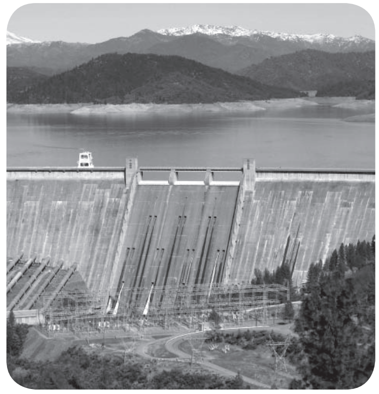
2013-2014

Secondary Energy Infobook

A comprehensive classroom resource containing fact sheets that introduce students to energy and describe energy sources, electricity consumption, efficiency, conservation, transportation, climate change, and emerging technologies. Infobooks can be used as a resource for many energy activities.





Grade Level:

Sec Secondary

Subject Areas:

- Science
- Social Studies
- Math
- Language Arts
- Technology

NEED
National Energy Education Development Project

Teacher Advisory Board

NEED Mission Statement

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

Teacher Advisory Board Statement

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

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Energy Data Used in NEED Materials

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

NEED
National Energy Education Development

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Secondary Energy Infobook

Table of Contents

Correlations to National Science Education Standards: Grades 9-12

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

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

Content Standard A | *SCIENCE AS INQUIRY*

- **Understandings About Scientific Inquiry**
  - Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.

Content Standard B | *PHYSICAL SCIENCE*

- **Structure of Atoms**
  - Matter is made of minute particles called atoms, and atoms are composed of even smaller components. Theses components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
  - 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 different isotopes of the element.
  - The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. 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.
- **Structure and Properties of Matter**
  - Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
  - 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.
- **Chemical Reactions**
  - 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. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.
- **Motions and Forces**
  - The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges and, as with gravitation, inversely proportional to the square of the distance between them.
  - Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.
- **Conservation of Energy and the Increase in Disorder**
  - 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.
  - All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.
  - 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.
- **Interactions of Energy and Matter**
  - Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.
  - In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

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Content Standard C | *LIFE SCIENCE*

- **The Cell**
  - Plant cells contain chloroplasts, the site of photosynthesis. 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 process of photosynthesis provides a vital connection between the sun and the energy needs of living systems.
- **The Interdependence of Organisms**
  - Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.
- **Matter, Energy, and Organization in Living Systems**
  - All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate.
  - The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.
  - The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.
  - 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.

Content Standard D | *EARTH AND SPACE SCIENCE*

- **Energy in the Earth System**
  - 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.
  - The outward transfer of Earth's internal heat drives convection circulation in the mantle that propels the plates comprising Earth's surface across the face of the globe.
  - Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
  - Global climate is determined by energy transfer from the sun at and near the Earth's surface. The energy transfer is influenced by dynamic processes such as cloud cover and the Earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Content Standard E | *SCIENCE AND TECHNOLOGY*

- **Understandings About Science and Technology**
  - Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
  - Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

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

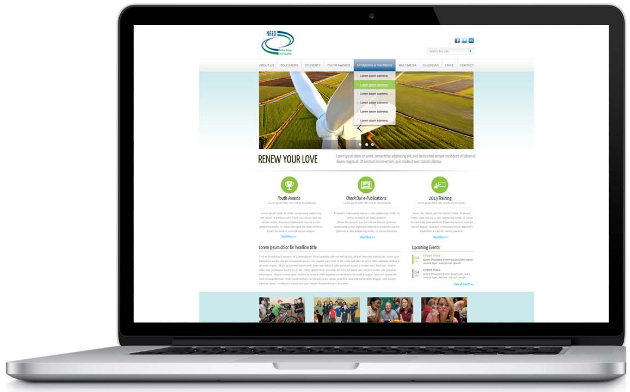
- **Personal and Community Health**
  - Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social, and technological—that can reduce and modify hazards.
- **Natural Resources**
  - Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.
  - The Earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.
  - Humans use 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.
- **Environmental Quality**
  - Materials from human societies affect both physical and chemical cycles of the Earth.
  - 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.
- **Natural and Human-induced Hazards**
  - Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.
  - 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. Students 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. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.
- **Science and Technology in Local, National, and Global Challenges**
  - Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. The latter involves human decisions about the use of knowledge.
  - 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, or global challenges.
  - Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.
  - Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use—which decreases space available to other species—and pollution—which changes the chemical composition of air, soil, and water.

Content Standard G | *HISTORY AND NATURE OF SCIENCE*

- **Science as a Human Endeavor**
  - Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society.
- **Nature of Scientific Knowledge**
  - Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.
- **Historical Perspectives**
  - The historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge.
  - In history, diverse cultures have contributed scientific knowledge and technologic inventions. Modern science began to evolve rapidly in Europe several hundred years ago. During the past two centuries, it has contributed significantly to the industrialization of Western and non-Western cultures. However, other non-European cultures have developed scientific ideas and solved human problems through technology.

NEED Curriculum Resources

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



INTRODUCTORY ACTIVITIES	Energy Games and Icebreakers Energy Polls
STEP ONE: Science of Energy	Energy Flows Secondary Science of Energy Thermodynamics
STEP TWO: Sources of Energy	Energy Enigma Energy Expos Energy Games and Icebreakers Exploring Hydroelectricity Exploring Nuclear Energy Exploring Oil and Gas Exploring Photovoltaics Exploring Wind Energy Fossil Fuels to Products Great Energy Debate H_2 Educate Liquefied Natural Gas: LNG Schools Going Solar Secondary Energy Infobook Activities U.S. Energy Geography Wind for Schools
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STEP SIX: Synthesis and Reinforcement	Carbon Capture, Utilization and Storage Energy Analysis Energy and Our Rivers Energy Around the World Energy Games and Icebreakers Energy Jeopardy Energy Math Challenge Energy on Stage Energy Rock Performances Global Trading Game NEED Songbook
STEP SEVEN: Evaluation	Energy Polls (Blueprint for Success) Question Bank
STEP EIGHT: Student Leadership and Outreach	Youth Awards Program (Blueprint for Success)

Note: Pre/Post Energy Polls are available for your students to take online at http://edu.need.org/.

Introduction to Energy

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. 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

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 later broken down, 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 binds 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, $E = mc^2$.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

Energy at a Glance, 2011

	2010*	2011
World Population	6,868,500,000	6,946,000,000
U.S. Population	309,300,000	311,600,000
World Energy Production	506.226 Q	n/a
U.S. Energy Production	74.806 Q	78.096 Q
• Renewables	8.136 Q	9.236 Q
• Nonrenewables	66.669 Q	68.860 Q
World Energy Consumption	510.551 Q	n/a
U.S. Energy Consumption	97.722 Q	97.301 Q
• Renewables	8.090 Q	9.135 Q
• Nonrenewables	89.543 Q	88.038 Q

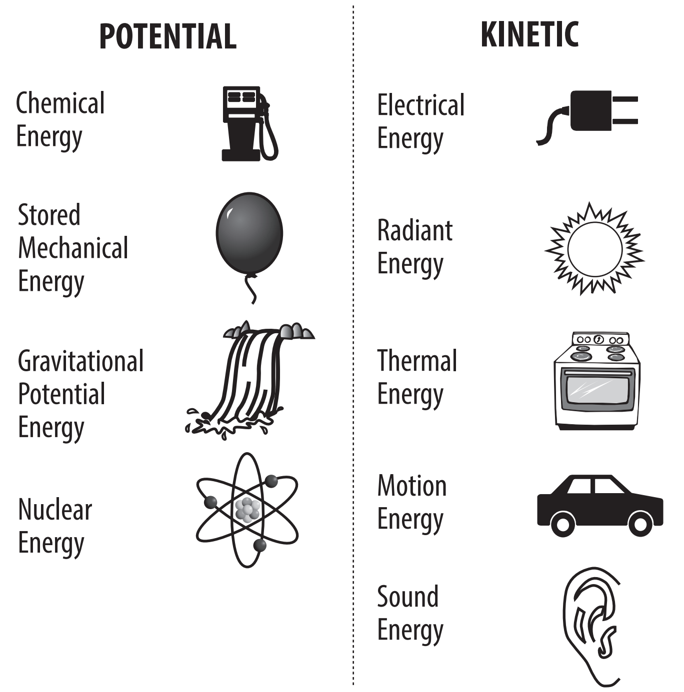
Q = Quad (10^{15} Btu) see Measuring Energy on page 10.

*The latest year for which final data for world and U.S. is available from EIA.

Note: 2011 data for World Energy Production and World Energy Consumption are not available at time of printing.

