairs. Propane heaters at construction sites are used to dry concrete, plaster, and fuel pitch. And because propane is a very low-emission fuel, forklift trucks powered by propane can operate safely inside factories and warehouses.

Propane is also a valuable feedstock for the chemical industry. About one–third of the propane used today is as a raw material for making plastic bags and other products.

Propane Today

The United States uses more propane gas than any other country in the world. Propane supplies 1.9 percent of our total energy needs and ranks as the seventh most important energy source.

About 90 percent of the propane used in this country is produced in the United States from petroleum and natural gas but, since we import two-thirds of the petroleum we use, more than 30 percent of the propane we produce here is made from imported fuel.

Propane and the Environment

Propane is a very clean burning fossil fuel, which explains its use in indoor settings. It has been approved as an alternative fuel under the Clean Air Act, as well as the **National Energy Policy Act of 1992**.

A delivery truck that runs on propane fuel.

PROPANE as a Transportation Fuel

Did you know that propane has been used as a transportation fuel for more than half a century? Taxicab companies, government agencies, and school districts often use propane, instead of gasoline, to fuel their fleets of vehicles. Today, about three percent of total propane consumption is used for transportation.

There are some interesting characteristics about propane that make it an ideal engine fuel. First, propane is cleaner burning than gasoline. Propane leaves no lead, varnish, or carbon deposits that cause the premature wearing of pistons, rings, valves, and spark plugs. The engine stays clean, free of carbon and sludge. This means less maintenance and an extended engine life.

Also, propane is all fuel. It doesn't require the additives that are usually blended into gasoline. Even without additive boosters, propane's octane rating of 110 is equal to and, in most cases, higher than available gasoline.

Propane-fueled engines produce less air pollution than gasoline engines. Carbon monoxide emissions from engines using propane are 50 to 92 percent lower than emissions from gasoline-fueled engines. Hydrocarbon emissions are 30 to 62 percent lower.

So why isn't propane used as a transportation fuel more often? For one reason, propane is not as conveniently available as gasoline. Second, an automobile engine has to be adjusted to use propane fuel, and the cost of converting an engine to use propane is often prohibitive. Third, there is a slight drop in miles per gallon when propane is used to fuel vehicles.

Solar

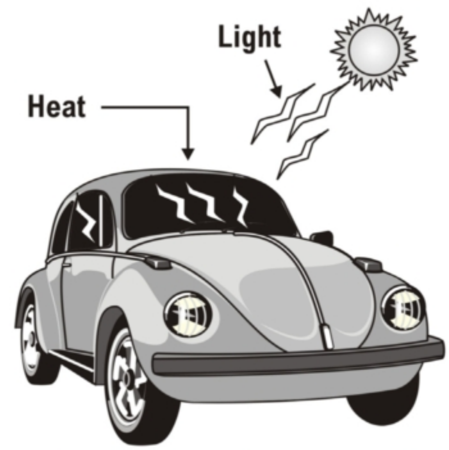
SOLAR at a Glance

Classification: Renewable

U.S. Energy Production	0.07 Q	0.1 %
U.S. Energy Consumption	0.07 Q	0.1 %

Major Use: light*, heat*, electricity
Most of the solar energy we use for light and passive solar heating can't be measured and isn't included in this data. Only harnessed solar energy is included.

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.

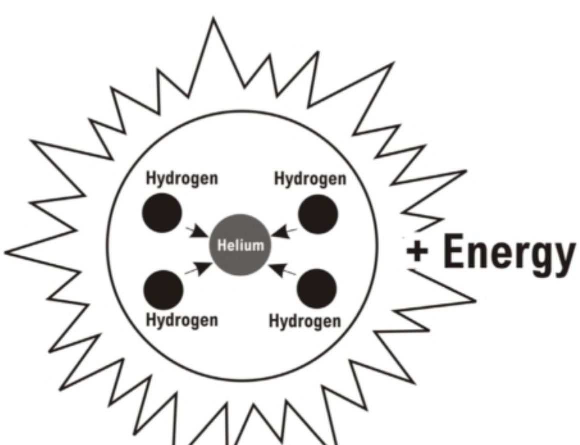
What Is Solar Energy?

Solar energy is radiant energy that is produced by the sun. Every day the sun radiates, or sends out, an enormous amount of energy. The sun radiates more energy in one second than people have used since the beginning of time!

Where does the energy come from that constantly radiates from the sun? It comes from within the sun itself. Like other stars, the sun is a big ball of gases—mostly hydrogen and helium atoms. The hydrogen atoms in the sun's core combine to form helium and generate energy in a process called **nuclear fusion**.

During nuclear fusion, the sun's extremely high pressure and temperature cause hydrogen atoms to come apart and their nuclei (the central cores of the atoms) to fuse or combine. Four hydrogen nuclei fuse to become one helium atom. But the helium atom contains less mass than the four hydrogen atoms that fused. Some matter is lost during nuclear fusion. The lost matter is emitted into space as radiant energy.

It takes millions of years for the energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes to travel the 93 million miles to earth. The solar energy travels to the earth at a speed of 186,000 miles per second, the speed of light.



During a process called FUSION, four hydrogen atoms combine to form one helium atom, with a loss of matter. This matter is emitted as radiant energy.

Only a small portion of the energy radiated by the sun into space strikes the earth, one part in two billion. Yet this amount of energy is enormous. Every day enough energy strikes the United States to supply the nation's energy needs for one and a half years!

Where does all this energy go? About 15 percent of the sun's energy that hits the earth is reflected back into space. Another 30 percent is used to evaporate water, which, lifted into the atmosphere, produces rainfall. Solar energy also is absorbed by plants, the land, and the oceans. The rest could be used to supply our energy needs.

History of Solar Energy

People have harnessed solar energy for centuries. As early as the 7th century B.C., people used simple magnifying glasses to concentrate the light of the sun into beams so hot they would cause wood to catch fire.

More than 100 years ago in France, a scientist used heat from a solar collector to make steam to drive a steam engine. In the beginning of this century, scientists and engineers began researching ways to use solar energy in earnest. One important development was a remarkably efficient solar boiler invented by Charles Greeley Abbott, an American astrophysicist, in 1936.

The solar water heater gained popularity at this time in Florida, California, and the Southwest. The industry started in the early 1920s and was in full swing just before World War II. This growth lasted until the mid-1950s when low-cost natural gas became the primary fuel for heating American homes.

The public and world governments remained largely indifferent to the possibilities of solar energy until the oil shortages of the 1970s. 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. How much solar energy a place receives depends on several conditions. These include the time of day, the season of the year, the latitude of the area, and the clearness or cloudiness of the sky.

A solar collector is one way to collect heat from the sun. A closed car on a sunny day is like a solar collector. As sunlight passes through the car's glass windows, it is absorbed by the seat covers, walls, and floor of the car.

The light that is absorbed changes into heat. The car's glass windows let light in, but don't let all the heat out. This is also why greenhouses work so well and stay warm year-round. A greenhouse or solar collector:

allows sunlight in through the glass (or plastic);

absorbs the sunlight and changes it into heat; and

traps most of the heat inside.

Solar Space Heating

Space heating means heating the space inside a building. Today many homes use solar energy for space heating. There are two general types of solar space heating systems: passive and active. **Hybrid systems** are a combination of passive and active systems.

Passive Solar Homes

In a passive solar home, the whole house operates as a solar collector. A passive house does not use any special mechanical equipment such as pipes, ducts, fans, or pumps to transfer the heat that the house collects on sunny days. Instead, a passive solar home relies on properly oriented windows. Since the sun shines from the south in North America, passive solar homes are built so that most of the windows face south. They have very few or no windows on the north side.

A passive solar home converts solar energy into heat just as a closed car does. Sunlight passes through a home's windows and is absorbed in the walls and floors. To control the amount of heat in a passive solar house, the doors and windows are closed or opened to keep heated air in or to let it out. At night, special heavy curtains or shades are pulled over the windows to keep the daytime heat inside the house.

In the summer, awnings or roof overhangs help to cool the house by shading the windows from the high summer sun.

Heating a house by warming the walls or floors is more comfortable than heating the air inside a house. It is not so drafty. And passive buildings are quiet, peaceful places to live. A passive solar home can get 50 to 80 percent of the heat it needs from the sun. Many homeowners install equipment (such as fans to help circulate air) to get more out of their passive solar homes. When special equipment is added to a passive solar home, the result is called a hybrid system.

Active Solar Homes

Unlike a passive solar home, an active solar home uses mechanical equipment, such as pumps and blowers, and an outside source of energy to help heat the house when solar energy is not enough.

Active solar systems use special solar collectors that look like boxes covered with glass. Dark-colored metal plates inside the boxes absorb the sunlight and change it into heat. (Black absorbs more sunlight than any other color.) Air or a liquid flows through the collectors and is warmed by this heat. The warmed air or liquid is then distributed to the rest of the house just as it would be with an ordinary furnace system.

Solar collectors are usually placed high on a roof where they can collect the most sunlight. They are also put on the south side of the roof in a location where no tall trees or tall buildings will shade them.

Storing Solar Heat

The challenge confronting any solar heating system—whether passive, active, or hybrid—is heat storage. Solar heating systems must have some way to store the heat that is collected on sunny days to keep people warm at night or on cloudy days.

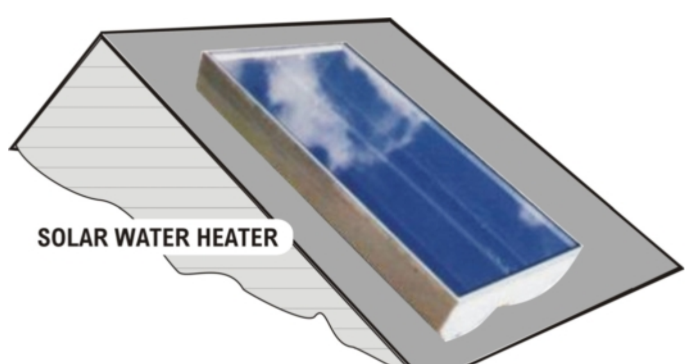
In passive solar homes, heat is stored by using dense interior materials that retain heat well—masonry, adobe, concrete, stone, or water. These materials absorb surplus heat and radiate it back into the room after dark. Some passive homes have walls up to one foot thick.

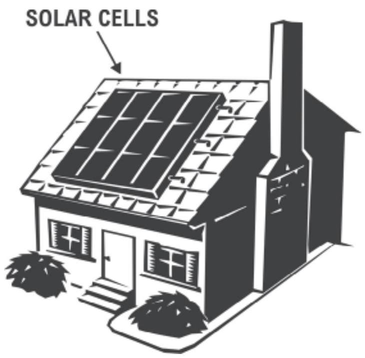
In active solar homes, heat can be stored in one of two ways—a large tank filled with liquid can be used to store the heat, or rock bins beneath a house can store the heat by heating the air in the bins.

Houses with active or passive solar heating systems may also have furnaces, wood-burning stoves, or other heat producing devices to provide heat during extremely cold temperatures or long periods of cold or cloudy weather. These are called backup systems.

Solar Water Heating

Solar energy is also used to heat water. Water heating is usually the third leading home energy expense, costing the average family over $400 a year.





Depending on where you live, and how much hot water your family uses, a solar water heater can pay for itself in as little as five years. A well-maintained system can last 15-20 years, longer than a conventional water heater.

A solar water heater works in the same way as solar space heating. A solar collector is mounted on the roof, or in an area of direct sunlight. It collects sunlight and converts it to heat. When the collector becomes hot enough, a thermostat starts a pump. The pump circulates a fluid, called a heat transfer fluid, through the collector for heating.

The heated fluid then goes to a storage tank where it heats water. The hot water may then be piped to a faucet or showerhead. Most solar water heaters that operate in winter use a heat transfer fluid, similar to antifreeze, that will not freeze when the weather turns cold. Today over 1.5 million homes in the U.S. use solar heaters to heat water for their homes or swimming pools.

In addition to heating homes and water, solar energy can be used to produce electricity. Two ways to generate electricity from solar energy are photovoltaics and solar thermal systems.

Photovoltaic Cells

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 already familiar with solar cells. Solar-powered calculators, toys, and telephone call boxes all use solar cells to convert light into electricity.

The four steps that show how a PV cell is made and how it produces electricity are explained on the next page. Current PV cell technology is not very efficient. Today's PV cells convert only about 10 to 20 percent of the radiant energy into electrical energy. Fossil fuel plants, on the other hand, convert from 30 to 40 percent of their fuel's chemical energy into electrical energy.

The cost per kilowatt-hour to produce electricity from PV cells is currently three to four times as expensive as from conventional sources. However, PV cells make sense for many uses today, such as providing power in remote areas or other areas where electricity is difficult to provide. Scientists are researching ways to improve PV cell technology to make it more competitive with conventional sources.

Concentrated Solar Power

Like solar cells, concentrated solar power systems use solar energy to make electricity. Since the solar radiation that reaches the earth is so spread out and diluted, it must be concentrated to produce the high temperatures required to generate electricity. There are three types of technologies that use mirrors or other reflecting surfaces to concentrate the sun's energy up to 5,000 times its normal intensity.

Parabolic troughs use long reflecting troughs that focus the sunlight onto a pipe located at the focal line. A fluid circulating inside the pipe collects the energy and transfers it to a heat exchanger, which produces steam to drive a conventional turbine. The world's largest parabolic trough is located in the Mojave Desert in California. This plant has a total generating capacity of 354 megawatts, one-third the size of a large nuclear power plant.

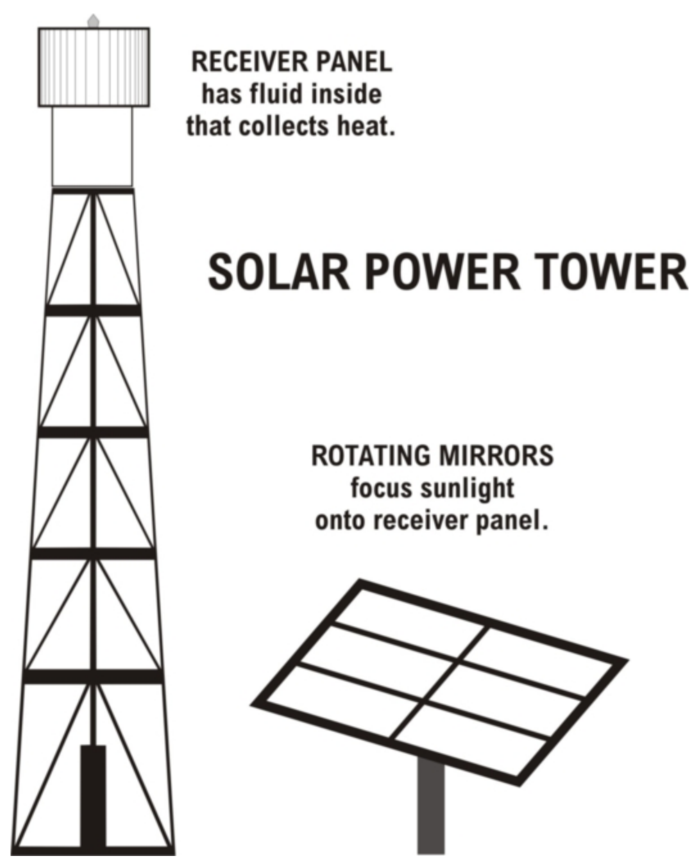
Power towers use a large field of rotating mirrors to track the sun and focus the sunlight onto a heat-receiving panel on top of a tall tower. The fluid in the panel collects the heat and either uses it to generate electricity or stores it for later use.

Dish/engine systems are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators are small mobile units that can be operated individually or in clusters, in urban and remote locations.