Note: Sum of renewable and nonrenewable energy consumption do not equal total, due to independent rounding.

Forms of Energy



KINETIC 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. 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 a substance, 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. According to **Newton's Laws of Motion**, objects and substances move when an unbalanced force is applied. 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.

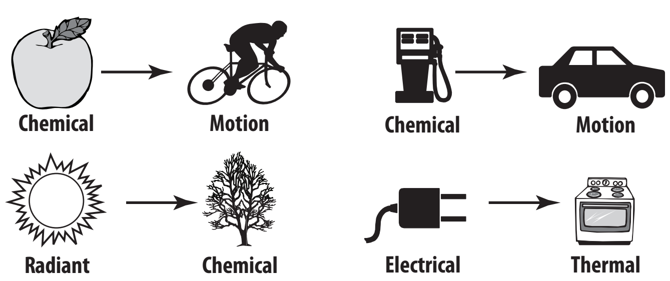
Conservation of Energy

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 completely—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 motion energy that makes the car move. Old-fashioned windmills changed the kinetic energy of the wind into motion 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.

Energy Transformations



Efficiency

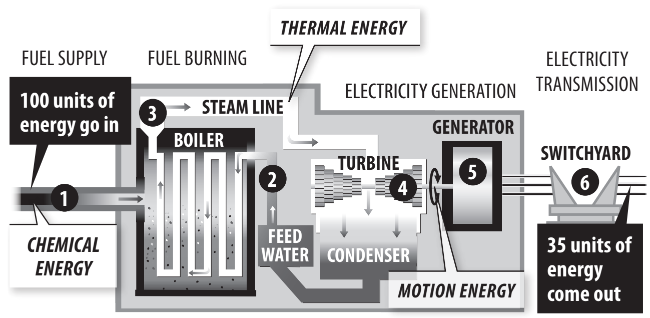
Energy efficiency is the amount of useful energy you can get out of a system. In theory, a 100 percent energy efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of thermal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

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. The rest of the energy is transformed into thermal energy.

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

Most electric power plants that use steam to spin turbines 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.

Efficiency of a Thermal Power Plant



How a Thermal Power Plant Works

1. Fuel is fed into a boiler, where it is burned to release thermal energy.
2. Water is piped into the boiler and heated, turning it into steam.
3. The steam travels at high pressure through a steam line.
4. The high pressure steam turns a turbine, which spins a shaft.
5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

Introduction to Energy

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 and the internet.

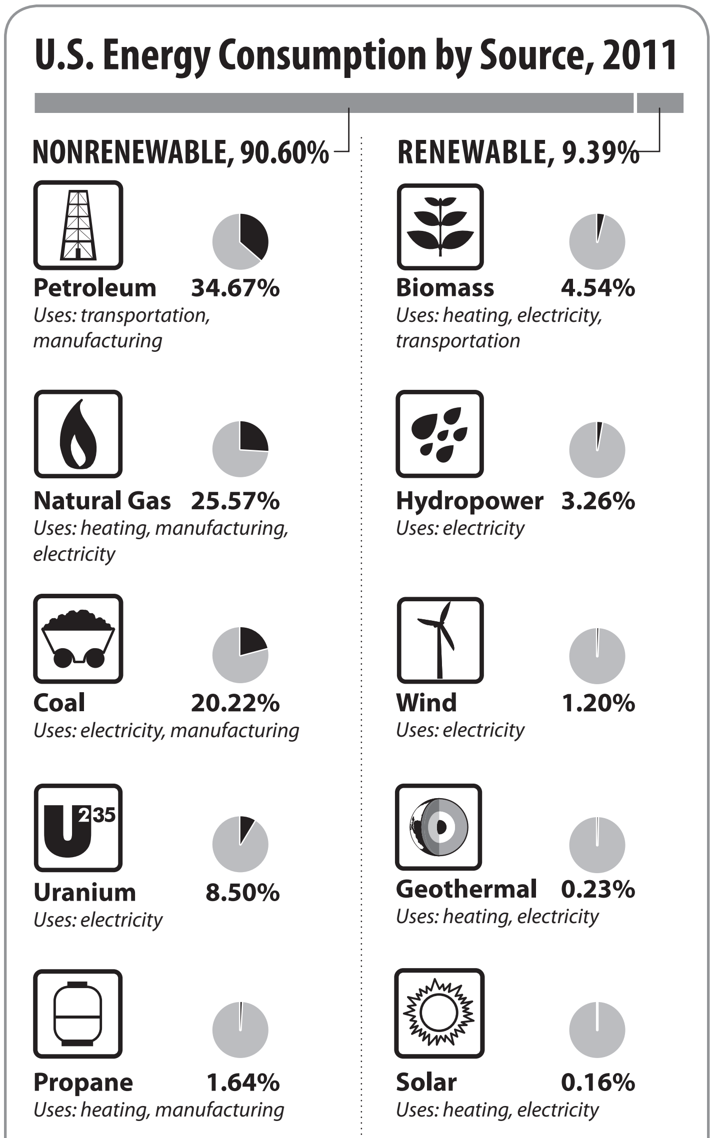
The ten major energy sources we use today are classified into two broad groups—nonrenewable and renewable.

Nonrenewable energy sources include coal, petroleum, natural gas, propane, and uranium. They are used to generate electricity, to heat our homes, to move our cars, and to manufacture products from candy bars to MP3 players.

These energy sources are called nonrenewable because they cannot be replenished in a short period of time. Petroleum, a fossil fuel, for example, was formed hundreds of millions of years ago, before dinosaurs existed. It was formed from the remains of ancient sea life, so it cannot be made 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 replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity.

Is electricity 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.



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

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), that's how. The energy contained in gasoline, wood, or other energy sources can be measured by the amount of heat in Btu 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 of energy.

Every day the average American uses about 855,000 Btu. We use the term quad (Q) to measure very large quantities of energy. A quad is one quadrillion (1,000,000,000,000,000 or 10^{15}) Btu. The United States uses about one quad of energy every 3.75 days. In 2007, the U.S. consumed 101.296 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 using electricity or natural gas.

You listen to music on your MP3 player 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 gasoline per person. This use of energy is called **energy consumption**.

Energy Users

The U.S. Department of Energy uses categories to classify energy users—residential, 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 40.74 percent of the total energy supply in 2011, more energy than either of the other sectors, with a total of 39.640 quads. The residential sector consumed 21.619 quads and the commercial sector consumed 18.021 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 30.592 quads of energy in 2011, which accounted for 31.44 percent of total consumption.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2011, the U.S. consumed 27.079 quads of energy for transportation. About 93 percent of this energy was from petroleum products such as gasoline, diesel, and jet fuel.

Energy Use and Prices

In 1973, Americans faced a major oil price shock due to an **oil embargo**. 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, 1980, and more recently in 2008—people used less energy. When prices started to drop, energy use began to increase.

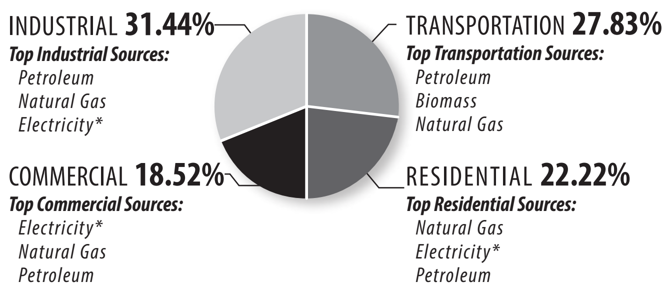
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

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 2011, the United States used 29 percent more energy than it did in 1973. That might sound like a lot, but the population increased by over 47 percent and the nation's **gross domestic product** was 1.7 times that of 1973.

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

U.S. Energy Consumption by Sector, 2011



*Electricity is an energy carrier, not a primary energy source.
Note: Figures are independently rounded, and do not add up to 100%.
Data: Energy Information Administration

Biomass

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 and **carbon dioxide** into oxygen and sugars. These 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 several types of biomass today, including wood, agricultural products, solid waste, landfill gas and biogas, and biofuels. The uses for alcohol fuels, like ethanol, will be discussed in depth in the coming pages.

▪ Wood

Most biomass used today is home grown energy. Wood—logs, chips, bark, and sawdust—accounts for about 45 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corncobs.

Wood and wood waste are used to generate electricity. Much of the electricity is used by the industries making the waste; it is not distributed by utilities, it is cogenerated. Paper mills and saw mills 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 63 percent 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

Burning trash 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 volume of garbage dumped in landfills by up 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.