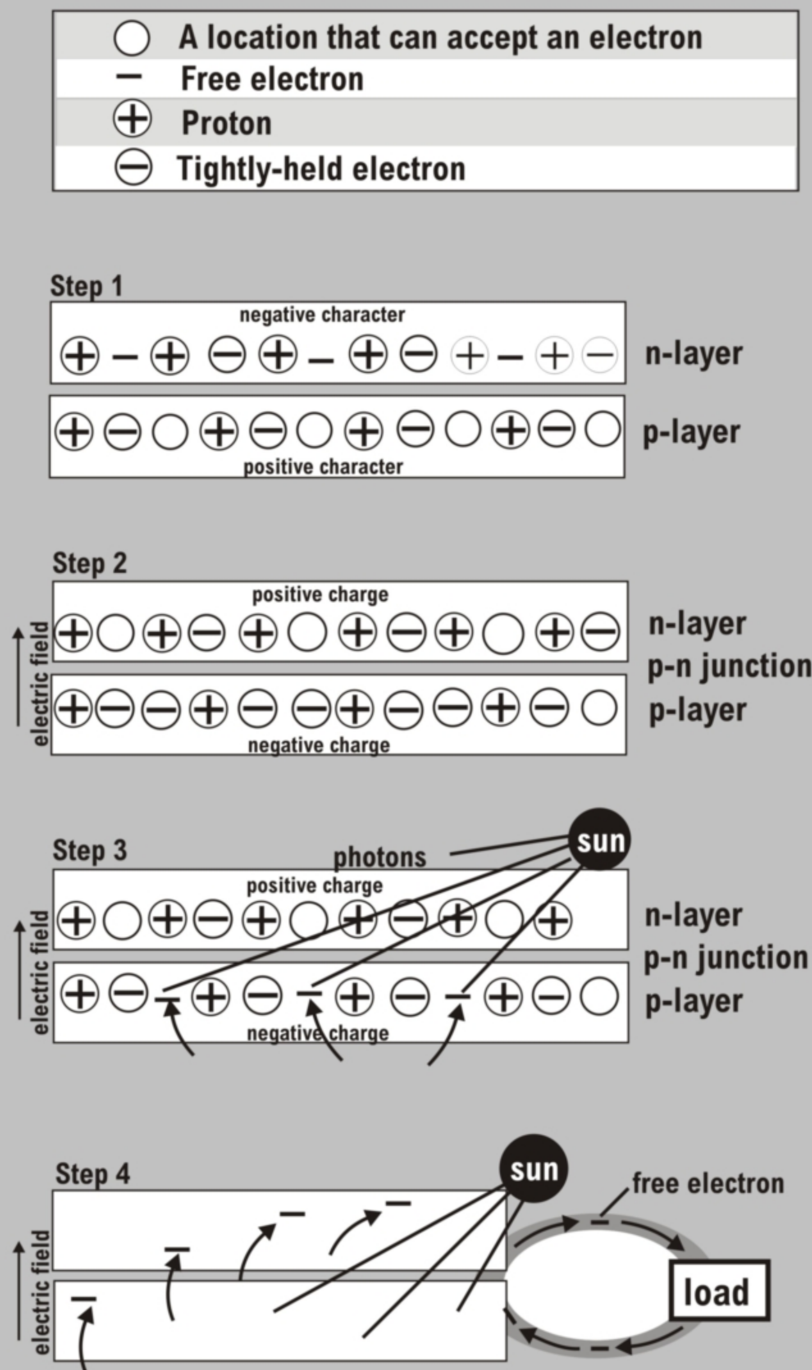
Concentrated Solar Power (CSP) technologies require a continuous supply of strong sunlight, like that found in hot dry regions such as deserts. Developing countries with increasing electricity demand will probably be the first to use CSP technologies on a large scale.

Solar Energy and the Environment

Using solar energy produces no air or water pollution, and it is a free and widely available energy source. Manufacturing the photovoltaic cells to harness that energy, however, consumes silicon and produces some waste products. In addition, large solar thermal farms can harm desert ecosystems if not properly managed. Most people agree, however, that solar energy, if it can be harnessed economically, is one of the most viable energy sources for the future.



HOW A PHOTOVOLTAIC CELL WORKS



STEP 1
Pure silicon is used to form very thin wafers. In half of the wafers, a small amount of the element phosphorous is added. In the other wafers, a small amount of the element boron is added. The phosphorous gives the wafer of silicon an excess of free electrons; therefore, it will have a negative character.

This wafer with the phosphorous is called the n-layer (n = negative). The n-layer is not a charged wafer—it has an equal number of protons and electrons—but some of the electrons are not held tightly to the atoms in the wafer. They are free to move to different locations within the layer.

The boron gives its wafer of silicon a positive character, because it has a tendency to attract electrons. The layer has an equal number of protons and electrons; it has a positive character but not a positive charge. This wafer with boron is called the p-layer (p=positive).

STEP 2
When the two wafers are placed together, the free electrons from the n-layer are attracted to the p-layer. At the moment of contact between the two wafers, free electrons from the n-layer flow into the p-layer for a split second, then form a barrier to prevent more electrons from moving between layers.

This contact point and barrier is called the p-n junction. Once the layers have been joined, there is a negative charge in the p-layer section of the junction and a positive charge in the n-layer section of the junction. This imbalance in charge at the p-n junction produces an electric field between the p-layer and the n-layer.

STEP 3
If a PV cell is placed in the sun, photons (packets) of light strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-layer and repelled by the negative charge in the p-layer.

STEP 4
If you attach a wire from the n-layer to the p-layer. As the free electrons are pushed into the n-layer, they repel each other. The wire provides a path for the electrons to get away. This flow of electrons is an electric current that can run a calculator or other electrical device as it travels from the n-layer to the p-layer.

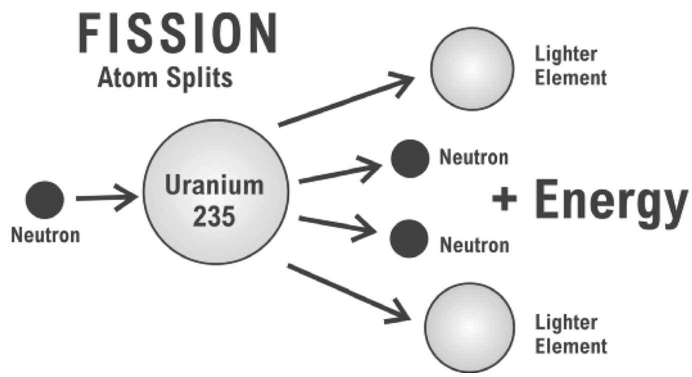
U 235 Uranium (Nuclear)

URANIUM at a Glance

Classification: Nonrenewable

U.S. Energy Production	8.23 Q	11.7 %
U.S. Energy Consumption	8.23 Q	8.2 %

Major Uses: electricity



What is Uranium?

Uranium is the heaviest of the 92 naturally occurring elements and is classified as a metal. It is the fuel used by nuclear power plants for fissioning.

It is also one of the few elements that is easily fissioned. Uranium was formed when the earth was created and is found in rocks all over the world. Rocks that contain a lot of uranium are called uranium ore, or pitch-blende. Uranium, although abundant, is a **nonrenewable** energy source.

Two forms (isotopes) of uranium are found in nature, uranium-235 and uranium-238. These numbers refer to the number of neutrons and protons in each atom. Uranium-235 is the form commonly used for energy production because, unlike uranium-238, its nucleus splits easily when bombarded by a neutron. During fissioning, the uranium-235 atom absorbs a bombarding neutron, causing its nucleus to split apart into two atoms of lighter weight.

At the same time, the fission reaction releases energy as heat and radiation, as well as releasing more neutrons. The newly released neutrons go on to bombard other uranium atoms, and the process repeats itself over and over. This is called a chain reaction.

What Is Nuclear Energy?

Nuclear energy is energy that comes from the nucleus (core) of an atom. Atoms are the particles that make up all objects in the universe. Atoms consist of neutrons, protons, and electrons.

Nuclear energy is released from an atom through one of two processes: **nuclear fusion** or **nuclear fission**. In nuclear fusion, energy is released when the nuclei of atoms are combined or fused together. This is how the sun produces energy.

In nuclear fission, energy is released when the nuclei of atoms are split apart. Nuclear fission is the only method currently used by nuclear plants to generate electricity.

History of Nuclear Energy

Compared to other energy sources, nuclear energy 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 protons and neutrons. Then in 1938, two German scientists split the nucleus of the atom apart by bombarding it with a neutron—a process called fission. Soon after, a Hungarian scientist discovered the chain reaction and its ability to produce enormous amounts of energy.

Under the dark cloud of World War II, nuclear fission was first used to make a bomb. After the war, nuclear fission was developed for generating electricity.

The first nuclear power plant came online in Shippingport, Pennsylvania in 1957. Since then, the industry has experienced dramatic shifts in fortune. Through the mid 1960s, government and industry experimented with demonstration and small commercial plants. A period of rapid expansion followed between 1965 and 1975. No new plants, however, have been ordered since the 1970s as a result of public opposition, as well as building costs, problems with siting a waste repository, and lower demand for power. Today, there is renewed interest in nuclear power to meet future demand for electricity.

The Nuclear Fuel Cycle

The steps—from mining the uranium ore, through its use in a nuclear reactor, to its disposal—are called the nuclear fuel cycle.

Mining

The first step in the cycle is mining the uranium ore. Workers mine the ore much like miners mine coal—in underground mines or surface mines. A ton of uranium ore in the U.S. typically contains three to ten pounds of uranium.

Milling

After it has been mined, uranium ore is crushed. The crushed ore is usually mixed with an acid, which dissolves the uranium, but not the rest of the crushed rock. The acid solution is drained off and dried, leaving a yellow powder called **yellowcake**, consisting mostly of uranium. This process of removing uranium from the ore is called **uranium milling**.

Conversion

The next step in the cycle is the conversion of the yellowcake into a gas called **uranium hexafluoride**, or UF6. The uranium hexafluoride is then shipped to a **gaseous diffusion plant** for enrichment.

Enrichment

Because less than one percent of uranium ore contains uranium-235, the form used for energy production, uranium must be processed to increase the concentration of uranium-235. This process—called enrichment—increases the percentage of uranium-235 from one to five percent. It typically takes place at a gaseous diffusion plant where the uranium hexafluoride is pumped through filters that contain very tiny holes. Because uranium-235 has three fewer neutrons and is one percent lighter than uranium-238, it moves through the holes more easily than uranium-238. This method increases the percentage of uranium-235 as the gas passes through thousands of filters.

Fuel Fabrication

The enriched uranium is taken to a fuel **fabrication plant** where it is prepared for the nuclear reactor. Here, the uranium is made into a solid ceramic material and formed into small barrel-shaped pellets. These ceramic fuel pellets can withstand very high temperatures, just like the ceramic tiles on the space shuttle. Fuel pellets are about the size of your fingertip, yet each one can produce as much energy as 150 gallons of oil. The pellets are sealed in 12-foot metal tubes called **fuel rods**. Finally, the fuel rods are bundled into groups called **fuel assemblies**.

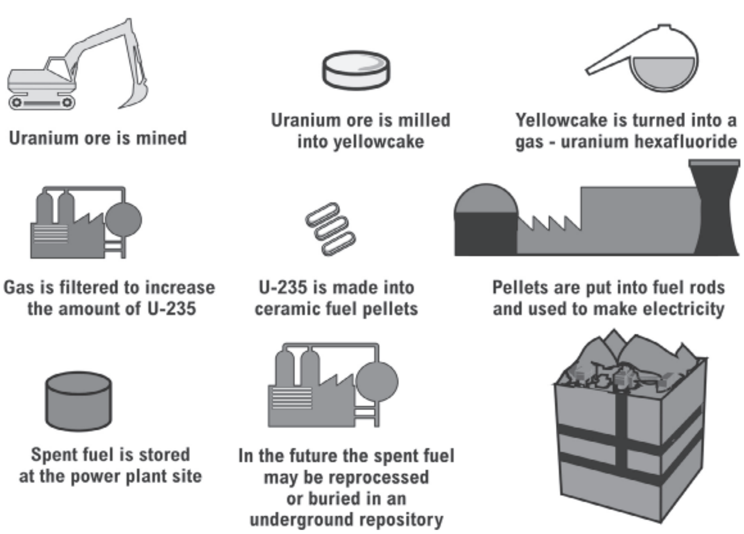
Nuclear Reactor

The uranium fuel is now ready for use in a nuclear reactor. Fissioning takes place in the reactor core. Surrounding the core of the reactor is a shell called the reactor pressure vessel. To prevent heat or radiation leaks, the reactor core and the vessel are housed in an airtight containment building made of steel and concrete several feet thick.

The reactor core houses about 200 fuel assemblies. Spaced between the fuel assemblies are movable control rods. Control rods absorb neutrons and slow down the nuclear reaction. Water also flows through the fuel assemblies and control rods to remove some of the heat from the chain reaction.

The nuclear reaction generates heat energy just as burning coal or oil generates heat energy. Likewise, the heat is used to boil water into steam that turns a **turbine generator** to produce electricity. Afterward, the steam is condensed back into water and cooled. Some plants use a local body of water for cooling; others use a structure at the power plant called a **cooling tower**.

URANIUM FUEL CYCLE



Used Fuel Storage

Like most industries, nuclear power plants produce waste. One of the main concerns about nuclear power plants is not the amount of waste created, which is quite small compared to other industries, but the radioactivity of some of that waste. The fission process creates radioactive waste products. After about three cycles, these waste products build up in the fuel rods, making the chain reaction more difficult. Utility companies generally replace one-third of the fuel rods every 12 to 18 months to keep power plants in continuous operation.

The fuel that is taken out of the reactor is called **used fuel**. The used fuel contains both radioactive waste products and unused fuel. The used fuel is usually stored near the reactor in a deep pool of water called the used fuel pool. The used fuel cools and loses most of its radioactivity through radioactive decay. In three months, the used fuel will lose 50 percent of its radiation; in one year, 80 percent; in 10 years, 90 percent. The used fuel pool is intended as a temporary method for storing nuclear waste.

Eventually, the used fuel will be reprocessed and/or transported to a permanent federal disposal site.

Reprocessing

Used fuel contains both radioactive waste products and unused nuclear fuel. In fact, about one-third of the nuclear fuel remains unused when the fuel rod must be replaced. Reprocessing separates the unused nuclear fuel from the waste products so that it can be used in a reactor again.

Currently, American nuclear power plants store the used fuel in used fuel pools—without reprocessing. Why? Reprocessing is more expensive than making new fuel from uranium ore. If uranium prices rise significantly or storage becomes a bigger problem, reprocessing may gain favor.

Waste Repository

Most scientists believe the safest way to store nuclear waste is in rock formations deep underground—called geological repositories. In 1982, Congress passed the **Nuclear Waste Policy Act**. This law directed the Department of Energy to site, design, construct, and operate America's first repository by 1998. This didn't happen. The repository, which is not projected to open until at least 2010, will store radioactive waste from nuclear power plants and defense weapons plants.

The same law also established the Nuclear Waste Fund to pay for the repository. People who use electricity from nuclear power plants pay 1/10 of a cent for each kilowatt-hour of electricity they use. An average household, which uses about 7,500 kilowatt-hours a year, contributes $7.50 a year to the fund.

Utility companies currently store their nuclear waste in pools of water at the power plants, but some companies will soon run out of space to store their used fuel. To remedy this situation, the U.S. Congress in 2002 voted to designate Yucca Mountain as the proposed national repository for used fuel.

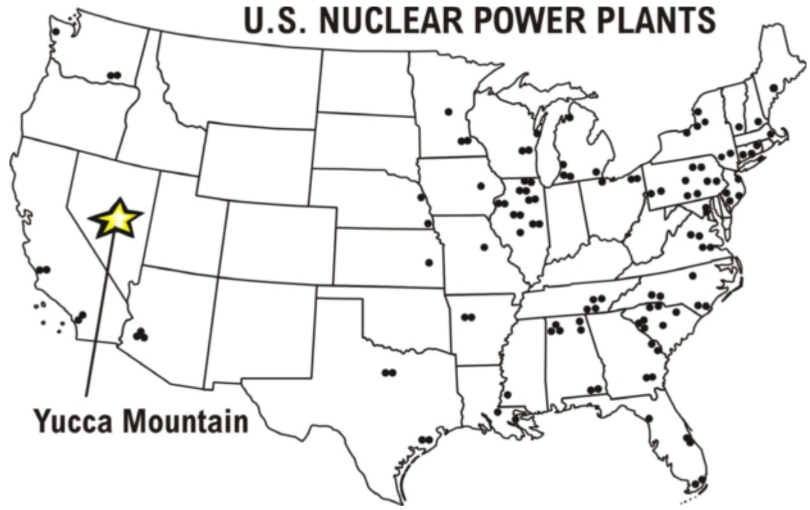
The U.S. Department of Energy is preparing to license the Yucca Mountain site as the federal repository. If approved, nuclear waste will be sealed in canisters and stored in vaults 1,000 feet beneath the surface.

Yucca Mountain, Nevada, is the proposed repository site because it is dry and geologically stable. Yucca Mountain is also very isolated and few people live in the area.

Nuclear Energy Use

Nuclear energy is an important source of electricity—second only to coal—providing 20 percent of the electricity in the U.S. today. There are 100 nuclear reactors in operation at 65 power plants. No new plants are under construction in the U.S. at this time, though several are in early planning stages.

Worldwide, however, nuclear energy is a growing source of electrical power. New plants are going on-line each year with many more were under construction. Nuclear energy now provides about 18 percent of the world's electricity. The U.S., France, Japan and Germany are world leaders. France generates 75 percent of its electricity with nuclear power.



What is RADIATION?

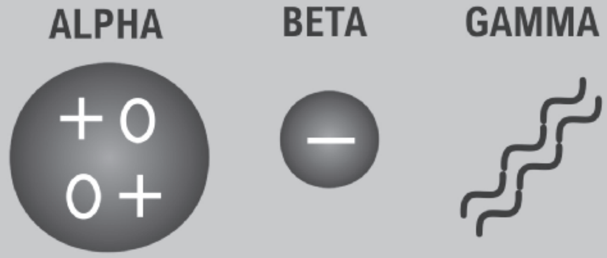
Radiation is energy released by atoms. It is very powerful and moves very fast. Not all atoms are radioactive. Some atoms—the radioactive ones—have more neutrons than protons, making them unstable. In a natural process called radioactive decay, these atoms give up their extra neutrons and become stable.

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

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

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

The unit used to measure radiation is the rem and millirem (1/1000 of one rem). The average American is exposed to about 360 millirem a year from natural and man-made sources, a harmless amount. About 260 millirem of this total comes from natural (background) sources of radiation such as soil, rocks, food, and water. Another 55 millirem comes from medical x-rays and about 10 millirem from a variety of sources including mineral mining, burning fossil fuels, and such consumer products as color television sets and luminous dial clocks. Radiation emitted from nuclear power plants accounts for only a tiny amount of exposure, only about .01 millirem of exposure per year.



URANIUM Prices

The United States has an abundant supply of domestic uranium. Today, however, about 80 percent of the uranium used in the U.S. is imported. This high level of import is the result of low uranium prices in other countries. In the last ten years, uranium prices have fallen from about $33 a pound to about $13 a pound. Prices will continue to be low since new supplies of uranium will be available from the dismantling of nuclear weapons in the U.S. and Russia. This highly enriched uranium will be blended with natural ore to produce reactor fuel.

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

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

Whether or not we should use nuclear energy to produce electricity has become a controversial and sometimes highly emotional issue.

Licensing Nuclear Power Plants

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

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

Economics of Nuclear Energy

The cost of electricity from nuclear energy is somewhat higher than the cost of electricity from coal. Much of the cost of producing electricity at a nuclear plant comes not from the fuel source—uranium is very inexpensive at about $13 a pound—but from the cost of building the plant. Nuclear plants have very high up-front costs because of the licensing, construction, and inspection requirements.

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

Uranium is an abundant natural resource that is found all over the world. At current rates of use, uranium resources could last more than 500 years. A process called **breeding**, which converts uranium into plutonium—an even better fuel—could extend uranium reserves for millions of years. Breeder reactors are being used in France, but they are not planned for use in this country. And because uranium is an extremely concentrated fuel source, it requires far less mining and transportation than other fuel sources for the energy it furnishes.

Nuclear Energy and the Environment

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

NUCLEAR Safety

The greatest potential risk from nuclear power plants is the release of high-level radiation. In the United States, plants are carefully designed to contain radiation, and emergency plans are in place to alert and advise nearby residents if there is an accident.

Two serious accidents have occurred since the industry began over 30 years ago—Three Mile Island in the U. S. (1979) and Chernobyl in the Ukraine (1986). At Three Mile Island, about half the uranium fuel melted when water to the reactor core was inadvertently cut off. A small amount of radioactive material escaped into the surrounding area before the mistake was discovered. But due to the safety design features of the plant—multiple barriers contained most of the radiation—no one was injured or died as a result of this accident.

The accident at Chernobyl was far more serious. It happened when 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 surrounding area. More than 100,000 people were evacuated from their homes and about 200 workers were treated for radiation sickness and burns; 31 of them died.

Could a Chernobyl–type accident occur at an American nuclear power plant? Many experts say no. Old nuclear plants like the one in Chernobyl do not have the safety systems and containment chambers that are standard on all American plants. Ukraine officials closed the last reactors still in operation at Chernobyl in December 2000. The U. S. has pledged funding to help clean up the remaining contamination.

Wind

WIND at a Glance

Classification: Renewable

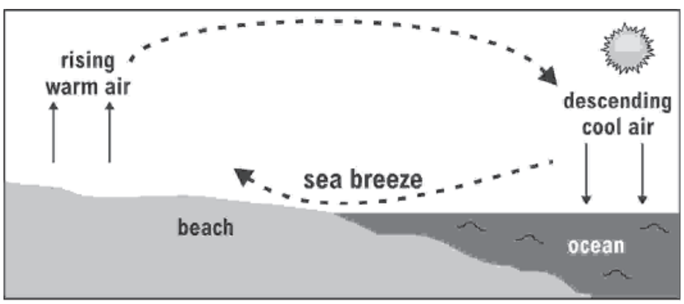
U.S. Energy Production	0.14 Q	0.1 %
U.S. Energy Consumption	0.14 Q	0.1 %

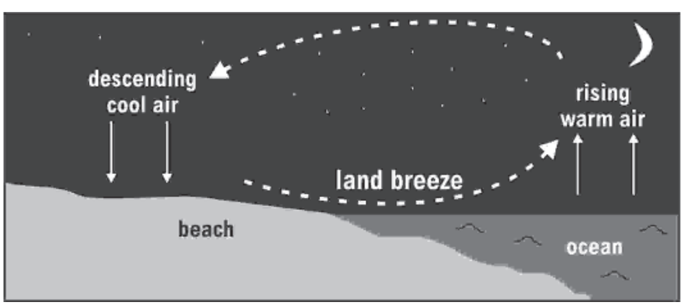
Major Use: electricity

What Is Wind?

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

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





Similarly, the large atmospheric winds that circle the earth are created because the surface air near the equator is warmed more by the sun than the air over the North and South Poles.

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

The History of Wind

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

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

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

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

Monitoring Wind Direction

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

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

Wind Velocity

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

Wind speed can be measured with wind gauges and **anemometers**.

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

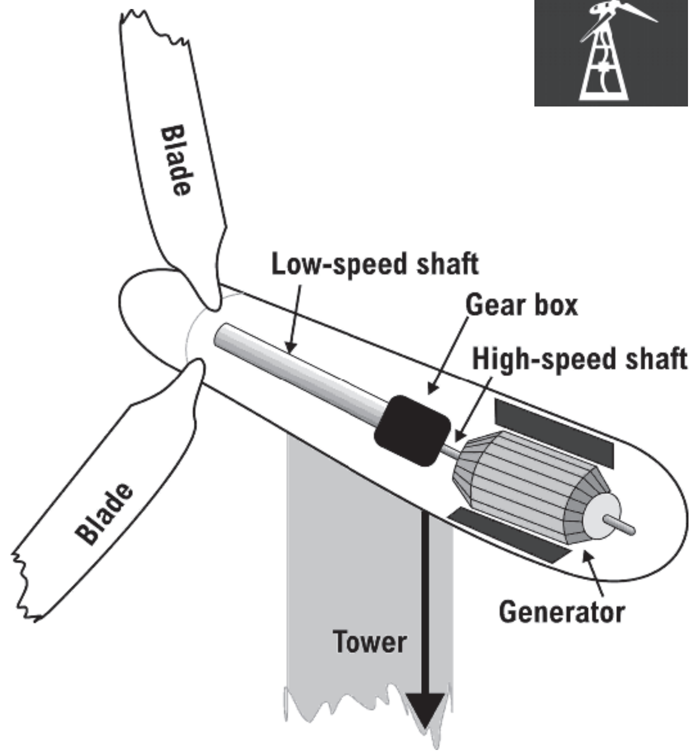
Modern Wind Machines

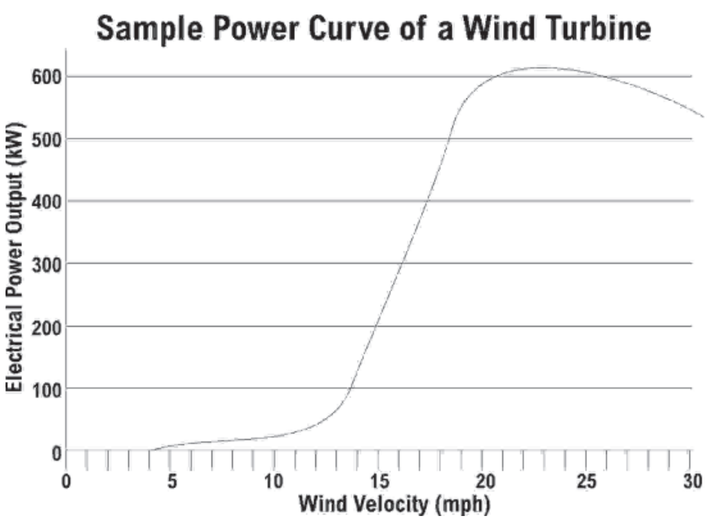
Today, wind is harnessed and converted into electricity using machines called ***wind turbines***. The amount of electricity that a turbine produces depends on its size and speed of the wind. All wind turbines have the same basic parts: blades, a tower, and a gearbox. These parts work together to convert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

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

Wind turbines are most efficient when they are built where winds blow consistently at least 13 miles per hour. Faster winds generate more electricity. High above ground, winds are stronger and steadier, so wind turbines should be placed on top of towers that are at least 30 meters (100 ft) tall.

There are many different types of wind turbines with different blade shapes. Different types of turbines operate most efficiently at different wind speeds. While one turbine might operate efficiently in winds as low as five miles per hour (5 mph), another may need winds up to 45 miles per hour.





Wind turbines also come in different sizes, based on the amount of electrical power they can generate. Small turbines may produce only enough electricity to power one home. Large turbines are often called utility-scale because they generate enough power for utilities, or electric companies, to sell. The largest turbines in the U.S. produce 2.5–3.5 MW, enough electricity to power 750 to 1,750 homes. Large turbines are grouped together into wind farms, which provide bulk power to the electrical grid.

Wind Power Plants

Wind power plants, or wind farms, are clusters of wind turbines grouped together to produce large amounts of electricity. These power plants are usually not owned by a public utility like other kinds of power plants are. Private companies own most wind farms and sell the electricity to electric utility companies.

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

The best sites for wind farms are on hilltops, the open plains, through mountain passes, and near the coasts of oceans or large lakes. Turbines are usually built in rows facing into the prevailing wind. Placing turbines too far apart wastes space. If turbines are too close together, they block each other's wind. There are many factors to consider when siting a wind farm, such as:

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

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

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

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

Wind plants also need a lot of land. Each wind machine requires about two acres of land. A wind power plant can cover hundreds of acres of land, depending on the number of machines. On the plus side, most of the land is still available for other uses. Ranchers, for example, can grow grain or graze cattle around the machines once they have been installed.

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

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

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

Wind Resources

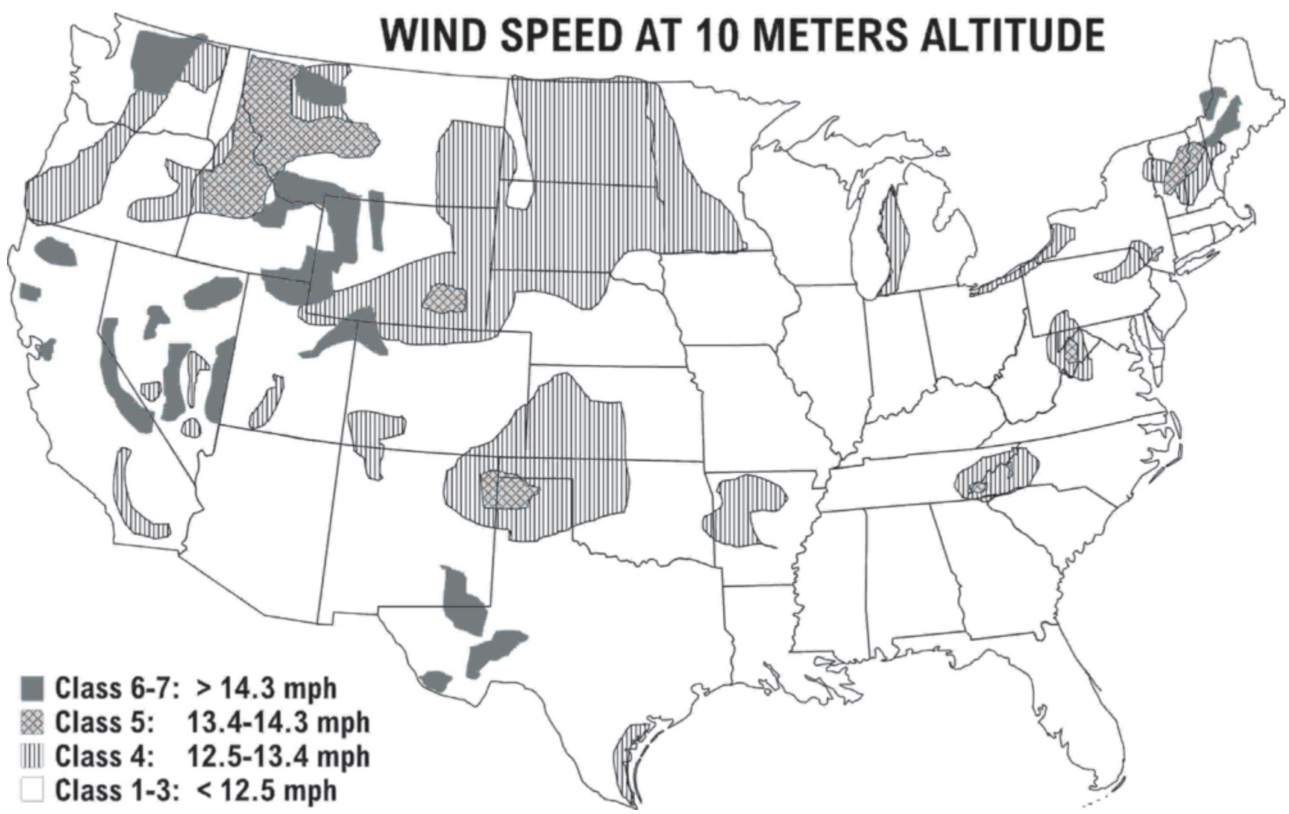
Where is the best place to build a wind plant? There are many good sites for wind plants in the United States including California, Alaska, Hawaii, the Great Plains, and mountainous regions. Scientists say there is enough wind in 37 states to produce electricity. An average wind speed of 14 mph is needed to convert wind energy into electricity economically. The average wind speed in the U.S. is 10 mph.

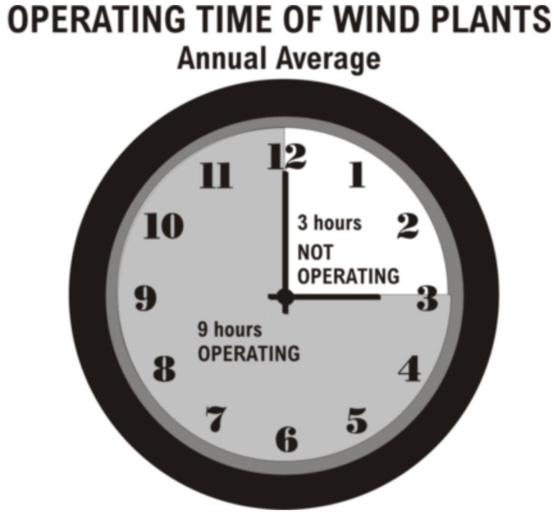
Wind Production

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

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

How efficient are wind machines? Wind machines are just as efficient as most other plants, such as coal plants. Wind machines convert 30-40 percent of the wind's kinetic energy into electricity. A coal-fired power plant converts about 30-35 percent of the chemical energy in coal into usable electricity.