Biomass at a Glance, 2011

Classification:
- renewable

Major Uses:
- electricity, transportation fuel, heating

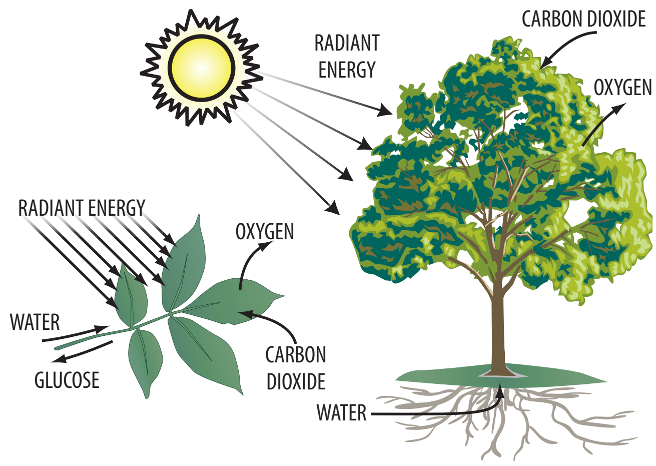
U.S. Energy Consumption:
- 4.411 Q
- 4.54%

U.S. Energy Production:
- 4.511 Q
- 5.78%

(Most electricity from biomass is for cogeneration, and is not included in these numbers.)

Photosynthesis

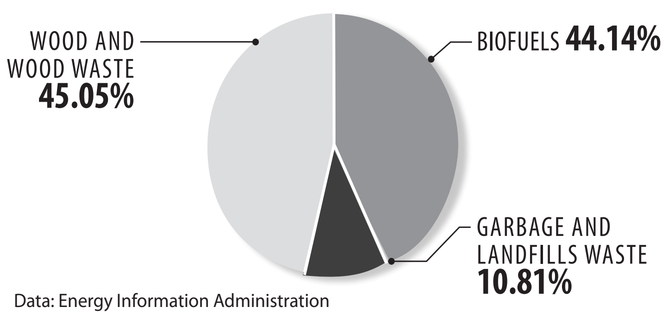
In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



water + carbon dioxide + sunlight ⟶ glucose + oxygen

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

U.S. Sources of Biomass, 2011



Data: Energy Information Administration

▪ Landfill Gas and Biogas

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.

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 now uses the gas at six landfills to generate enough electricity to power about 9,000 Kentucky 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 through combustion than to 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, 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 4.54 percent of the total energy we consume. Biomass has largely been replaced by coal, natural gas, and petroleum.

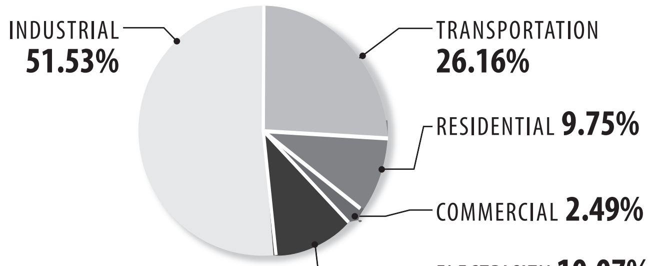
Almost half of the biomass used today comes from burning wood and wood scraps such as saw dust. More than 44 percent is from **biofuels**, principally ethanol, that are used as a gasoline additive. The rest comes from crops, garbage, and landfill gas.

Industry is the biggest user of biomass. Almost 52 percent of biomass is used by industry. Electric utilities use 10 percent of biomass for power generation. Biomass produces 1.38 percent of the electricity we use.

Transportation is the next biggest user of biomass; over 26 percent of biomass is used by the transportation sector to produce biofuels like ethanol and biodiesel, (see pages 14-15).

The residential sector uses almost 10 percent of the biomass supply. About one-tenth of American homes burn wood for heating, but few use wood as the only source of heat. Most of these homes burn wood in fireplaces and wood stoves for additional heat.

U.S. Biomass Consumption by Sector, 2011



Data: Energy Information Administration

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 plant to produce ethanol. One of the newest processes involves using enzymes to break down the cellulose in the plant 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 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.

Biofuels: Ethanol

What Is Ethanol?

Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. The majority of the ethanol produced in the United States comes from corn. New technologies are producing ethanol from cellulose in woody fibers from trees, grasses, and crop residues.

Today nearly all of the gasoline sold in the U.S. contains 10 percent ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency approved the introduction of E15 (15 percent ethanol, 85 percent gasoline) for use in passenger vehicles from model year 2001 and newer. Fuel containing 85 percent ethanol and 15 percent gasoline (E85) qualifies as an alternative fuel. There are almost nine million flexible fuel vehicles (FFV) on the road that can run efficiently on E85. However, only seven percent of these vehicles use E85.

Characteristics of Ethanol

With one of the highest octane ratings of any transportation fuel, ethanol increases the energy efficiency of an engine. When using ethanol blends, vehicles have comparable power, acceleration, payload capacity, and cruise speed to those using gasoline. However, because ethanol contains less energy per gallon than gasoline, vehicle range (the distance a vehicle can travel on a tank of fuel) can be slightly less. Ethanol is also less flammable than gasoline; it is safer to store, transport, and refuel.

Vehicle maintenance for ethanol-powered vehicles is similar to those using gasoline. Oil changes, in fact, are needed less frequently. Due to its detergent properties, ethanol tends to keep fuel lines and injectors cleaner than gasoline. Because ethanol has a tendency to absorb moisture, using ethanol fuel can help reduce the possibility of fuel-line-freeze-up during the winter.

Distribution of Ethanol

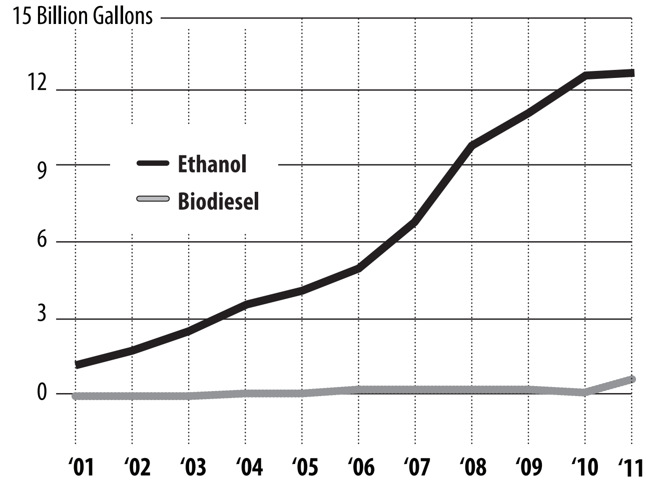
In 2011, ethanol plants in the U.S. produced almost 14 billion gallons of ethanol. There are over 190 plants operating nationwide. These plants are located mostly in the Midwest. Many new plants are in the planning stages. There are currently more than 2,500 E85 fueling stations in 47 states. Ethanol fuels for heavy-duty applications are available only through bulk suppliers.

Economics of Ethanol

The federal government mandated that by 2012, 12 billion gallons of renewable fuels be produced per year. The U.S. is already exceeding this mark, producing over 12 billion gallons of ethanol alone in 2010 and 2011. For comparison, the U.S. consumed 120 billion gallons of gasoline in 2011. Today, it costs more to produce ethanol than gasoline, however, federal and state tax advantages make ethanol competitive in the marketplace.

Since it is the second largest use of corn, ethanol production adds value to crops for farmers. As new technologies for producing ethanol from all parts of plants and trees become cost-effective, the production and use of ethanol will increase dramatically.

U.S. Consumption of Biofuels, 2001-2011



Environmental Impacts

Ethanol is both water soluble and biodegradable. If a fuel spill occurs, the effects are less environmentally severe than with gasoline. Because ethanol contains oxygen, using it as a fuel additive results in lower carbon monoxide emissions. The E10 blend results in 12 to 25 percent less carbon monoxide emissions than conventional gasoline. E10 is widely used in areas that fail to meet the EPA's air quality standards for carbon monoxide. However, some research indicates that under common driving conditions E10 can increase ozone concentrations. Breathing ozone in unhealthy concentrations can result in damage to the lungs and cause coughing and shortness of breath. In contrast to E10, E85 reduces ozone-forming volatile organic compounds and carbon monoxide.