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

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

A wind turbine at a typical wind farm operates 65-80 percent of the time, but usually at less than full capacity, because the wind speed is not at optimum levels. Therefore, its capacity factor is 30-35 percent.

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

One wind turbine can produce 1.5 to 4.0 million kilowatt-hours (kWh) of electricity a year. That is enough electricity for 150-400 homes per year. In this country, wind turbines produce 10 billion kWh of energy a year. Wind energy provides about 0.1 percent of the nation's electricity, a very small amount. That is enough electricity to serve a million households.

Wind is the fastest growing energy technology in the world today. In the last three years, wind capacity worldwide has more than doubled. Experts expect the production from wind machines to triple in the next few years. India and many European countries are planning major new wind facilities.

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

Wind Economics

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

Second, the cost of producing electricity from the wind has dropped dramatically in the last two decades. Electricity generated by the wind cost 30 cents per kWh in 1975, but now costs about four cents per kWh. New turbines are lowering the cost even more.

Wind Energy and the Environment

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

The most serious environmental drawbacks to wind machines may be their negative effect on wild bird populations and the visual impact on the landscape.

To some, the glistening blades of windmills on the horizon are an eyesore; to others, they're a beautiful alternative to conventional power plants.

Wind Churner

With a blade that's 144 feet in diameter, the Vestas V44-600 is the largest wind turbine in operation. Perched atop a 160-foot tower west of Traverse City, Michigan, the turbine provides slightly less than one percent of the Traverse City Light and Power Company's total output. But, that's enough for about 200 residential customers. These patrons, who get all their electricity from wind power, agreed to pay about 20 percent more than other utility customers to support the project.

The turbine was built in Denmark. The blade tips pitch to capture the most energy from the winds and the rotor and generator speed can vary slightly to smooth out power fluctuations. In average winds of 14 to 15 mph, the annual production from the wind turbine is estimated at between 1.1 and 1.2 million kWh.

Global Climate Change

Earth's Atmosphere

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

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

Carbon dioxide is the gas that is produced when we breathe, and when we burn biomass and fossil fuels. Methane is the main gas in natural gas—a fossil fuel. Methane is also found in oil and coal deposits, in magma, and in offshore methane hydrate formations. Methane is released into the atmosphere through natural processes such as volcanic eruptions, as well as during oil drilling and coal mining. Methane is also produced when plants and animals decay.

The other heat-trapping gases (ozone, CFCs and nitrous oxide) are produced when fuels are burned, as by-products of manufacturing processes, 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 molecules in the atmosphere and are reflected back into space. Some rays are absorbed by molecules in the atmosphere and are turned into thermal energy (heat).

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

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

The Greenhouse Effect

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

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

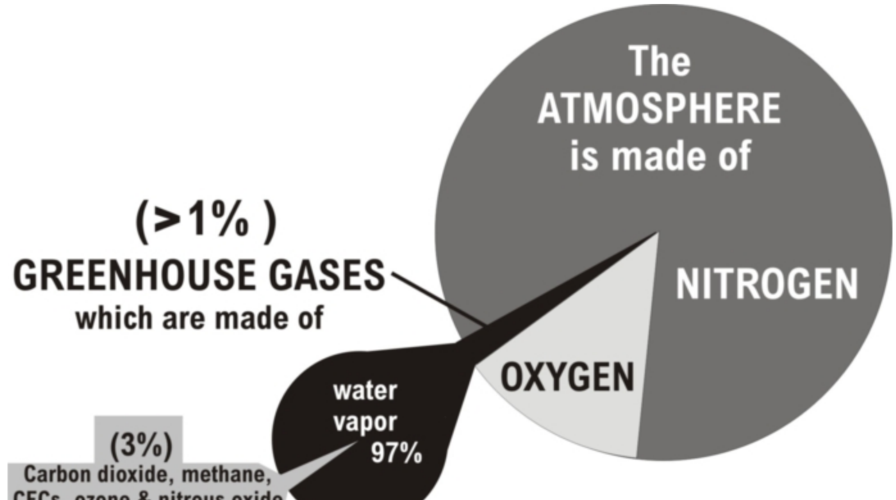
According to studies conducted by NASA and many other researchers around the world, the concentration of carbon dioxide has increased by about 25 percent since the Industrial Revolution in the early 19th century. Climate change experts have concluded that this increase is due in large part to the expanding use of fossil fuels.

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

The Atmosphere

Earth's atmosphere is made mainly of nitrogen, oxygen, and greenhouse gases. Greenhouse gases make up less than one percent of the atmosphere.

Greenhouse gases are more than 97 percent water vapor and less than three percent other gases such as carbon dioxide, methane, CFCs, ozone, and nitrous oxide.



Global Climate Change

Increased levels of greenhouse gases are trapping more heat in the atmosphere. This phenomenon is called **global climate change** or **global warming**. According to NASA, the National Air and Space Agency, the average temperature of the earth has risen by 1.4°F since the Industrial Revolution. This increase in average temperature has been the major cause of a 4–8 inch rise in sea level over that time period, as well as an increase in extreme precipitation events. Sea levels are rising because land-based ice is melting in the Arctic and Antarctic and in glaciers. Regions such as the Gulf Coast of the United States and several Pacific islands have already experienced losses to their coastlines. Recent research has also linked the increased severity of hurricanes and typhoons to global warming.

Climate scientists use sophisticated computer models to make predictions about the future effects of climate change. Because of the increased level of carbon dioxide and other greenhouse gases already in the atmosphere, NASA has determined that the earth will experience at least another 2°F temperature increase by the end of the century. The climate models predict more floods in some places and droughts in others, along with more extreme weather, such as powerful storms and hurricanes. They predict an additional rise in sea level of up to one foot, which would lead to the loss of low–lying coastal areas.

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

Kyoto Protocol

In December 1997 in Kyoto, Japan, representatives from countries around the world agreed upon a landmark treaty to reduce greenhouse gas emissions. In November 1998, the global community met again, in Buenos Aires, Argentina to discuss implementation of the Kyoto Treaty. Representatives of more than 160 countries agreed upon deadlines and an action plan for implementing the treaty.

The Kyoto Treaty was signed by the United States on November 12, 1998, but still must be ratified by the U.S. Senate and signed by the president before it becomes law. President Bush has stated that he will not approve the treaty in its present form, because it does not include limits on emissions for developing countries such as China, which will soon surpass the United States as the world's leading emitter of greenhouse gases.

In 2005, seven Northeastern and Mid-Atlantic states—Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont—announced an agreement to implement the Regional Greenhouse Gas Initiative. These states are developing a set of regulations and incentives designed to decrease greenhouse gas emissions. Meanwhile, California adopted the most stringent greenhouse gas regulations in the country. Recently, Massachusetts, Oregon, and Washington passed regulations based on the California model.

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).

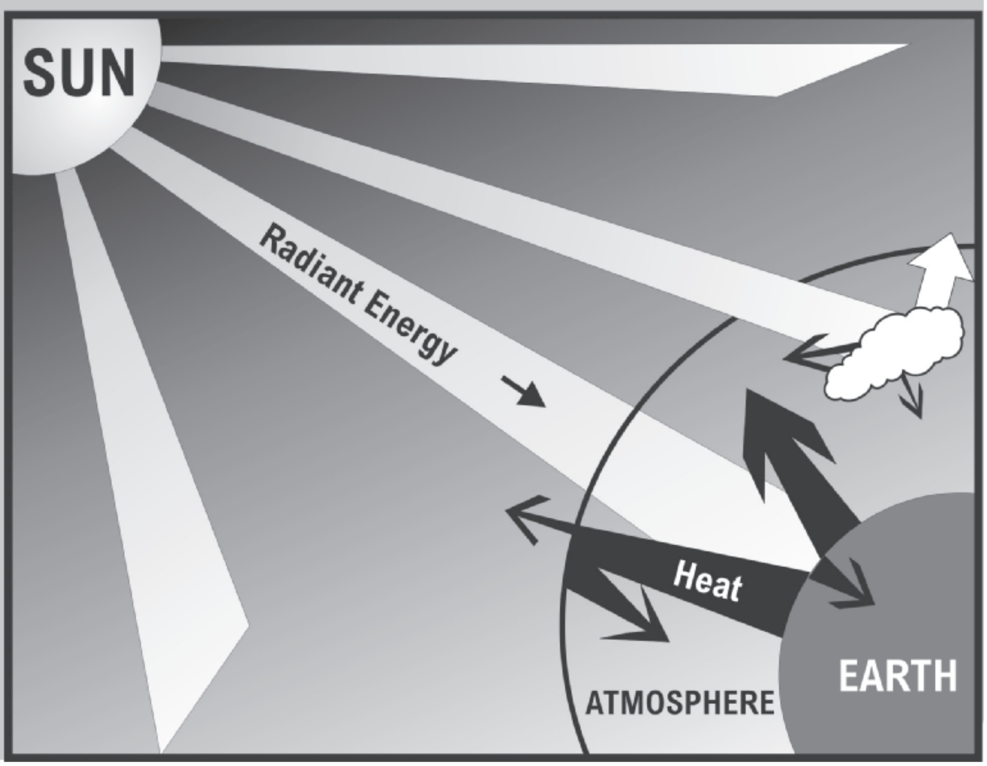
Half of the radiant energy that is directed at earth passes through the atmosphere and reaches the earth, where it is transformed into heat.

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 the earth.



Hydrogen

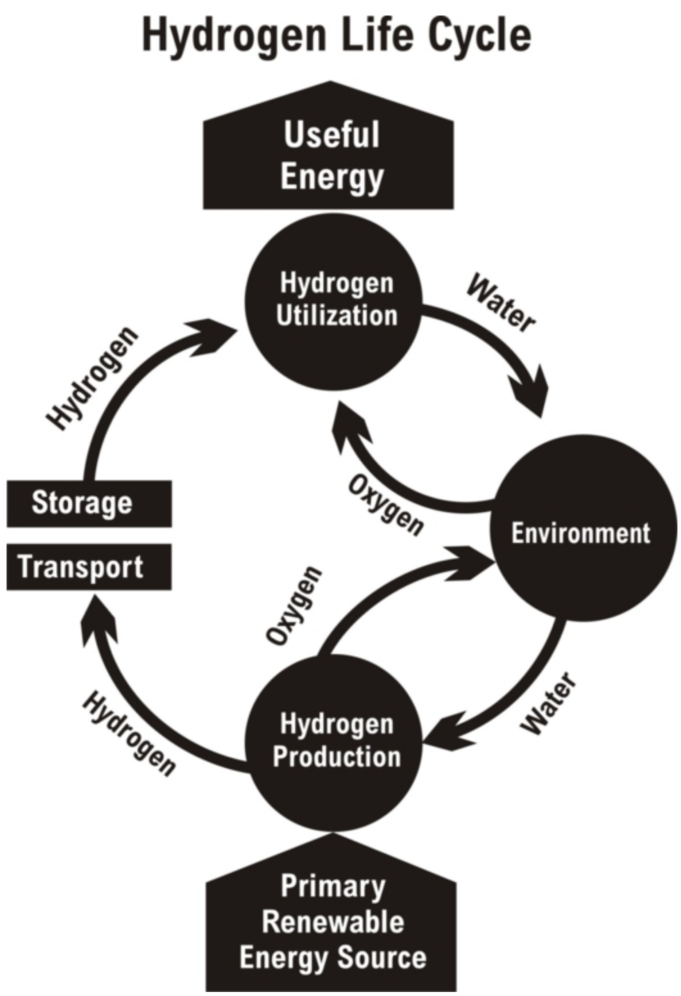
What Is Hydrogen?

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

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

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

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



Most of the energy we use today comes from fossil fuels. Only six percent comes from renewable energy sources. Usually renewable sources are cleaner, and can be replenished in a short period of time. We won't run out of hydrogen either.

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

Hydrogen is one of the most promising energy carriers for the future. It is a high efficiency, low polluting fuel that can be used for transportation, heating, and power generation in places where it is difficult to use electricity. Since hydrogen gas is not found on earth, it must be manufactured. There are several ways to do this.

How is Hydrogen Made?

Industry produces the hydrogen it needs by a process called **steam reforming**. High-temperature steam separates hydrogen from the carbon atoms in methane (CH_4). The hydrogen produced by this method isn't used as a fuel, but industrial processes. This is the most cost-effective way to produce hydrogen today, but it uses fossil fuels both in the manufacturing process and as the heat source.

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

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

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

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

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

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

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

Hydrogen Uses

The U.S. hydrogen industry currently produces about nine million tons of hydrogen a year, enough to power 20-30 million cars or 5-8 million homes. Most of this hydrogen is used for industrial applications such as refining, treating metals, and food processing.

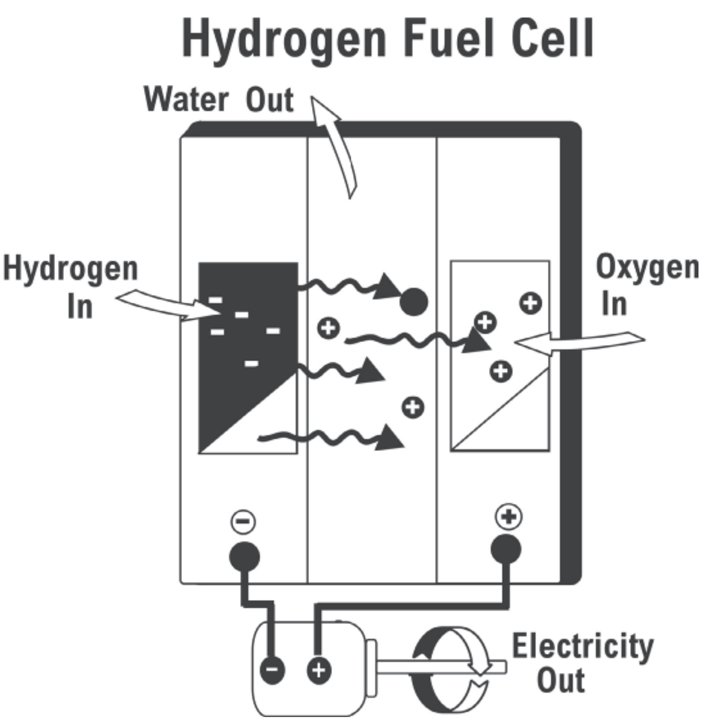
At the present time, hydrogen's main use as a fuel is in the NASA space program. Liquid hydrogen is the fuel that has propelled the space shuttle and other rockets since the 1970s. Hydrogen fuel cells power the shuttle's electrical systems, producing pure water, which is used by the crew as drinking water.

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

The first widespread use of hydrogen will probably be as an additive to transportation fuels. Hydrogen can be combined with gasoline, ethanol, methanol, and natural gas to increase performance and reduce pollution. Adding just five percent hydrogen to gasoline can reduce nitrogen oxide (NO_x) emissions by 30 to 40 percent in today's engines. An engine converted to burn pure hydrogen produces only water and minor amounts of NO_x as exhaust.

A few hydrogen-powered vehicles are on the road today, but it will probably be 10-20 years before you can walk into your local car dealer and drive away in one. Finding a hydrogen fuel station today might be difficult.

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



The space shuttle uses hydrogen fuel cells (batteries) to run its computer systems. The fuel cells basically reverse electrolysis—hydrogen and oxygen are combined to produce electricity. Hydrogen fuel cells are very efficient and produce only water as a by-product, but they are expensive to build.

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

As the production of electricity from renewables increases, so will the need for energy storage and transportation. Many of these sources—especially solar and wind—are located far from population centers and produce electricity only part of the time. Hydrogen may be the perfect carrier for this energy. It can store the energy and distribute it to wherever it is needed. It is estimated that transmitting electricity long distances is four times more expensive than shipping hydrogen by pipeline.

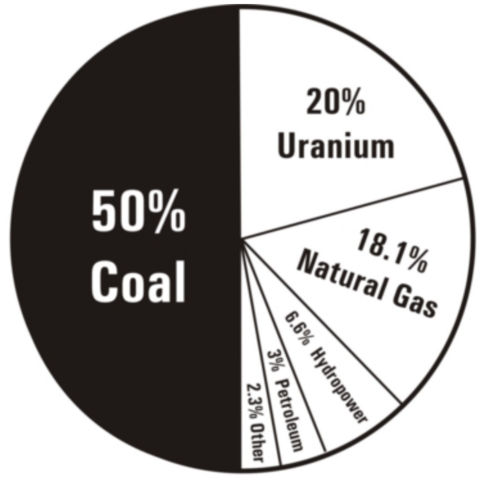
Future of Hydrogen

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

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

The goal of the U.S. Department of Energy's Hydrogen Program is for hydrogen to produce ten percent of our total energy demand by the year 2030. Hydrogen can reduce our dependence on foreign oil and provide clean, renewable energy for the future.