Compared to gasoline, the production and use of corn ethanol could result in little to no carbon dioxide (CO_2) reductions in the near future. This is because an increased demand for ethanol may lead to converting forests and grasslands to crop land for fuel and food. This conversion releases carbon dioxide into the atmosphere. When these factors are taken into account, switching to corn ethanol from gasoline would provide little or no climate change benefit in the next 50 years. By comparison, the production and use of cellulosic ethanol could reduce CO_2 emissions by 18 to 25 percent compared to gasoline, even when the impacts from clearing land for crops are considered.

Land Use and Ethanol

One concern with the use of corn ethanol is that the land required to grow the corn might compete with land needed to grow food. If this is true, the increased demand for corn could cause food prices to rise. Poultry farmers and ranchers are concerned that the cost of feed for their animals would rise. A global spike in food prices in 2008 was partially caused by increased demand for ethanol. Though it was only a small component of the price spike it has caused concern that greatly increasing the use of corn ethanol could affect food prices more significantly.

A study by the Department of Energy and the Department of Agriculture concluded that by 2030 it would be possible to replace 30 percent of our gasoline use with ethanol without increasing demands on crop land. While we can't sustainably meet all of our transportation fuel needs with ethanol, in the future it could significantly decrease our dependence on petroleum.

Biofuels: Biodiesel

What Is Biodiesel?

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Most biodiesel today is made from soybean oil. Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as neat (pure) biodiesel (B100). Biodiesel fuels are compatible with and can be used in unmodified diesel engines with the existing fueling infrastructure. It is one of the fastest growing alternative transportation fuels in the U.S.

Biodiesel contains virtually no sulfur, so it can reduce sulfur levels in the nation's diesel fuel supply, even compared with today's low sulfur fuels. While removing sulfur from petroleum-based diesel results in poor lubrication, biodiesel is a superior lubricant and can reduce the friction of diesel fuel in blends of only one or two percent. This is an important characteristic because the Environmental Protection Agency now requires that sulfur levels in diesel fuel be 97 percent lower than they were prior to 2006.

Characteristics of Biodiesel

Biodiesel exceeds diesel in cetane number (performance rating of diesel fuel), resulting in superior ignition. Biodiesel has a higher flashpoint, making it more versatile where safety is concerned. Horsepower, acceleration, and torque are comparable to diesel. Biodiesel has the highest Btu content of any alternative fuel, though it is slightly less than that of diesel. This might have a small impact on vehicle range and fuel economy.

Distribution of Biodiesel

Biodiesel is available throughout the United States, mainly through commercial fuel distributors. Currently there are relatively few public pumps that offer biodiesel; it is a more practical fuel for fleets with their own fueling facilities. Availability for consumers is steadily expanding as demand grows.

Economics of Biodiesel

Today, B99-B100 costs between $3.77 and $5.67 a gallon, depending on region, the base crop, purchase volume, and delivery costs. Historically, all biodiesel blends cost more than diesel. In 2005, the Biodiesel Excise Tax Credit went into effect. Blenders of biodiesel receive tax credits for the biodiesel they blend with diesel, allowing them to make biodiesel fuel available at a lower cost. This incentive expires at the end of 2013.

Because it is stored in existing infrastructure and can fuel vehicles without modification, biodiesel has emerged as a popular alternative fuel for fleets regulated by the Energy Policy Act (EPACT). The cost difference will likely decrease in the future due to production improvements in the biodiesel industry. In addition, many states are considering legislation that will encourage greater use of biodiesel fuels to improve air quality.

Another economic consideration is the agriculture industry. The expanded use of biodiesel in the nation's fleets will require the agriculture industry to substantially increase production of soybeans and other oilseed crops that can be used as **feedstocks** for biodiesel. Farmers will have new crops and markets to support economic stability.

BIODIESEL-POWERED GARBAGE TRUCK

Image courtesy of NREL

Any vehicle that operates on diesel fuel can switch to B100 or a biodiesel blend without changes to its engine. Many state fleets and school districts are switching from diesel to biodiesel blends to reduce emissions and improve air quality.

Environmental Impacts

Biodiesel is renewable, nontoxic, and biodegradable. Compared to diesel, biodiesel (B100) reduces sulfur oxide emissions by 100 percent, particulates by 48 percent, carbon monoxide by 47 percent, unburned hydrocarbons by 67 percent, and hydrocarbons by 68 percent. Emissions of nitrogen oxides, however, increase slightly (10 percent). Biodiesel blends generally reduce emissions in proportion to the percentage of biodiesel in the blend.

When biodiesel is burned it releases carbon dioxide (CO_2), which is a major contributor to climate change. However, biodiesel is made from crops that absorb carbon dioxide and give off oxygen. This cycle would maintain the balance of CO_2 in the atmosphere, but because of the CO_2 emissions from farm equipment and production of fertilizer and pesticides, biodiesel adds more CO_2 to the atmosphere than it removes.

Compared to diesel, the production and use of soybean biodiesel could result in little to no CO_2 reductions in the near future. This is because an increased demand for biodiesel may lead to converting forests and grasslands to crop land for fuel and food. This conversion releases carbon dioxide into the atmosphere. When these factors are taken into account, switching to soy biodiesel from petroleum diesel would provide little or no climate change benefit in the next 50 years. By comparison, the production of and use of biodiesel from recycled waste oils could reduce CO_2 emissions by over 80 percent compared to petroleum diesel.

Land Use and Biodiesel

One concern with the use of biodiesel is that the land required to grow the increased amount of soybeans might compete with land needed to grow food. If this is true, the increased demand for soybeans could cause food prices to rise. A study by the Department of Energy and the Department of Agriculture concluded that by 2030 it would be possible to replace 30 percent of our gasoline and diesel use with biofuels without increasing demands on cropland. This would be accomplished by using mostly agricultural and forestry waste and perennial crops grown on marginal lands.

Biodiesel is a domestic, renewable fuel that can improve air quality. The expanded use of biodiesel by fleets, as well as individual consumers, has the potential to reduce the importation of foreign oil and promote national security.

Coal

Coal at a Glance, 2011

Classification:
- nonrenewable

Major Uses:
- electricity, industry

U.S. Energy Consumption:
- 19.643 Q
- 20.22%

U.S. Energy Production:
- 22.181 Q
- 28.40%

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.

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

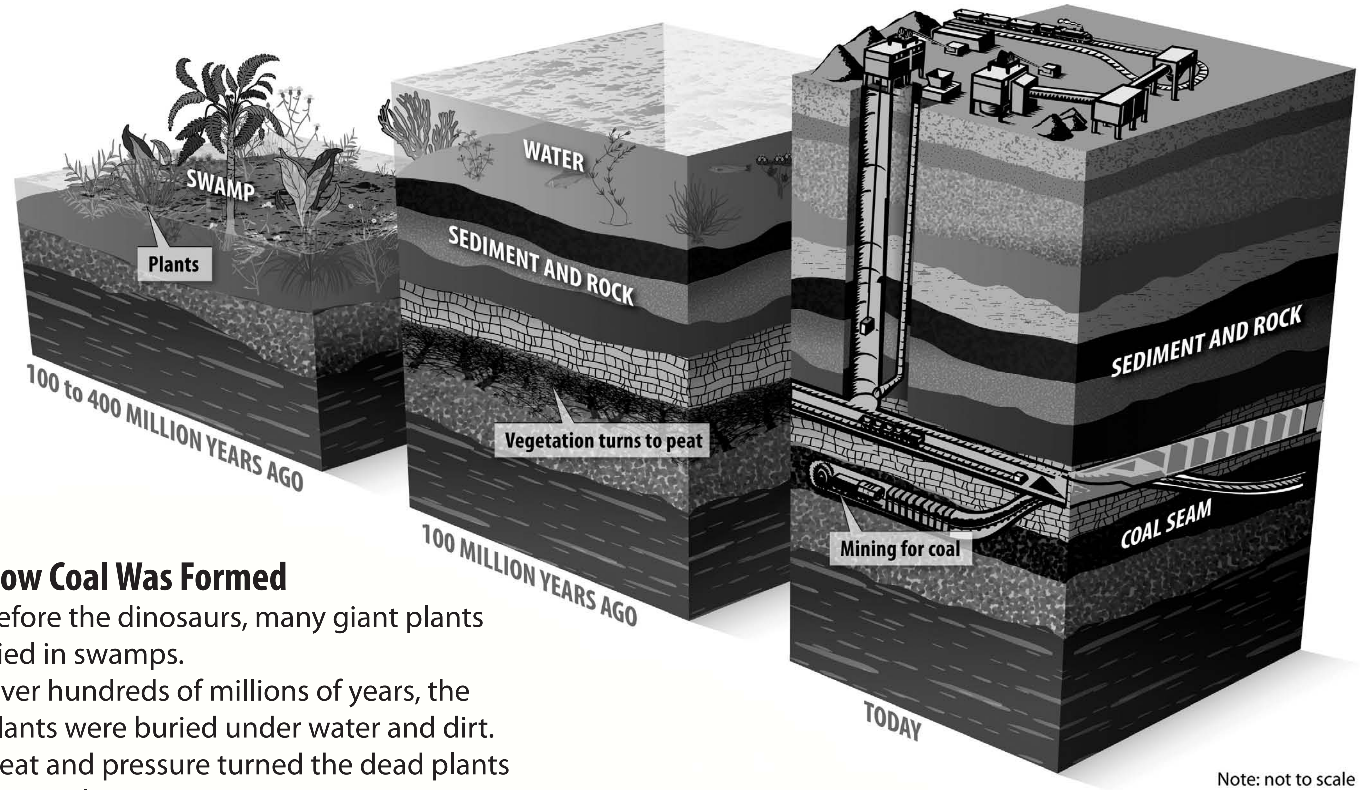
Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

History of Coal

Native Americans 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.



How Coal Was Formed

Before the dinosaurs, many giant plants died in swamps.
Over hundreds of millions of years, the plants were buried under water and dirt.
Heat and pressure turned the dead plants into coal.

Coal production reached its low point in 1961. Since then, coal production has increased by more than 160 percent, reaching a record high in 2008. Today, coal supplies 20 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.

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, more than 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, surface mining productivity has almost doubled 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

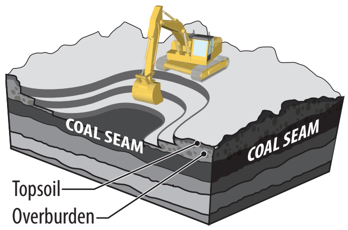
After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other impurities, increasing the heating value of the coal.

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.

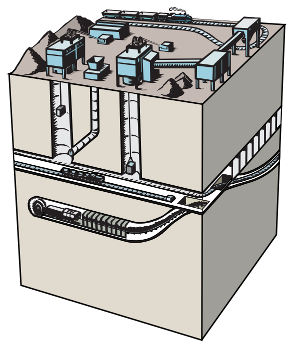
Underground pipelines can easily move petroleum and natural gas to market. But that's not so for coal. Huge trains transport most coal (over 70 percent) for at least part of its journey to market.

It is cheaper to transport coal on river barges, but this option is not 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.

Surface Mining



Deep Mining



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 to 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 to 35 percent carbon. About seven percent of the coal mined in 2011 was lignite.

Subbituminous coal typically contains less heating value than bituminous coal (8,300 to 13,000 Btu per pound) and more moisture. It contains 35 to 45 percent carbon. Forty-four percent of the coal mined in 2011 in the U.S. was subbituminous.

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 to 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 to 86 percent carbon. Forty-eight percent of the coal mined in 2011 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 to 97 percent carbon. Less than one percent of coal mined in 2011 was anthracite.

Coal

Coal Reserves

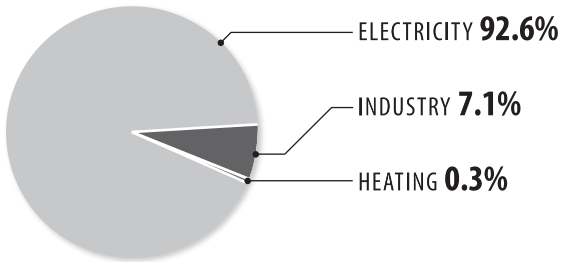
When scientists estimate how much coal, petroleum, natural gas, or other energy sources there are in the United States, they use the term **reserves**. Reserves are deposits that can be harvested using today's methods and technology.

Experts estimate that the United States has over 258 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 170 to 240 years, depending on consumption rates. This vast amount of coal makes the United States the world leader in known coal reserves.

Where is all this coal located? Coal reserves can be found in 31 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.

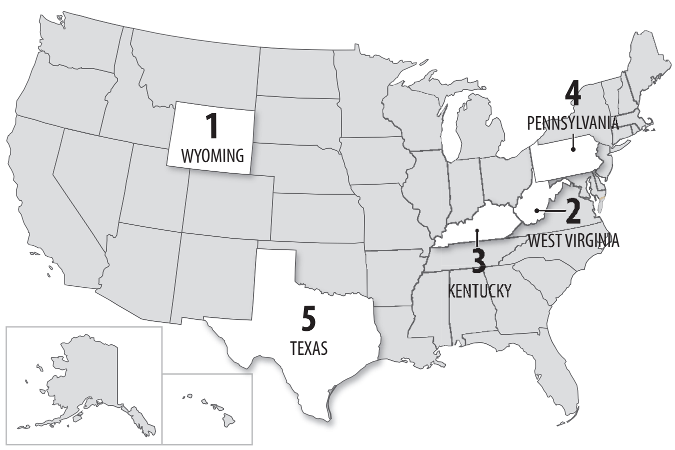
The federal government is by far the largest owner of the nation's coalbeds. In the West, the federal government owns 60 percent of the coal and indirectly controls another 20 percent. Coal companies must lease the land from the federal government in order to mine this coal.

U.S. Coal Consumption by Sector, 2011



Data: Energy Information Administration

Top Coal Producing States, 2011



Data: Energy Information Administration

Coal Production

Coal production is the amount of coal mined and taken to market. Where does mining take place in the United States? Today, coal is mined in 25 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.

In the 1950s and 1960s, the East mined approximately 95 percent of the coal produced in the U.S. As of the early 1970s, the amount of coal produced by western mines steadily increased. In 2011, the West provided 58 percent of total production, and states east of the Mississippi River provided 42 percent.

Total U.S. production of coal was 1.09 billion tons in 2011, an 83 percent increase since 1973. The leading coal producing states are Wyoming, West Virginia, Kentucky, Pennsylvania, and Texas. These five states produce 72 percent of the coal in the U.S.

Some coal produced in the United States is exported to other countries. In 2011, foreign countries bought 9.8 percent of all the coal produced in the U.S. The biggest foreign markets for U.S. coal are the Netherlands, Brazil, the United Kingdom, Japan, and Canada.

How Coal Is Used

The main use of coal in the United States is to generate electricity. In 2011, 92.57 percent of all the coal in the United States was used for electricity production. Coal generates about 42 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.

Coal is no longer a major energy source for heating American homes or other buildings. Less than one-third 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

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. Low sulfur coal produces fewer pollutants.

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 devices called **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. Utilities that burn coal 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 two-thirds and have increased efficiency significantly.

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

Carbon dioxide is released when coal is burned, just as it is released from the human body during respiration. CO_2 combines with other gases, such as those emitted from automobiles, to form a shield that allows the sun's light through the atmosphere, but doesn't let the heat that is produced out of the atmosphere. This phenomenon is called the **greenhouse effect**. Without this greenhouse effect, the Earth would be too cold to support life.

There is concern that human activities are causing major changes in greenhouse gas levels in the Earth's atmosphere that are responsible for a change in the Earth's climate.

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

Cleaner Coal Technology

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 began 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.

Carbon Capture, Utilization and Storage: Research and demonstration projects are underway around the U.S. and the world to capture carbon dioxide from power plants and use it or store it deep underground in geologic formations. Researchers are investigating the best ways to capture carbon dioxide, either before or after coal is combusted. The carbon dioxide will then be compressed converting the gas to a liquid. It can then be utilized by industry or transported via pipeline to appropriate storage sites. Three different types of locations have been identified as being able to hold carbon dioxide: 1) deep saline formations, 2) oil and gas reservoirs that are near depletion or have been depleted, and 3) unmineable coal seams.

Geothermal

Geothermal at a Glance, 2011

Classification:
- renewable

Major Uses:
- heating, electricity

U.S. Energy Consumption:
- 0.226 Q
- 0.23%

U.S. Energy Production:
- 0.226 Q
- 0.29%

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 to 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).

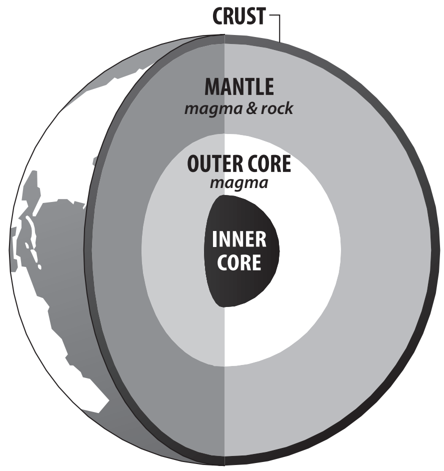
Surrounding the Earth's core is the **mantle**, thought to be partly rock and partly **magma**. The mantle is about 1,800 miles thick. The outermost layer of the Earth, the insulating **crust**, is not one continuous sheet of rock, like the shell of an egg, but is broken into pieces called plates.