Electricity



U.S. ELECTRICITY PRODUCTION

ELECTRICITY at a Glance

Secondary Source of Energy, Energy Carrier

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

Percentage of Energy Consumed in U.S.: 39 %

U.S. Electricity Production: 3953 BkWh

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

The Nature of Electricity

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

Making Electricity

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

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

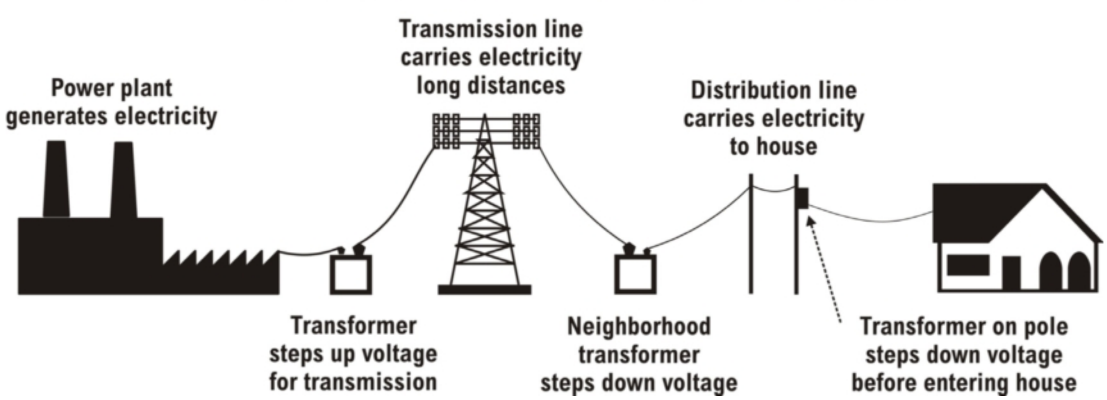
Moving Electricity

We are using more and more electricity every year. One reason that electricity is used by so many consumers is that it's easy to move from one place to another. Electricity can be produced at a power plant and moved long distances before it is used. Let's follow the path of electricity from a power plant to a lightbulb in your home.

First, the electricity is generated at the power plant. Next, it goes by wire to a **transformer** that "steps up" the voltage. A transformer steps up the voltage of electricity from the 2,300 to 22,000 volts produced by a generator to as much as 765,000 volts (345,000 volts is typical). Power companies step up the voltage because less electricity is lost along the lines when the voltage is high.

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

TRANSPORTING ELECTRICITY



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

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

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

Power to the People

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

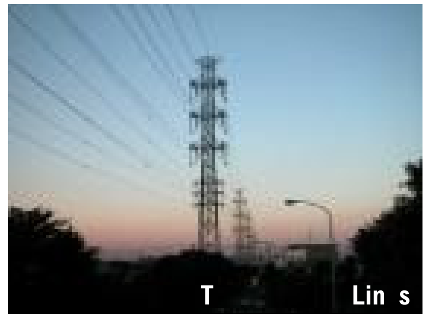
It is the responsibility of electric utility companies to make sure electricity is there when we need it. They must consider reliability, capacity, base load, power pools, and peak demand.

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

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

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

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



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

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

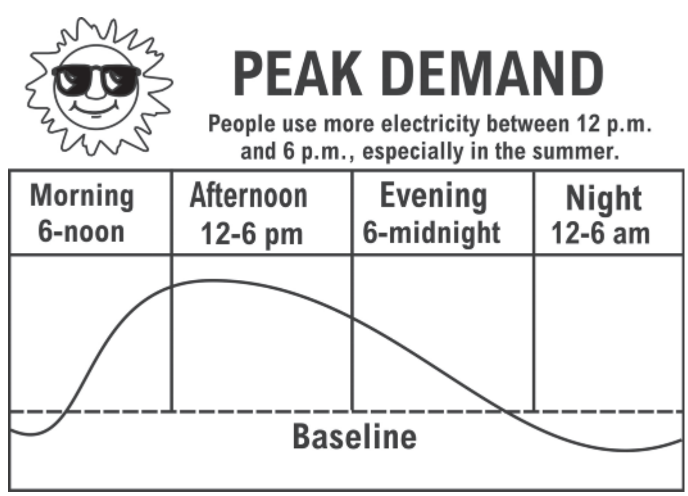
Demand-Side Management

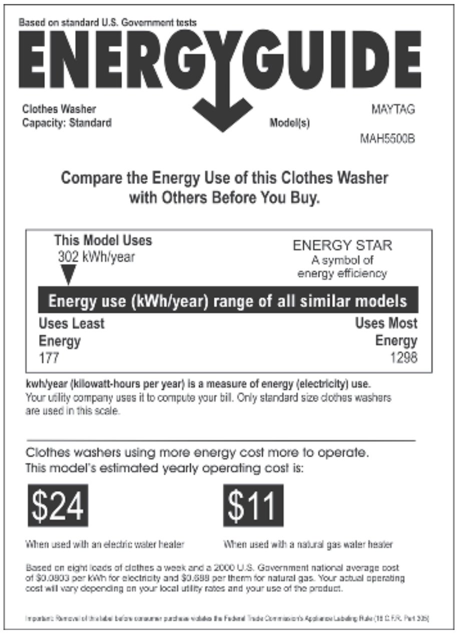
Demand-side management is all the things a utility company does to affect how much people use electricity and when. It's one way electric companies manage those peak-load periods.

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

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

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





Appliance Efficiency

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

Using energy efficient appliances can significantly reduce electricity demand. In the last 20 years, comparing appliance efficiency has been made easier by government regulation.

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

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

Efficiency Standards

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

New electric appliances use less electricity but still produce the same amount of work. Appliance efficiency has improved dramatically in the last 25 years. Today's freezers are 77 percent more efficient than those made in the early 1970s, and central air conditioners are 50 percent more efficient.

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (50 percent), the cost of transmission (20 percent) and local distribution (30 percent). The average cost of electricity is nine cents per kWh for residential customers and a little over seven cents for industrial customers. A major key to cost is the fuel used to generate the power. Electricity produced from natural gas, for example, costs more than electricity produced from coal or hydropower.

Generating ELECTRICITY

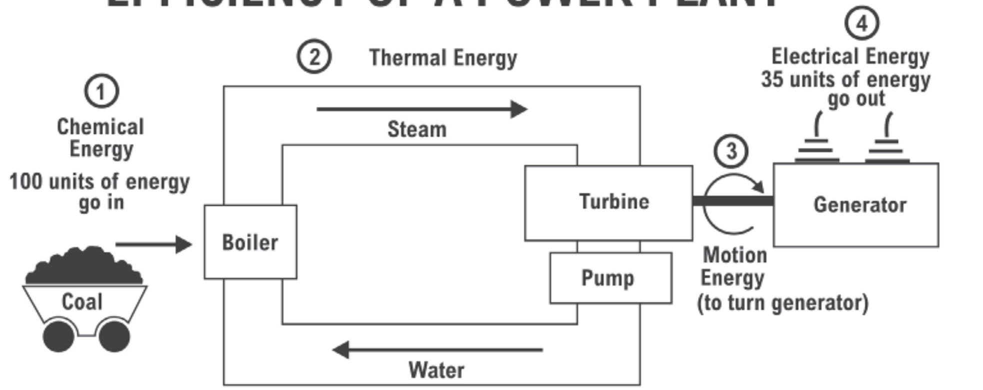
Three basic types of power plants generate most of the electricity in the United States—fossil fuel, nuclear, and hydropower. There are also wind, geothermal, trash-to-energy, and solar power plants, but they generate only about 2.3 percent of the electricity produced in the United States.

FOSSIL FUEL POWER PLANTS: Fossil fuel plants burn coal, natural gas, or oil. These plants use the chemical energy in fossil fuels to superheat water into steam, which drives a turbine generator. Fossil fuel plants are sometimes called thermal power plants because they use heat to generate electricity. Coal is the fossil fuel of choice for most electric companies, producing 50 percent of total U. S. electricity. Natural gas plants produce 18 percent. Petroleum produces three percent of the electricity in the U. S.

NUCLEAR POWER PLANTS: Nuclear plants generate electricity much as fossil fuel plants do except that the furnace is called a reactor and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller elements, producing heat in the process. The heat is used to superheat water into high-pressure steam, which drives a turbine generator. Like fossil plants, nuclear power plants are called thermal plants because they use heat to generate electricity. Nuclear energy produces 20 percent of the electricity in the U. S.

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

EFFICIENCY OF A POWER PLANT



Most power plants are about 35% efficient. For every 100 units of energy that go into a plant, 65 units are lost as one form of energy is converted to other forms. Thirty-five units are produced to do usable work.

Another consideration is how much it costs to build a power plant. A plant may be very expensive to construct, but the cost of the fuel can make it competitive to other plants, or vice versa. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is very cheap. Coal-fired plants, on the other hand, are much less expensive to build than nuclear plants, but their fuel—coal—is more expensive.

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

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

You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on newer power plants. A modern coal plant burns about 8,000 tons of coal each day, and about two-thirds of this is lost when the heat energy in coal is converted into electrical energy.

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

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

Measuring ELECTRICITY

Power is the rate (time) of doing work. A watt is a measure of the electric power an electrical device uses. Most electrical devices require a certain number of watts to work correctly. All lightbulbs, for example, are rated by watts (60, 75, 100 watts), as are appliances, such as a 1500-watt hairdryer.

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

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

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

Deregulation

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

Under this model, utilities generated the power, transmitted it to the point of use, metered it, billed the customer, and provided information on efficiency and safety. The price was regulated by the state.

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

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

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

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

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

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

In some states, individual consumers now have the option of choosing their electric utility, much like people can now choose their long-distance telephone carrier. Their local utility would distribute the power to the consumer.

Some experts say this could lower electric bills, but don't expect to see this happening on a large scale in the next few years. It will take the industry and the states several years to decide if residential competition is a good thing and figure out how to implement the changes.

Independent Power Producers

The business of generating electricity once was handled solely by electric utility companies, but today many others are generating—and selling—electricity. Independent power producers, sometimes called private power producers or non-utility generators, generate electricity using many different energy sources.

Independent power producers (IPPs) came on strong after the oil crises of the 1970s. At that time, Congress wanted to encourage greater efficiency in energy use and the development of new forms of energy. In 1978, Congress passed the Public Utility Regulatory Policies Act or PURPA. This law changed the relationship between electric utilities and smaller IPPs. Under the law, a public utility company cannot ignore a nearby IPP. A utility must purchase power from an IPP if the utility has a need for the electricity, and if the IPP can make electricity for less than what it would cost the utility to make it.

The relationship between IPPs and utilities varies from state to state. Some utilities welcome the IPPs because they help them meet the growing demand for electricity in their areas without having to build new—and expensive—power plants. Other utilities worry that power from IPPs will make their systems less reliable and increase their costs. They fear that this may cause industries to think twice before locating in their areas.

For different reasons, some environmentalists also worry that IPPs may not be subject to the same pollution control laws as public utilities. In reality, the opposite is true. Because they are generally the newest plants, IPPs are subject to the most stringent environmental controls. In any case, most experts predict that IPPs will produce more and more electricity. Today, IPPs generate about 25.1 percent of the nation's electricity. In the last five years, more than half of all new electric generation in the U.S. has come from IPPs.

COGENERATORS: A special independent power producer is a cogenerator—a plant that produces electricity and uses the waste heat to manufacture products. Industrial plants, paper mills, and fast-food chains can all be cogenerators. These types of plants are not new. Thomas Edison's plant was a cogenerator. Plants generate their own electricity to save money and ensure they have a reliable source of energy that they can control. Now, some cogenerators are selling the electricity they do not use to utilities. The electric utilities supply that energy to their customers. So, even though your family's electric bill comes from a utility company, your electricity may have been made by a local factory. Today, about seven percent of the electricity produced in the U.S. is cogenerated.

Future Demand

Home computers, answering machines, FAX machines, microwave ovens, and video games have invaded our homes and they are demanding electricity! New electronic devices are part of the reason why Americans are using more electricity every year.

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

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

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

Can we produce more electricity from renewable energy sources such as wind or solar? And where should we build new power plants? No one wants a power plant in his backyard, but everyone wants the benefits of electricity.

Experts predict we will need 200 thousand more megawatts of generating capacity by the year 2010. Demand for electricity will only increase in the future. We must also make machines and appliances much more energy efficient or we will have to build the equivalent of 350 coal plants by the year 2010 to meet that demand.

Right now, most new power generation comes from natural gas. Natural gas is a relatively clean fuel and is abundant in the United States. New natural gas combined-cycle turbines use the waste heat they generate to turn a second turbine. Using this waste heat increases efficiency to 50 or 60 percent, instead of the 35 percent efficiency of conventional power plants.

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

Research and Development

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

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

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

Some obstacles remain in the way of incorporating this new technology into commercial products, however. First, researchers have conducted most experiments using only very small samples of the new ceramic materials, which tend to be very brittle and difficult to shape. Second, researchers are still not sure the ceramic materials can carry large electric currents without losing their superconductivity. Still, the development of the new superconductors has the potential to dramatically change, perhaps even revolutionize, the electronics, electric power, and transportation industries.

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

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

History of Electricity

Starting with Ben

Many people think Benjamin Franklin discovered electricity with his famous kite-flying experiments in 1752. That isn't the whole story. Electricity was not "discovered" all at once.

Benjamin Franklin

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

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

A Different Kind of Power: The Battery

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

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

A Current Began

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

Mr. Edison & His Light

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

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

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

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

The Question: AC or DC?

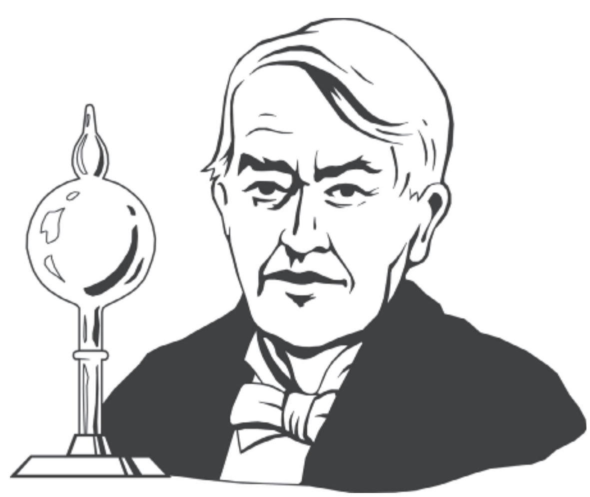
The turning point of the electric age came a few years later with the development of AC (alternating current) power systems. Now power plants could transport electricity much farther than before. In 1895, George Westinghouse and his associates opened a major power plant at Niagara Falls that used AC power.

While Edison's DC (direct current) plant could only transport electricity within one square mile of his Pearl Street Power Station, the Niagara Falls plant was able to transport electricity over 200 miles!

Electricity didn't have an easy beginning. While many people were thrilled with all the new inventions, some people were afraid of electricity and wary of bringing it into their homes. They were afraid to let their children near this strange new power source.

Many social critics of the day saw electricity as an end to a simpler, less hectic way of life. Poets commented that electric lights were less romantic than gaslights. Perhaps they were right, but the new electric age could not be dimmed.

In 1920, about two percent of U.S. energy was used to make electricity. In 2004, it was 39 percent. By 2010, that figure will probably grow to more than 40 percent with the increasing use of technologies powered by electricity.



Thomas Edison

The Facts of Light

Americans use electricity to power our lives. In homes and offices all over the country, people rely on electricity to operate most of our appliances, computers, and entertainment systems. Electricity cooks our food and warms our bodies. And, at the flip of a switch, electricity gives us light. Almost half of the electricity used by industry is for lighting. In the residential sector, up to 25 percent of our electric bill is for lighting.

Most of the light is produced by **incandescent light bulbs (ILs)**, 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. There are better ways. If the country converted to state-of-the-art technologies, the electricity consumed to produce light could be reduced by up to 70 percent! This would lower carbon dioxide emissions equivalent to removing one-third of the nation's cars from the highways. Reducing the electricity consumed by just one percent would eliminate the need for an average-sized power plant.

Recent developments have produced **compact fluorescent lights (CFLs)** that 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.

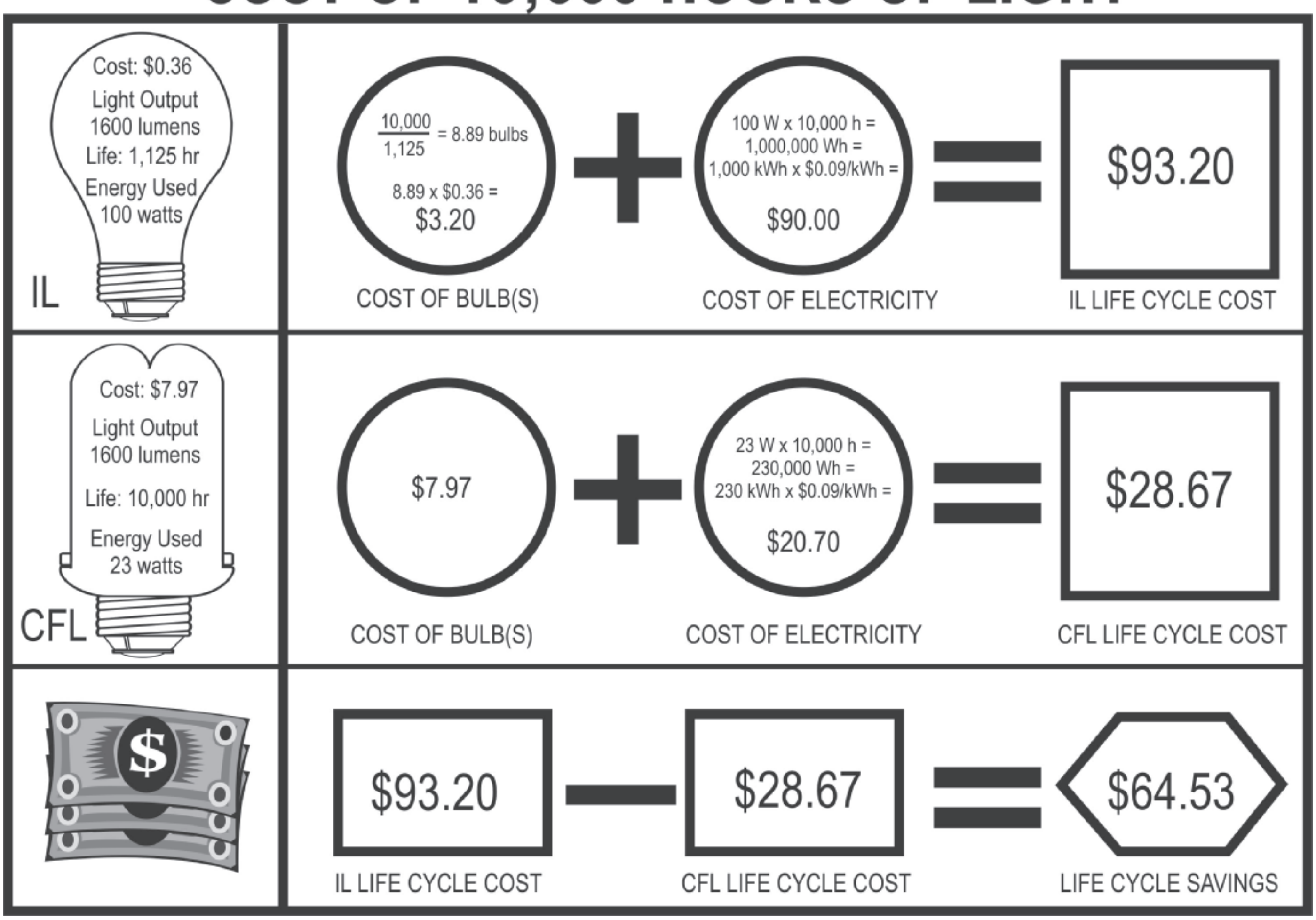
Over the life of the bulbs, CFLs cost the average consumer less than half the cost of traditional incandescent bulbs for the same amount of light. In addition, CFLs produce very little heat, reducing the need for air conditioning in warm weather.

Why doesn't everyone use CFLs? There are three reasons: lack of education about CFLs, the high initial cost ($5 to $10 per bulb) and consumer buying habits. Lots of people have never heard of CFLs, and few know that converting to CFLs can save so much money and electricity. Many people see the price tag and think they're getting a great bargain when they buy 10 incandescents for the same amount of money. They don't understand that they can reduce their electric bills 25 to 50 percent by converting to CFLs.

Another consideration is consumer buying habits. Most people buy light bulbs at the supermarket or local discount store. It's a lot easier to hand over five dollars for ten incandescents than a hundred dollars for ten CFLs.

It will take a massive education campaign to change Americans' buying habits. People must be convinced that lighting is a long-term investment that can really save money, as well as save energy and contribute to air quality.

COST OF 10,000 HOURS OF LIGHT



Measuring Electricity

Electricity makes our lives easier, but it can seem like a mysterious force. Measuring electricity is confusing because we cannot see it. We are familiar with terms such as watt, volt, and amp, but we do not have a clear understanding of these terms. We buy a 60-watt light bulb, a tool that requires 120 volts, or an appliance that uses 8.8 amps, but we don't think about what those units mean.

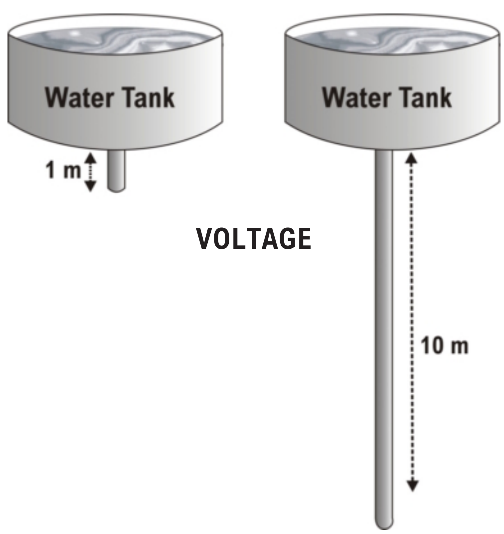
Using the flow of water as an analogy can make electricity easier to understand. The flow of electrons in a circuit is similar to water flowing through a hose. If you could look into a hose at a given point, you would see a certain amount of water passing that point each second. The amount of water depends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

Voltage

The pressure that pushes electrons in a circuit is called **voltage**. Using the water analogy, if a tank of water were suspended one meter above the ground with a 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-volt; they apply a small amount of voltage for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a dangerous voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous voltage.

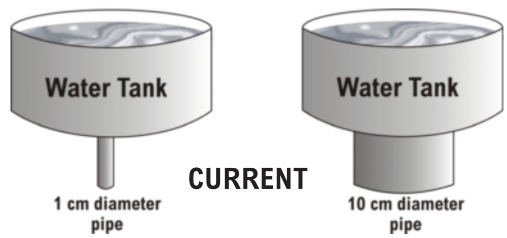


Current

The flow of electrons can be compared to the flow of water. The water current is the number of molecules of water flowing past a fixed point; 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 6.25×10^{18} electrons per second passing through a circuit.

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

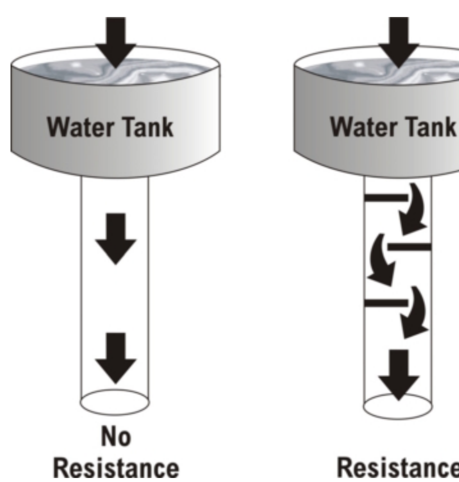


Resistance

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

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

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



Ohm's Law

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

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

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

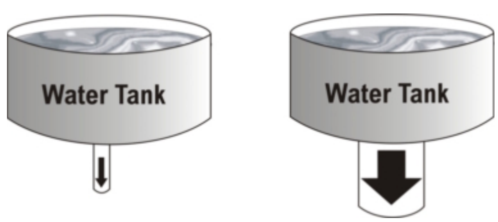
Electrical Power

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, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work.

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

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)**. The formula is:

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



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)**.

$$\text{energy (E)} = \text{power (P)} \times \text{time (t)}$$
$$E = P \times t \quad \text{or} \quad E = W \times h = Wh$$

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

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

$$\text{distance} = 40 \text{ mph} \times 1 \text{ hour} = 40 \text{ miles}$$

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

$$\text{distance} = 40 \text{ mph} \times 3 \text{ hours} = 120 \text{ miles}$$

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 five hours with a 100-W lightbulb, for example, you would use the formula as follows:

$$\text{energy} = \text{power} \times \text{time } (E = P \times t)$$
$$\text{energy} = 100 \text{ W} \times 5 \text{ hour} = 500 \text{ Wh}$$

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 $0.09.

To calculate the cost of reading with a 100-W lightbulb for five hours, you would change the watt-hours into kilowatt-hours, then multiply the kilowatt-hours used by the cost per kilowatt-hour, as shown below:

$$500 \text{ Wh divided by } 1{,}000 = 0.5 \text{ kWh}$$
$$0.5 \text{ kWh} \times \$0.09/\text{kWh} = \$0.045$$

Therefore, it would cost about four and a half cents to read for five hours with a 100-W lightbulb.

$ Energy Consumption

RESIDENTIAL/COMMERCIAL

The residential and commercial sector—homes and buildings—consumes 38.8 percent of the energy used in the United States today. We use energy to heat and cool our homes and buildings, to light them, and to operate appliances and office machines. In the last 25 years, Americans have significantly reduced the amount of energy we use to perform these tasks, mostly through technological improvements in the systems we use, as well as in the manufacturing processes to make those systems.

HEATING & COOLING

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

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

The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, more than half of the nation's homes are heated by natural gas, a trend that will continue, at least in the near future. **Natural gas** is the heating fuel of choice for most consumers in the United States. It is a clean-burning fuel. Most natural gas furnaces in the 1970s and 1980s were about 60 percent efficient—they converted 60 percent of the energy in the natural gas into usable heat. Many of these furnaces are still in use today, since they can last 20 or more years with proper maintenance.

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

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

To Save ENERGY at Home

Maintain Heating & Cooling Systems Properly

Use Programmable Thermostats to Control Indoor Temperature

Make Sure There is Adequate Insulation in Walls and Attic Spaces

Use Weatherstripping & Caulking to Reduce Air Infiltration

Electricity is the second leading source of energy for home heating and provides almost all of the energy used for air conditioning. The efficiency of air conditioners and heat pumps has increased more than 50 percent in the last 25 years.

In 1973, air conditioners and heat pumps had an average **Seasonal Energy Efficiency Rating**, or **SEER**, of 7.0. Today, the average unit has a SEER of 11.1, and high-efficiency units are available with SEER ratings as high as 18. These high-rated units are more expensive to buy, but their payback period is only three to five years.

Heating oil is the third leading fuel for home heating and is widely used in northeastern states. In 1973, the average home used 1,294 gallons of oil a year. Today, that figure is 833 gallons, a 35 percent decrease.

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

Saving Energy on Heating and Cooling

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

Maintenance

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

Programmable Thermostats

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

Insulation

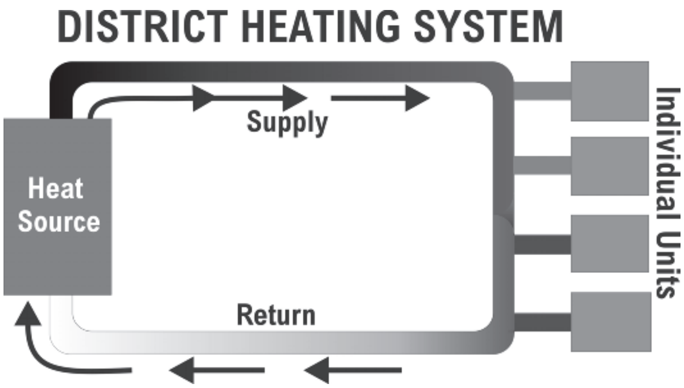
Most heat enters and escapes from homes through the ceilings and walls. Adequate insulation is very important to reduce heat loss and air infiltration. The amount of insulation required varies with the climate of the region in which the house is located.

Caulking & Weatherstripping

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

District Energy Systems

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



If the system relies on a fossil fuel cogeneration plant for heat, the overall efficiency of the plant can increase from 30 to 90 percent. Cogeneration can also reduce emissions per unit of energy produced by 50 to 60 percent.

If the district energy system uses a renewable energy source, such as geothermal energy or waste heat, emission levels can be reduced even more. A major benefit of district heating is its ability to use materials as fuel that would otherwise be waste products. These fuels may include biomass, such as waste from the forest product industry, straw, garbage, industrial waste heat, and treated sewage. In the next 25 years, district energy systems will double their current output, using natural gas, as well as cogeneration from biomass and geothermal sources.

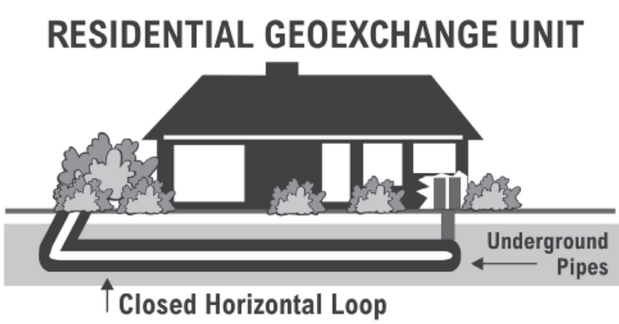
GeoExchange Systems

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

Geothermal systems cost more to install than conventional systems, but over the life of the system, they can save a significant amount of money and energy. They can reduce heating costs by 50-70 percent and cooling costs by 20-40 percent. It is estimated that the average homeowner can save $20,000 over the life of the system. Today, there are about 300,000 geothermal systems in homes and buildings. By the year 2023, the geothermal industry estimates that more than 10 million homes and businesses will be equipped with this new technology.

Building Design

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



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

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

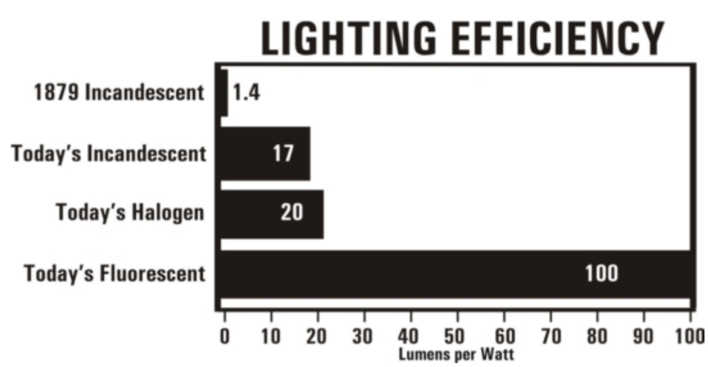
For existing houses and buildings, there are many ways to increase efficiency. Adding insulation and replacing windows and doors with high efficiency models can significantly reduce energy costs. Adding insulated draperies and blinds, and using them wisely, can also result in savings. Even planting trees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

LIGHTING

Lighting is essential to a modern society. Lights have revolutionized the way we live, work, and play. Today, about five percent of the energy used in the nation is for lighting our homes, buildings, and streets. Lighting accounts for about 25 percent of the average home's electric bill, but for stores, schools, and businesses, the figure is much higher. On average, the commercial sector uses about 60 percent of its electricity for lighting.

Most homes still use the traditional incandescent bulbs invented by Thomas Edison. These bulbs convert only ten percent of the electricity they use to produce light; the other 90 percent is converted into heat. With new technologies, such as better filament designs and gas mixtures, these bulbs are more efficient than they used to be. In 1879, the average bulb produced only 1.4 lumens per watt, compared to about 17 lumens per watt today. By adding halogen gases, this efficiency can be increased to 20 lumens per watt.