These slabs of continents and ocean floor drift apart and push against each other at the rate of about two centimeters 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.

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 radioactive decay of particles that naturally occur in all rocks.

The Earth's Interior



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 250ºF to 700ºF—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:

▪ Flash Steam Plants

Most geothermal power plants are **flash 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 1911. 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 50 years, still produces enough electricity to supply a city the size of San Francisco.

▪ Binary Cycle Power Plants

Binary cycle plants transfer the thermal energy 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. The Puna Geothermal Venture Facility produces 38 megawatts of power, or 20 percent of the electricity needed by 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 humankind.

▪ Hot Spring Bathing and 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 and 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 raises market species such as Arctic char and Atlantic salmon 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, OR, hot water is piped under sidewalks and bridges to keep them from freezing in winter.

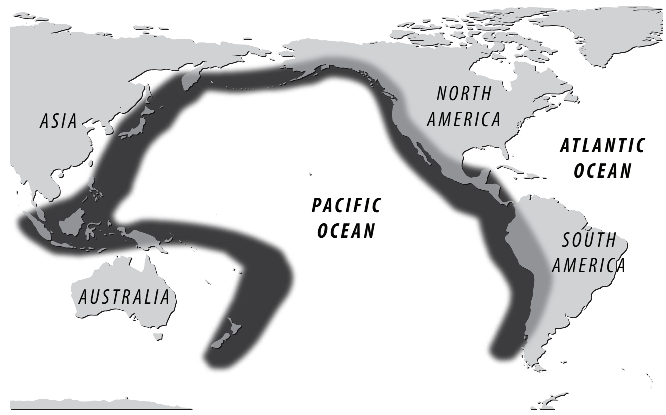
▪ Heating

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 150,000 homes in France use geothermal heat today.

Geothermal **district energy 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, ID, 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 Iceland, almost 90 percent of residents use geothermal energy for heat and hot water. In Reykjavik, Iceland, a district heating system provides heat for 95 percent of the buildings.

Ring of Fire



Geothermal

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 to 70 degrees Fahrenheit, 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.

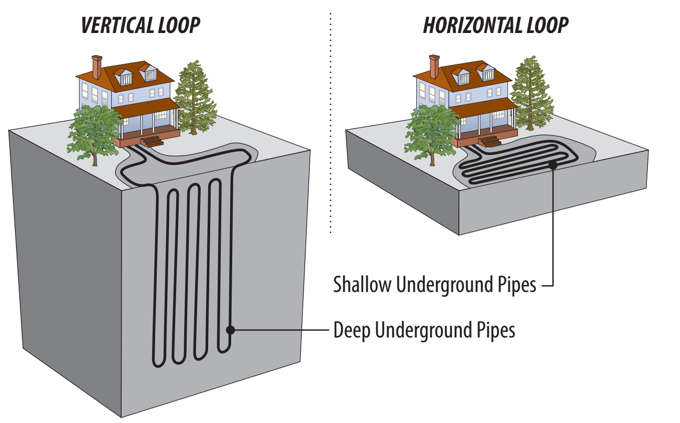
One advantage of a geothermal exchange system is that it doesn't have to manufacture heat. The heat is free, renewable, and readily available in the ground. The only energy this system needs is the electricity to pump the liquid through the pipes and deliver the conditioned air to the building. The pump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

Residential Geoexchange Units



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 30 to 70 percent, and cooling costs by 20 to 50 percent. If the cost of the installation is spread out over several years, users see savings from the day they begin using the system. In addition, there is a Federal Tax Credit incentive of up to 30 percent of the cost for homeowners that install qualified ENERGY STAR® **geothermal** heat pumps by the end of 2016.

Geothermal systems are low maintenance and should last twice as long as conventional systems. The pumps should last 25 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 a million homes and buildings in the United States use geothermal heat exchange systems. They are an 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.

Geothermal power plants operate in California, Nevada, Utah, Hawaii, Idaho, Alaska, Oregon, and Wyoming. Today, the total installed capacity of geothermal power plants in the United States is around 3,000 megawatts (MW). There are currently 123 projects in development in 15 states that could add about 1,000 MW to geothermal's capacity.

In 2011, geothermal energy produced about 16.70 billion kilowatt-hours (kWh) of electricity, or 0.41 percent of the electricity used in this country. This is enough to serve the electricity needs of about one and a half 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. Operating and maintenance costs range from one to three cents per kilowatt-hour (kWh) at a geothermal power plant, while the electric power generated sells for about five cents per kWh. In comparison, new coal-fired and natural gas plants produce electricity at about 3.5 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 **base load power**. Base load power is power that electric utility companies must deliver all day long. Base load geothermal plants can sell electricity any hour, day or night.

Geothermal Energy and the Environment

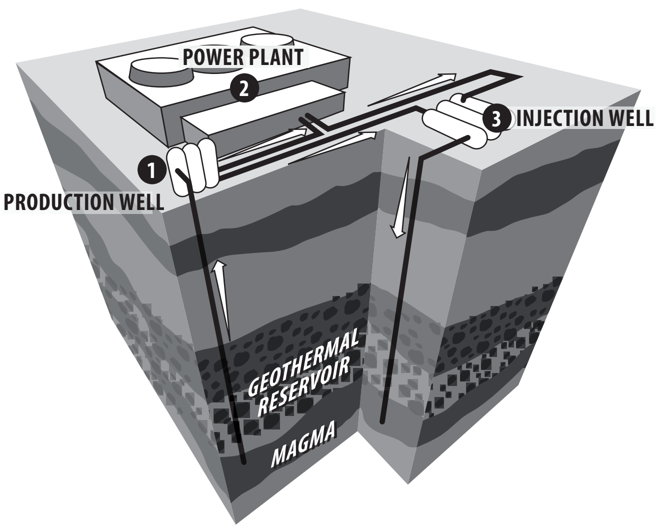
Geothermal energy is a renewable energy source that does little damage to the environment. Geothermal steam and hot water do contain naturally occurring traces of hydrogen sulfide (a gas that smells like rotten eggs) and other gases and chemicals that can be harmful in high concentrations.

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 are clean. Energy can be extracted without burning a fossil fuel such as coal, gas, or oil. Geothermal fields produce only about one-sixth of the carbon dioxide that a relatively clean natural-gas-fueled power plant produces, and very little, if any, of the nitrous oxide or sulfur-bearing gases. Binary cycle plants, which are closed cycle operations, release essentially no emissions.

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 Power Plant



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

Geothermal Resources

The Earth has no shortage of geothermal activity, but not all geothermal resources are easy or economical to use. Hydrothermal resources—reservoirs of steam or hot water—are available primarily in the western states, Alaska, and Hawaii. However, geothermal energy can be tapped almost anywhere with geoexchange systems and direct-use applications. Other enormous and world-wide geothermal resources—hot dry rock and magma, for example—are awaiting further technology development.

In 2010, there were geothermal power plants in 24 countries, generating 63.9 billion kilowatt-hours of electricity. Direct uses of geothermal reservoirs amount to over 50,000 megawatts of thermal energy in 78 countries.

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.

Geopressurized 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.

Hydropower

Hydropower at a Glance, 2011

Classification:
- renewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 3.171 Q
- 3.26%

U.S. Energy Production:
- 3.171 Q
- 4.06%

What Is Hydropower?

Hydropower (from the Greek word *hydor,* meaning water) is energy that comes from the force of moving water. The fall and movement 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 moving water, transporting 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 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 on the Fox River in Appleton, WI in 1882. 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.