Most commercial buildings have converted to fluorescent lighting, which costs more to install, but uses much less energy to produce the same amount of light. Buildings can lower their long-term lighting costs by as much as 50 percent with fluorescent systems.



Compact fluorescent bulbs have made inroads into home lighting systems in the last few years. They are more expensive, but they last much longer and use much less energy, producing significant savings over the life of the bulb. New fluorescent bulb technology has made more dramatic advances in lighting efficiency. Some of the new fluorescent systems have increased the efficiency of these bulbs to as high as 100 lumens per watt.

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

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

Consumers should make use of new fluorescent bulbs wherever feasible and use only the amount of light they need for the task at hand. Most people use higher wattage bulbs than are necessary in most fixtures. Automatic turn-off and dimmer switches can also contribute to energy savings. Keeping lightbulbs free of dust is an energy-saver, too. One of the most important actions consumers can take is to turn off lights they aren't using, buy lamps that are suited to their needs in different rooms, and make energy conservation a priority in their daily lives.

APPLIANCES

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

Water Heating

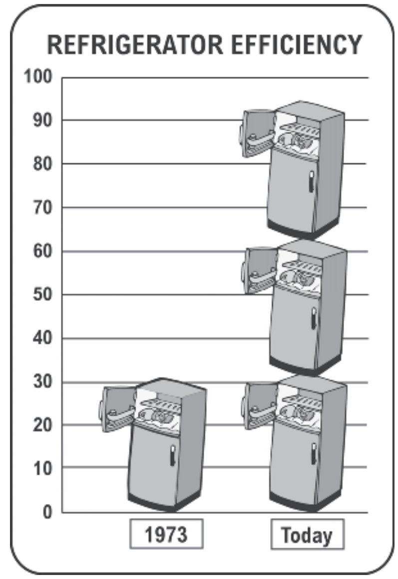
Heating water uses more energy than any other task, except for home heating and cooling. Most water heaters use natural gas or electricity as fuel. New water heaters are much more energy efficient than earlier models. Many now have timers that can be set to the times when hot water is needed, so that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

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

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

Refrigerators

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



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

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

Laundry Machines

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

New washing machines are being designed with a horizontal axis, rather than the traditional top-load design. These machines use 40 percent less water and 60 percent less energy than the top-loading models. They also have higher capacity; they can wash large items such as comforters and sleeping bags.

Appliance Efficiency Ratings

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

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

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

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

Energy Consumption

INDUSTRIAL SECTOR

The United States is a highly industrialized society. We use a lot of energy. Industry consumed 33.3 percent of the energy in 2004. Since 1973, the industrial sector has grown by more than 60 percent, but it has required only about 15 percent more energy. Advanced technologies have allowed industry to do more with less. Industry has also been a leader in developing cogeneration technology. Cogenerators produce electricity and using the waste heat for manufacturing, increasing overall energy efficiency by 50 percent.

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

Petroleum Refining

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

On average, operating the refineries consumes about nine percent of the energy in the crude oil. On a per barrel basis, today's refineries use about 25 percent less energy than they did in 1973.

Steel Manufacturing

The steel industry consumes about three percent of total U.S. energy demand. The energy is used to convert iron ore and scrap metal into hundreds of products we use daily. The cost of energy represents between 15-20 percent of the manufacturing cost of steel. Most of this energy (60 percent) comes directly from coal and electricity generated by coal–fired plants.

Since 1973, the steel industry has reduced its energy consumption by 45 percent per ton of steel. This increase in efficiency has been accomplished through advanced technologies, the closing of older plants, and the increased use of recycled steel.

The increased use of recycled steel also saves energy. It requires 33 percent less energy to recycle steel than to make it from iron ore. Today, steel is the nation's leading recycled product, with 68 percent of new steel being manufactured from recycled scrap.

Aluminum Manufacturing

It takes huge amounts of electricity to make aluminum from **bauxite**, or aluminum ore. It requires six to seven kilowatt-hours of electricity to convert one pound of bauxite into aluminum. The cost of electricity accounts for 30 percent of the total manufacturing cost.

Today, it requires 23 percent less energy to produce a pound of aluminum than it did 25 years ago, mostly because of the growth of recycling. Aluminum recycling has almost doubled since the 1970s. Using recycled aluminum requires 95 percent less energy than converting bauxite into aluminum.

Paper Manufacturing

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

To produce a ream (500 sheets) of copy paper requires 27,500 Btu's of energy, the equivalent of about two gallons of gasoline. In 1973, it required 47,500 Btu's, or the equivalent of 3.7 gallons of gasoline, to produce the same amount of paper.

The pulp and paper industry has reduced its energy consumption per ton of paper by about 42 percent in the last 25 years, mostly through the use of better technology and cogeneration systems. Almost 56 percent of the fuel the industry uses to power the cogeneration equipment comes from wood waste, a renewable energy source.

Chemical Manufacturing

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

Petroleum is one of the major sources of hydrocarbons used by the chemical industry today. New technology has made the chemical industry about 41 percent more energy efficient today than it was in 1973. Technology has allowed the industry to use less energy, as well as produce more product from an equivalent amount of petroleum feedstock.

Cement Manufacturing

Some people think the United States is becoming a nation of concrete. New roads and buildings are being built everywhere, every day. Concrete is made from cement, water, and crushed stone. Making cement is an energy-intensive industry because of the extremely high temperatures required—up to 3,500 degrees Fahrenheit.

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

More than half of the 118 cement plants in the U.S. now use some type of waste by-product for fuel, including used printing inks, dry cleaning fluids, and used tires—all of which have high energy content. The average used tire, for example, has the energy equivalent of two gallons of petroleum.

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

Energy Consumption

Transportation Sector

America is a nation on the move. More than 27 percent of the energy we use every day goes to transporting people and goods from one place to another.

The Automobile

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

In 1973, there were 102 million cars on the road, driving an average of 9,600 miles a year. In 2004, there were more than 150 million cars, driving 12,000 miles a year. Even with the scares of the oil embargos, we are driving more cars, more miles. It's a good thing we're doing it more efficiently and cleanly.

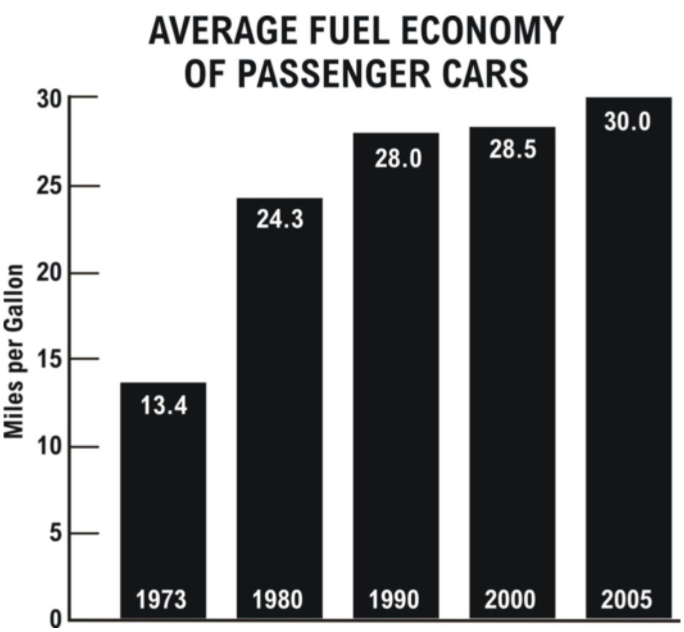
Although the oil crises didn't alter Americans' driving habits much, they did bring about changes in vehicle design. Automakers downsized many large and mid-sized models and significantly reduced vehicle weight. Aerodynamic designs were incorporated and engine size reduced. More important, engines were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

All of these improvements have resulted in a doubling of average mileage ratings for vehicles since 1973. If mileage had remained the same, we would be consuming 30 percent more fuel today.

The import of foreign cars has also increased. In 1973, foreign cars had a seven percent share of the market. Today, that figure is 30 percent and many foreign car companies have opened assembly plants in the United States.

Mileage Requirements

Most of the improvements in automobile efficiency have been the result of mandates by the Federal government. Today, passenger cars are required to achieve a combined city and highway mileage of 28.0 miles per gallon. For every mile per gallon below this standard, a tax of $1,000 is placed on the purchase price. Currently, only a few high-performance vehicles are subject to this tax. Furthermore, this standard does not apply to vans, pick-up trucks, and sport utility vehicles.



In the last few years, when gas prices were low, consumers made no great effort to buy fuel-efficient vehicles. In 2004, for example, sales of the ten most efficient cars and ten most efficient trucks totaled less than one percent of total sales. On the other hand, sport utility vehicles and light trucks made up half of total passenger vehicle sales.

Advocates of further increases in fuel efficiency think the mileage standard should be raised even higher and that vans, sport utility vehicles, and trucks should be required to meet the same standards as other vehicles. Opponents think consumer choice would be limited and consumers could not afford the vehicles of their choice. They also think vehicles might become smaller and less safe.

To promote more fuel-efficient vehicles, the federal government entered into a partnership with the "Big Three" automakers in 1993 to develop an environmentally friendly car by 2003. This vehicle, called the Supercar, was supposed to achieve a mileage rating of 80 miles per gallon without sacrificing safety, affordability, or performance. This hasn't happened yet.

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

Alternative Fuels

There is also a push to develop vehicles that run on fuels other than petroleum products or on blended fuels. Today, there are vehicles that run on electricity, natural gas, propane, biodiesel, ethanol, and hydrogen. There are even solar-powered cars on the roads. In 1973, there were only a few vehicles that ran on alternative fuels. Today, there are more than 500,000 in the United States, and that figure is increasing by about eight percent a year. The largest barriers to widespread acceptance are:

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

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

If these barriers can be removed, alternative fuel vehicles can develop a strong niche market in the U.S. New technologies are being developed to make these vehicles more practical and convenient for consumers. President Bush's hydrogen fuel cell initiative will also encourage the development of alternative vehicles.

Commercial Transportation

The United States is a large country. We use a lot of energy moving goods and groups of people from one place to another. Passenger vehicles consume about two-thirds of the transportation fuel and commercial vehicles consume the remaining third. The fuel efficiency of trains, trucks, buses, and planes has increased significantly in the last 25 years, as well as the number of miles traveled.

Trucks

Trucks use more transportation fuel than any other commercial vehicle. Almost all products are at some point transported by truck. In 1977, the average tractor-trailer traveled about 4.8 miles on a gallon of fuel. New trucks manufactured today can travel about seven miles on a gallon of fuel. This increase in fuel efficiency is due mainly to improvements in engine design and computerized electronic controls.

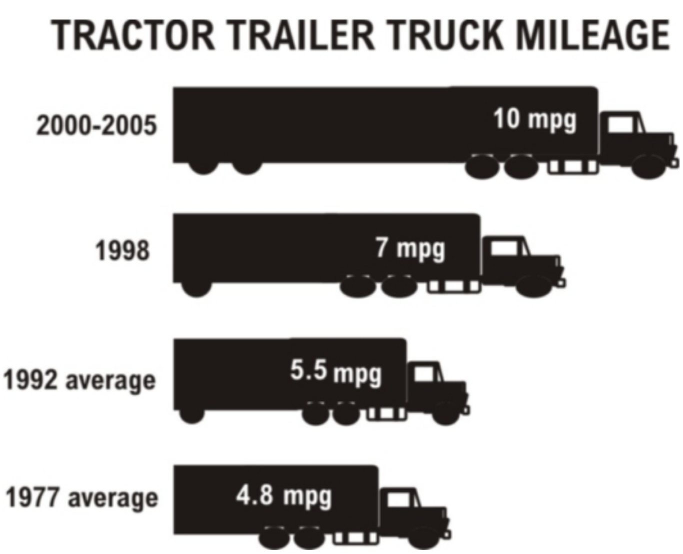
New diesel engines can convert about 45 percent of the energy in the fuel into vehicle movement, while gasoline engines can convert only about 24 percent. Federal research is aimed at improving diesel efficiency to 55 percent, by redesigning engines, redesigning braking systems to use air flow to help slow down vehicles, and engineering tires to roll more easily.

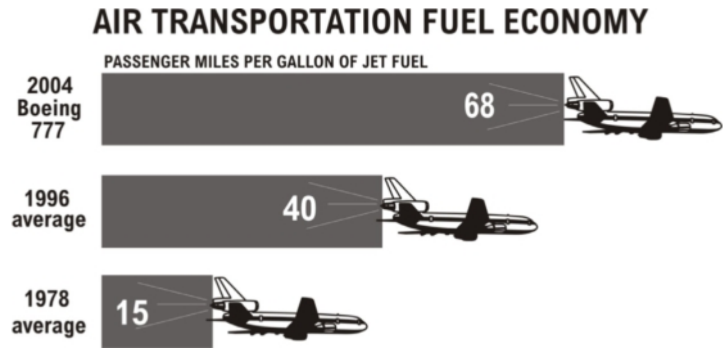
Planes

Since 1973, the amount of cargo and the number of passengers on planes have more than doubled. Planes all use petroleum products for fuel, which is the largest cost item for air transport after labor. The airline industry has been a leader in efficiency. While consumer prices in general have more than doubled, airline prices have remained almost unchanged.

In 1970, the average number of passenger miles per gallon was 15. Today, that figure is almost 40 miles per gallon of fuel. Passenger and cargo miles have more than doubled in the same time period. In 2004, more than 600 million passengers flew on airplanes. That number is expected to reach one billion by the year 2010.

There is also research being done into the use of alternative fuels for airplanes. One advantage that airlines have is that refueling stations are more centralized; the airline industry doesn't need the vast infrastructure that ground vehicles do. Changing the engines of airplanes is a technical challenge for engineers, however, to ensure that all of the systems can work together.





Railroads

Railroads are the nation's leading carrier of freight between cities. Since 1975, the fuel efficiency of freight trains has increased by more than half.

This reduction in energy use was accomplished by using longer trains with less handling and fewer changes and stops. The equipment is stronger and lighter to handle more cargo. There have also been major improvements in rail technology that have contributed to ease of movement.

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

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

Mass Transit

Mass transit is the system of public transportation for moving people on buses, trains, light rail, and subways. In 2004, about eight billion trips were taken on public transit systems, two-thirds on buses. This figure sounds huge, but it is less than the number of trips in 1970. Why this decrease? Americans love their cars; most families own more than one. As more people have moved from cities into suburbs, public transportation has not been economically feasible for many dispersed locations.

This situation may change in the future. Congress recently passed legislation increasing the funding for public transit. There is growing awareness of the problems caused by increased traffic congestion. The number of hours that people are delayed in traffic has increased by 95 percent in the last ten years. Building more roads can't be the only answer, especially with environmental concerns over vehicle emissions.

Efficiency & Conservation

Introduction

The United States uses a lot of energy— a million dollars worth of energy each minute, 24 hours a day, every day of the year. With less than five percent of the world's population, we consume almost one quarter (24 percent) of the world's energy resources. We are not alone among industrialized nations; 16 percent of the world's population consumes 80 percent of its natural resources.

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

Representative Countries & Energy Consumption

Country	Population in millions (2005)	Consumption in quads (2003)
China	1304	45.5
India	1104	14.0
United States	296	98.8
Indonesia	222	4.7
Brazil	184	8.8
Pakistan	162	1.9
Russia	144	29.1
Bangladesh	144	0.6
Nigeria	132	1.0
Japan	128	22.4
Mexico	107	6.8
Germany	82	14.2
Iran	70	6.0
Thailand	65	3.1
France	61	11.2
United Kingdom	60	9.8
Italy	59	8.0
South Africa	50	4.9
South Korea	48	8.6
Canada	32	13.5
Saudi Arabia	25	5.7
Taiwan	23	4.2
Australia	20	6.1

Energy Efficiency & Conservation

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

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

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

The U.S. Department of Energy divides the way we use energy into three categories—residential and commercial, industrial, and transportation. As individuals, our energy choices and actions can result in a significant reduction in the amount of energy used in all three sectors of the economy.

Residential/Commercial

Households use about one-fifth of the total energy consumed in the United States each year. The typical U.S. family spends almost $1,300 a year on utility bills. About 60 percent is in the form of electricity; the remainder comes mostly from natural gas and oil.

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

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

Household operations account for 35 percent of the greenhouse gas emissions that contribute to global climate change and 32 percent of the common air polluting emissions. The average home contributes up to two times as much carbon dioxide as the average automobile. Using a few inexpensive energy-efficient measures can reduce the average energy bill by 10 to 50 percent and, at the same time, reduce air pollution.

Heating and Cooling

Heating and cooling systems use more energy than any other systems in American homes. Natural gas and electricity are used to heat most American homes, electricity to cool almost all. Typically, 44 percent of the average family's utility bills goes to keeping homes at a comfortable temperature.

The energy sources that power these heating and cooling systems emit more than 500 million tons of carbon dioxide into the atmosphere each year. They also generate about 24 percent of the nation's sulfur dioxide and 12 percent of the nitrogen oxide emissions, the active components in acid rain.

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

A two-degree adjustment to your thermostat setting 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 for maximum efficiency.

Insulation and Weatherization

Warm air leaking into your home in cooling seasons and out of your home in heating seasons can waste a substantial amount of energy. You can increase home comfort and reduce heating and cooling needs by up to 30 percent by investing a few hundred dollars in proper insulation and weatherization products. Insulation is rated using an R-value that indicates the resistance of the material to heat flow. You need a minimum R-value of 26, or more than three inches of insulation, in ceilings and walls. In very cold climates, a higher R-value is recommended.

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

Doors and Windows

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

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

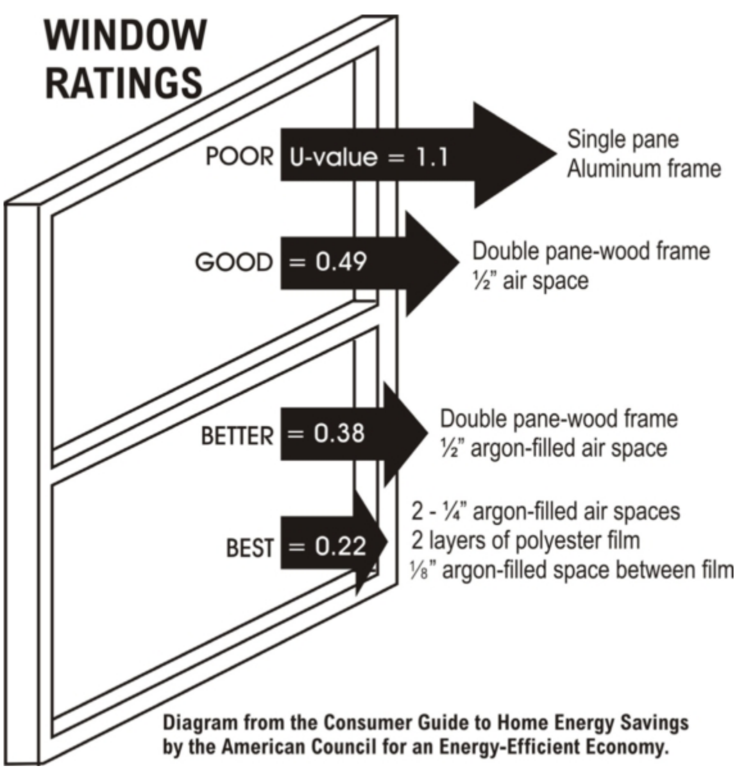
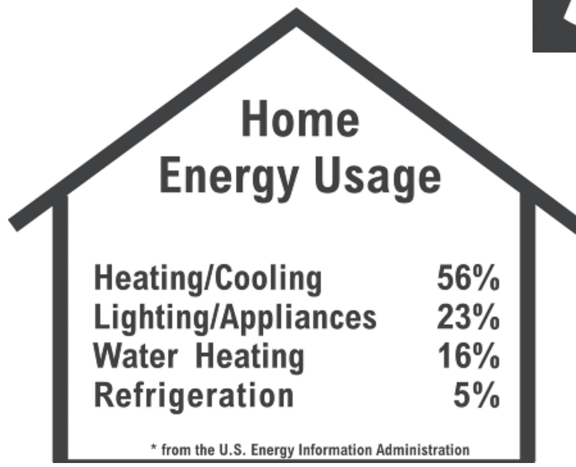


Diagram from the Consumer Guide to Home Energy Savings by the American Council for an Energy-Efficient Economy.



Windows, doors, and skylights are part of the government-backed EnergyStar® program that certifies energy-efficient products. To meet EnergyStar® requirements, windows, doors, and skylights must meet requirements tailored for the country's three broad climate regions. Windows and doors in the northern states must have a U-factor of 0.35 or less; in the central climate, a U-factor of 0.40 or less; and in the southern climate, a U-factor of 0.75 or less. They must also meet other criteria that measure the amount of solar energy that can pass through them.

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

Landscaping

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

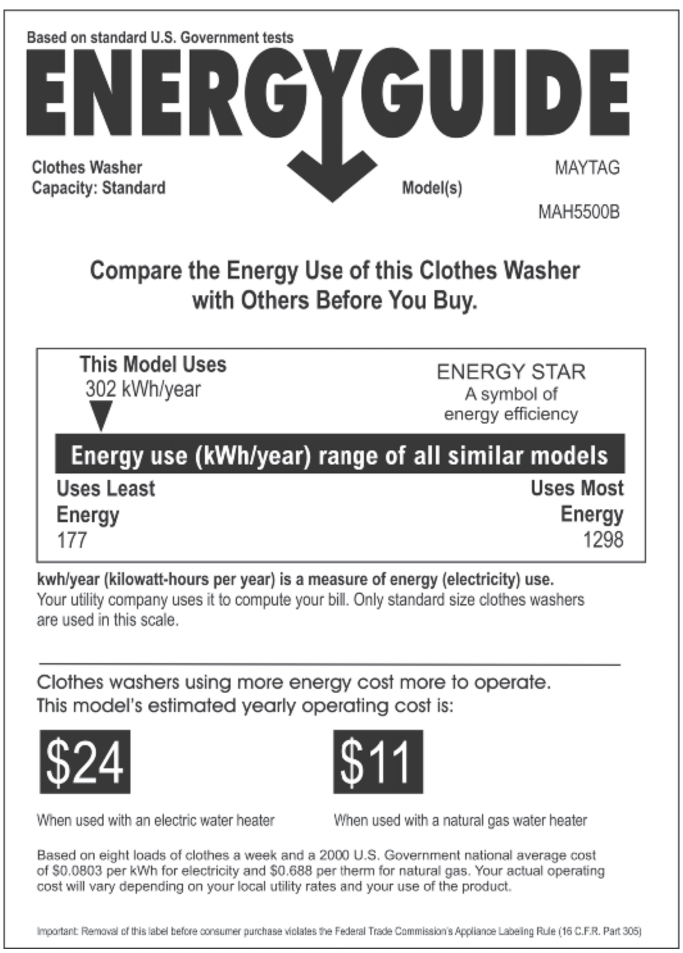
Electricity & Appliances

Appliances account for about 20 percent of a typical household's energy consumption, with refrigerators, clothes washers, and dryers at the top of the consumption list.

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

When you shop for a new appliance, look for the ENERGY STAR® label—your assurance that the product saves energy. ENERGY STAR® appliances have been identified by the Environmental Protection Agency and Department of Energy as the most energy-efficient products in their classes. If the average American were to equip his home only with ENERGY STAR® products, he would cut his energy bills, as well as greenhouse gas emissions, by about 30 percent. A list of these appliances can be found on the ENERGY STAR® website at ***www.energystar.gov***.

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



Appliance Energy Consumption

Appliance	Average Yearly Usage in kWh
Color TV	250
Furnace Fan	500
Waterbed Heater	900
VCR	80
Aquarium	600
Computer	130
Clock	25
Toaster	45
TV Cable Box	80
Ceiling Fan	50
Coffee Maker	50
Iron	50
Humidifier	100
Garbage Disposal	20
Window Fan	20
Hot Tub	2300

Refrigerators, for example, account for about 20 percent of household electricity use. Replacing an older refrigerator with a new energy-efficient model can save significantly on energy bills, as well as emissions. With older models, a large amount of electricity can be saved by setting the refrigerator temperature at 37 degrees, the freezer temperature at three degrees, and making sure that the energy saver switch is operational and in use.

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

Lighting

As a nation, we spend about one-quarter of the electricity we use on lighting, at a cost of more than $37 billion annually. Much of this expense is unnecessary, caused by using inefficient incandescent light bulbs. Only 10 percent of the energy consumed by an incandescent bulb produces light; the remainder is given off as heat.

Technologies developed during the last 10 years with fluorescent lighting can help cut lighting costs 30 to 60 percent while enhancing light quality and reducing environmental impacts.

Increasing your lighting efficiency is one of the quickest and easiest ways to decrease your energy bill. If you replace 25 percent of your light bulbs in high-use areas with fluorescents, you can save about 50 percent on your lighting bill. Compact fluorescent light bulbs (CFLs) provide the equivalent amount of bright, attractive light and no longer flicker or buzz.

Although CFLs cost more initially, they save money in the long run because they use only one-quarter the energy of an equivalent incandescent bulb and last 8-12 times longer. Each CFL you install can save you $30 to $60 over the life of the bulb.

In a typical home, one compact fluorescent bulb can reduce carbon dioxide emissions by 260 pounds per year. If every American household replaced one of its incandescent light bulbs with a CFL, it would save the same amount of energy as a large nuclear power plant produces in a year.

Water Heating

Water heating is the third largest energy expense in your home. It typically accounts for about 14 percent of your utility bill. Heated water is used for showers, baths, laundry, dishwashing and general cleaning. There are four ways to cut your water heating bills—use less hot water, turn down the thermostat on your water heater, insulate your water heater and pipes, and buy a new, more efficient water heater.

One of the easiest and most practical ways to cut the cost of heating water is to simply reduce the amount of hot water used. In most cases, this can be done with little or no initial cost and only minor changes in lifestyle. A family of four, each showering for five minutes a day, uses 700 gallons of water a week. You can cut that amount in half simply by using low-flow, non-aerating showerheads and faucets. Other ways to conserve hot water include taking showers instead of baths, taking shorter showers, fixing leaks in faucets and pipes, and using the lowest temperature wash and rinse settings on clothes washers.

Most water heater thermostats are set much higher than necessary. Lowering the temperature setting on your water heater can save energy. Every ten-degree reduction of the thermostat can create energy savings of 3-5 percent. A new, energy-efficient water heater can save $200 or more annually in water-heating costs. A solar water-heating system can save up to $350 a year.

Transportation

Americans own one third of the world's automobiles. The transportation sector of the U.S. economy accounts for 28 percent of total energy consumption and 66 percent of petroleum consumption each year. America is a country on the move; we love the freedom provided by our vehicles.

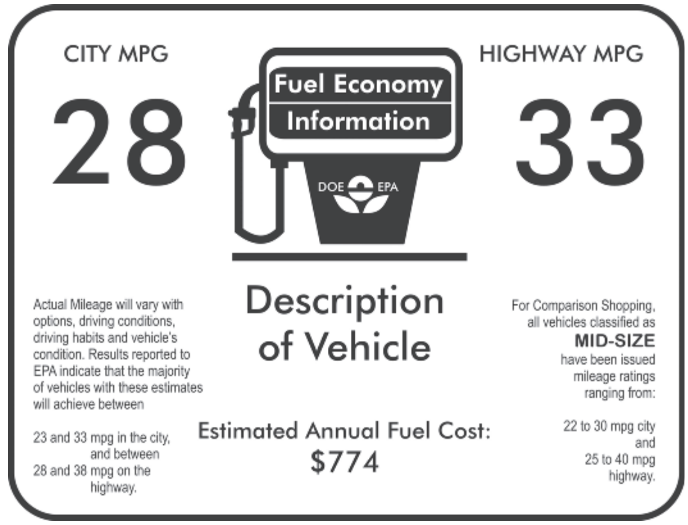
Fuel Economy

These behaviors increase fuel economy:

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

These behaviors lower fuel economy:

- **Quick acceleration.**
- **Traveling at high speeds. Traveling at 65 mph instead of 55 mph lowers fuel economy by 15 percent.**
- **Carrying unnecessary weight in the vehicle.**
- **Revving the engine.**
- **Operating the vehicle with the suspension out of alignment or with the wheels and tires out of balance.**
- **Using electrical accessories that require high amperage when they are not needed.**



The average American uses 500 gallons of gasoline every year, driving each vehicle about 12,000 miles. At $2.50 per gallon, that equals $1,250 in fuel costs alone. The number of miles we drive each year is predicted to increase by 40 percent during the next 20 years if we don't change our behavior by using public transportation, carpooling, walking or bicycling.

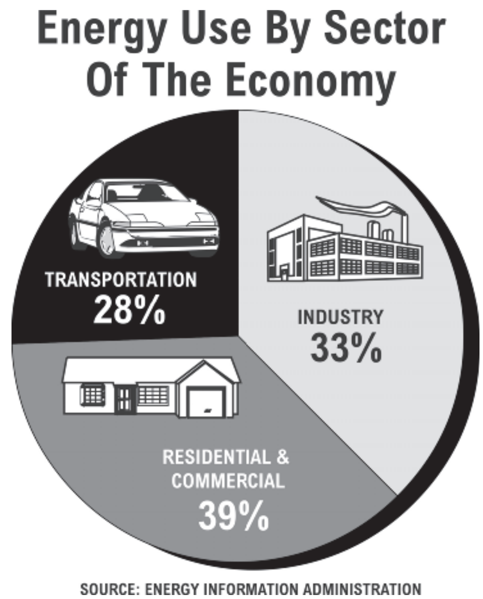
Most people must use a personal vehicle, too; the key is to use it wisely. When you are on the road, you can achieve 10 percent fuel savings by improving your driving habits and keeping your car properly maintained.

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

Unfortunately, the average fuel economy of new passenger vehicles declined from a high of about 26 miles per gallon (mpg) in 1988 to less than 24 mpg in 1999 due to increased vehicle size and horsepower, the rising market share of sport utility vehicles (SUVs) and trucks, and the lack of more stringent regulations.

Today, 50 percent of new passenger vehicles are SUVs and light trucks that do not have to meet high fuel economy standards. The U.S. imports almost two-thirds of the oil we use. Our dependence on foreign oil could be almost completely eliminated if the average fuel economy of vehicles were 45 mpg instead of 25 mpg.

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



INDUSTRY

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

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

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

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

A Consumer Society

Not only is America a consumer society, it is also a 'throw away' society. America produces almost twice as much solid waste as any other developed country; the average citizen produces more than 1,000 pounds of trash each year.

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

The 3 Rs of an energy-wise consumer are easy to put into practice. Reducing waste saves money, energy and natural resources, and it helps protect the environment.

Reduce

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

Reuse

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

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

Recycle

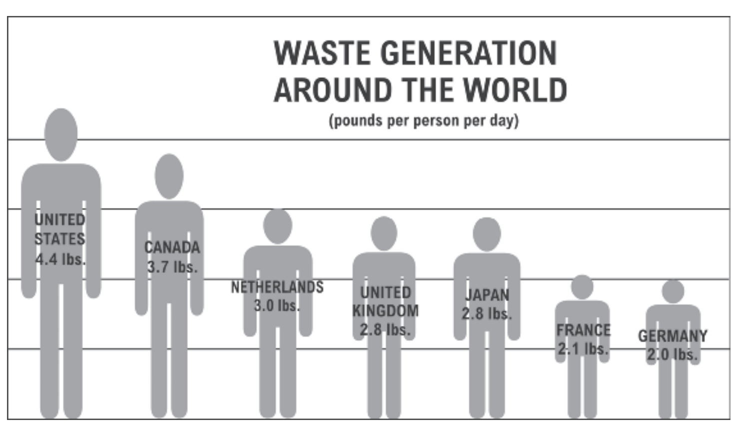
Make it a priority to recycle all materials that you can. Using recycled material as the feedstock for manufacturing almost always consumes less energy than using virgin (raw) materials. Reprocessing used materials reduces energy needs for mining, refining, and many other manufacturing processes.

Recycling a pound of steel saves 5,450 BTUs of energy, enough to light a 60-watt bulb for 26 hours. Recycling a ton of glass saves the equivalent of nine gallons of fuel oil. Recycling aluminum cans saves 95 percent of the energy required to produce aluminum from bauxite. Recycling paper cuts energy usage in half.

ENERGY SUSTAINABILITY

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

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



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