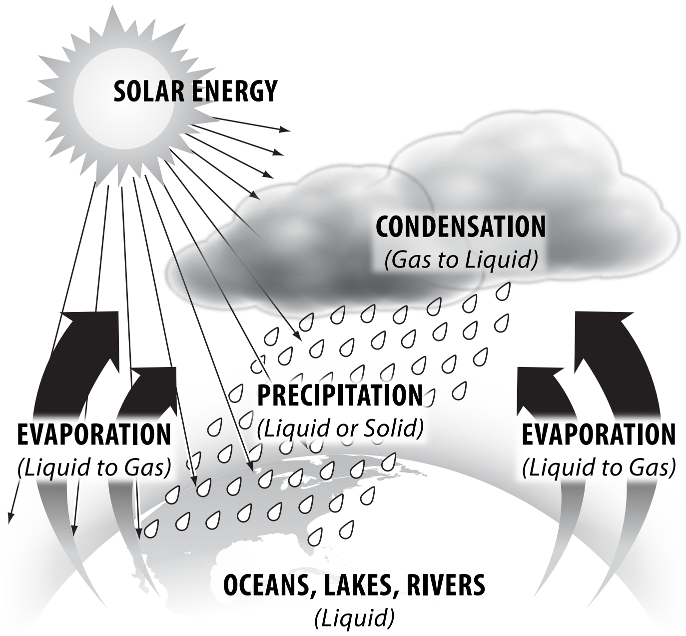
By the late 1940s, the best sites for big dams had been developed. Inexpensive fossil fuel plants also entered the picture. At that time, plants burning coal or oil could make electricity more cheaply than hydro plants. Soon they began to underprice the smaller hydroelectric plants. It wasn't until the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

Hydro Dams

It is easier to build a hydropower plant where there is a natural waterfall. That's why both U.S. and Canada have hydropower plants 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 84,000 dams in the United States, but less than three percent (2,200) were built specifically for electricity generation. Most dams were built for recreation, flood control, fire protection, and irrigation.

The Water Cycle



A dam serves two purposes at a hydropower plant. First, a dam increases the **head**, or height, of the water. 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 motion 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, natural gas, nuclear) power plants do, except they do not produce heat to spin the turbines.

How a Hydropower Plant Works

A typical hydropower plant is a system with three parts:

- a power plant where the electricity is produced;
- a dam that can be opened or closed to control water flow; and
- a reservoir (artificial lake) where water can be stored.

To generate electricity, a dam opens its gates to allow water from the reservoir above to flow down through large tubes called **penstocks**. At the bottom of the penstocks, the fast-moving water spins the blades of turbines. The turbines are connected to generators 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 generating power during the summer, or to save water from wet years for generating electricity during dry years.

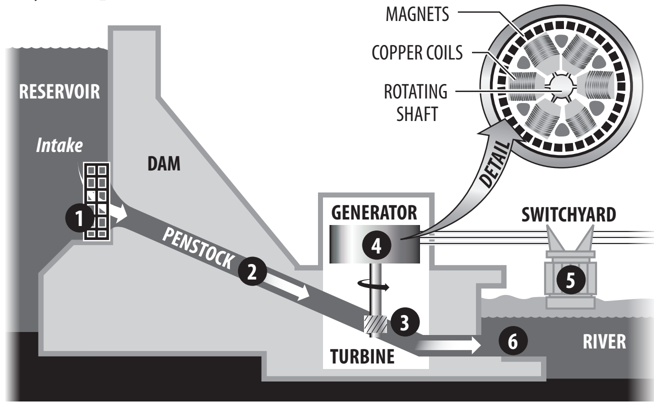
Pumped Storage Systems

Some hydropower plants use pumped storage systems. A **pumped storage system** operates much like a public fountain does; the same water is used again and again.

At a pumped storage hydropower 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 peak 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 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 Plant



1. Water in a reservoir behind a hydropower dam flows through an intake screen, which filters out large debris, but allows fish to pass through.

2. The water travels through a large pipe, called a penstock.

3. The force of the water spins a turbine at a low speed, allowing fish to pass through unharmed.

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

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

6. Water flows out of the penstock into the downstream river.

Hydropower 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 (the most recent high was 10.21 percent in 1997, and the most recent low was 5.81 percent in 2001). In Oregon, Washington, and Idaho, hydropower accounts for more than half (55 to 76 percent) of each state's electricity generation.

Today, there is about 78,000 megawatts of conventional hydro generating capacity in the United States, and about 98,000 megawatts when including pumped storage. That's equivalent to the generating capacity of 80 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 U.S. also gets some hydropower generated electricity from Canada. Some New England utilities buy this imported electricity.

What does the future look like for hydropower? The most economical sites for hydropower dams in the U.S. have already been developed, so the development of big hydro plants is unlikely.

Existing plants could be modernized with turbine and generator upgrades, operational improvements, and adding generating capacity. Plus, many flood-control dams not equipped for electricity production could be retrofitted with generating equipment. The National Hydropower Association estimates 60,000 megawatts of additional generating capacity could be developed in the United States by 2025.

Hydropower

Hydropower for Base Load 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. **Base load power** is the electricity that utilities have to generate all the time. For that reason, base load power should be cheap and reliable. Hydropower meets both of 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.

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 are about 90 percent efficient at converting the kinetic energy of the moving water into electricity.

Economics of Hydropower

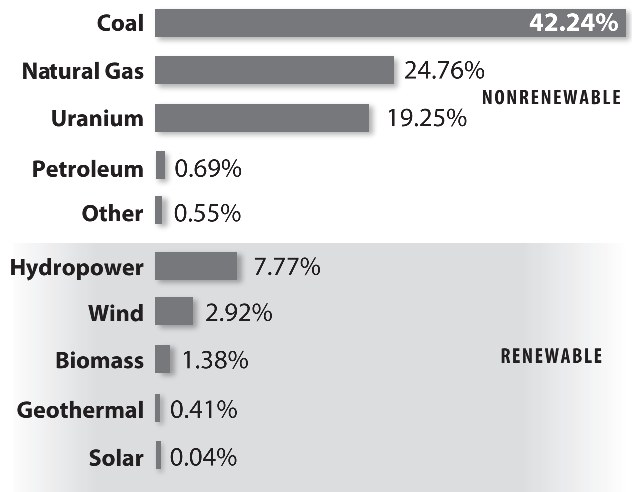
Hydropower is the cheapest way to generate electricity today. No other energy source, renewable or nonrenewable, can match it. Today, it costs less than one cent per kilowatt-hour (kWh) to produce electricity at a typical hydro plant. In comparison, it costs coal plants about four cents per kWh and nuclear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

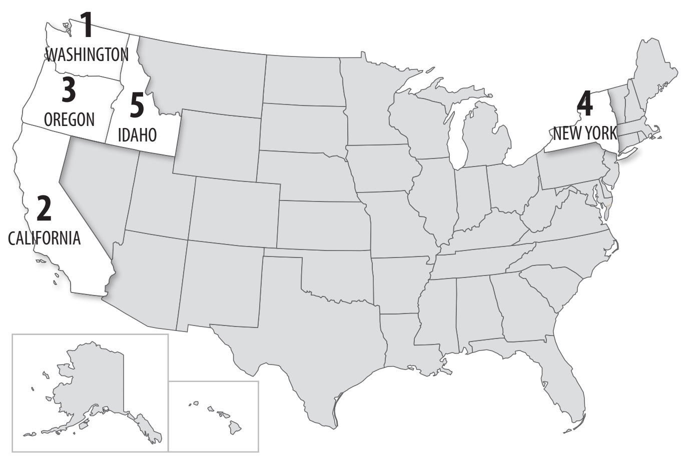
One requirement may increase hydropower's costs in the future. The procedure for licensing and relicensing dams has become a lengthy and expensive process. Many environmental impact studies must be undertaken and multiple state and federal agencies must be consulted. It takes up to seven years to get a license to build a hydroelectric dam or a relicense to continue operations.

U.S. Electricity Net Generation, 2011



* Total does not equal 100%, due to independent rounding.
** Other: non-biogenic waste, fossil fuel gases.
Data: Energy Information Administration

Top Hydropower Producing States, 2011



Data: Energy Information Administration

Hydropower and the Environment

Hydropower dams can cause several environmental problems, even though they burn no fuel. Damming rivers may permanently alter river systems and wildlife habitats. 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.

Hydrokinetic Technologies

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 1966.

Tidal plants have very high development costs. 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 have very low operating costs. The plants should run for a hundred years with regularly scheduled maintenance.

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.

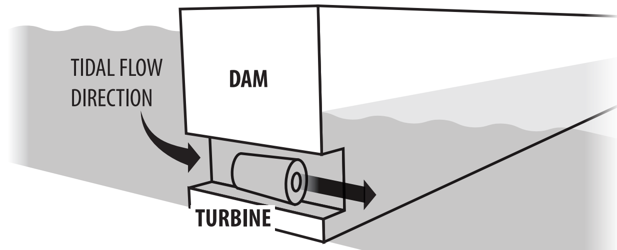
The United States has no tidal plants and only a few sites where tidal energy could be produced economically. France, England, Canada, and Russia have much more potential. The keys are to lower construction costs, increase output, and protect the environment.

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 Australia and Southern Africa 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.

Tidal Barrage



Tidal water is captured at high tide behind a dam. When the tide turns, the water is released to the sea, passing through a set of turbines.

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

Other ways to produce electricity using wave energy are currently under development. Some devices are anchored to the ocean floor while others float on top of the waves.

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 much 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.

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, potable water, and new surface water is added to the system.

An OTEC system is only about 3 percent efficient. Pumping the water is a giant engineering challenge. In addition, the electricity must be transported to land. OTEC systems work best with a temperature difference of at least 20°C to operate. This limits its 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 OTEC plants in design and development phases. However, none of these plants are operating as commercialized power production facilities. It may take several 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

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 natural gas was formed from the remains of tiny sea animals and plants that died 300 to 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

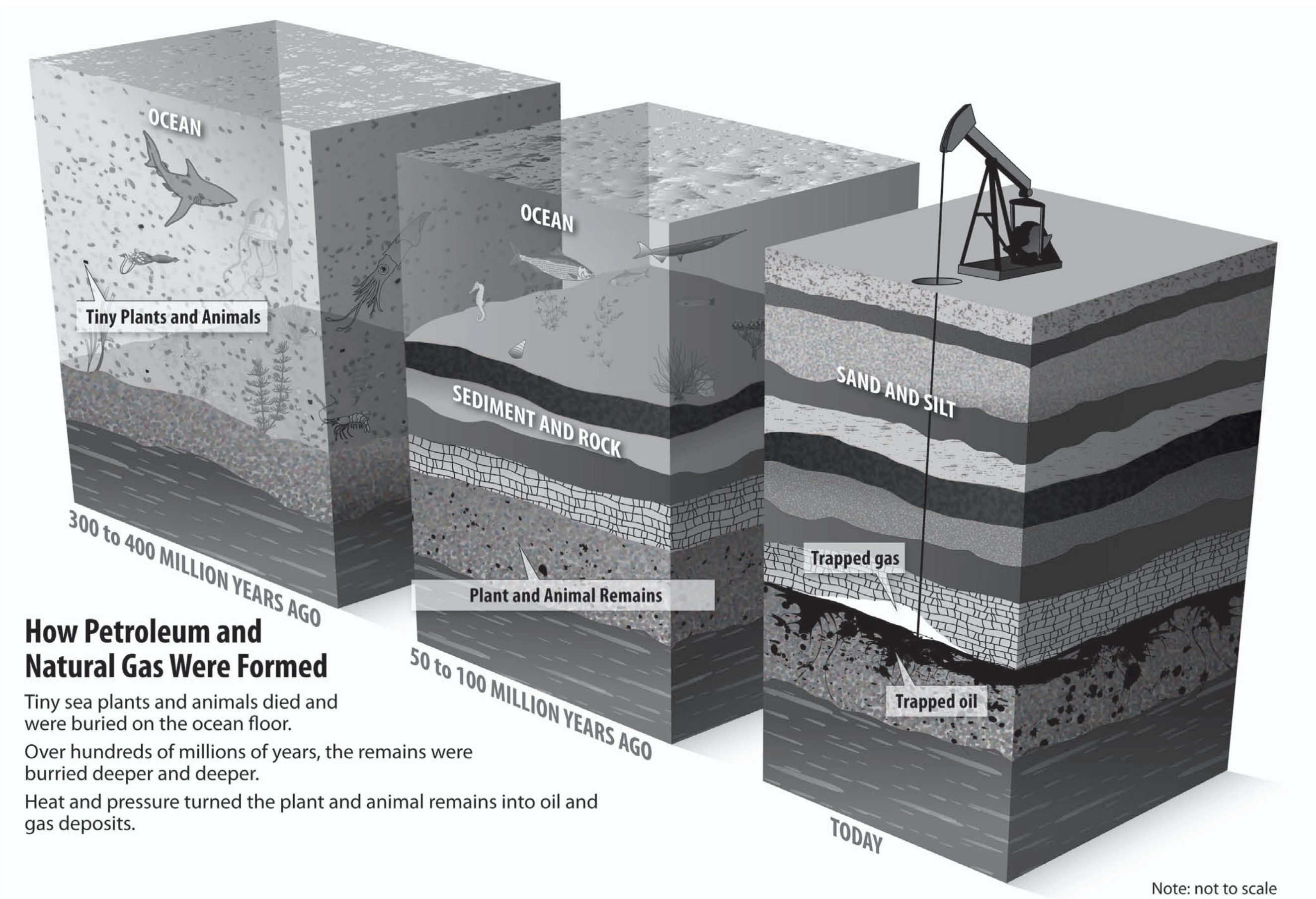
The ancient peoples of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeping from cracks in the ground was ignited by lightning. They sometimes built temples around these eternal flames so they could worship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

Natural gas was first used in America in 1816 to illuminate the streets of Baltimore with gas lamps. Lamplighters walked the streets at dusk to light the lamps.

Soon after, in 1821, William Hart dug the first successful American natural gas well in Fredonia, NY. 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 25.57 percent of the energy we use.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor.

Over hundreds of millions of years, the remains were burried deeper and deeper.

Heat and pressure turned the plant and animal remains into oil and gas deposits.

Note: not to scale

Natural Gas at a Glance, 2011

Classification:
- nonrenewable

Major Uses:
- heating, industry, electricity

U.S. Energy Consumption:
- 24.843 Q
- 25.57%

U.S. Energy Production:
- 23.506 Q
- 30.10%

Producing Natural Gas

Natural gas can be difficult to find since it is usually 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 Earth's 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 8,600 feet deep and can cost hundreds of dollars per foot to drill, so it's important to choose sites carefully.

In 2010, 61 percent of the **exploratory wells** produced gas. The others came up dry. The odds are better for **developmental wells**—wells drilled on known gas fields. That year, 91 percent of the developmental wells yielded 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 seams of coal. Until recently, coalbed methane was just considered a safety hazard to miners, but now it is a valuable source of natural gas. Nine percent of the total gas produced in 2010 came from coalbeds.

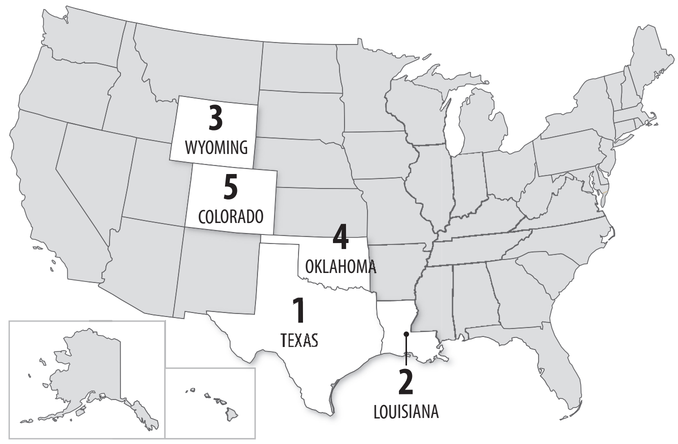
Another source of natural gas is the methane produced in landfills. Landfill gas is considered a renewable source of methane since it comes from decaying garbage. This **biogas** recovered from landfills is usually burned on the landfill site to generate electricity for the facility itself.

Today, natural gas is produced in 32 states, but the top five states—Texas, Louisiana, Wyoming, Oklahoma, and Colorado—produce 71percent of the total. Altogether, the U.S. produces about one-fifth of the world's natural gas each year.

Transporting and Storing Natural Gas

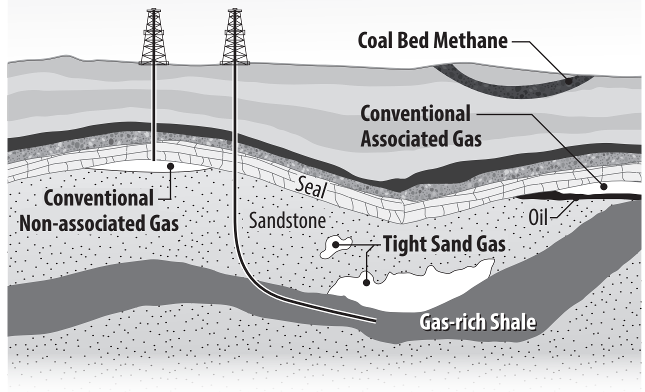
How does natural gas get to you? Usually by pipeline. Approximately 300,000 miles of underground **pipelines** link natural gas wells to cleaning plants to major cities across the United States. Natural gas is sometimes transported thousands of miles by pipeline to its final destination.

Top Natural Gas Producing States, 2011



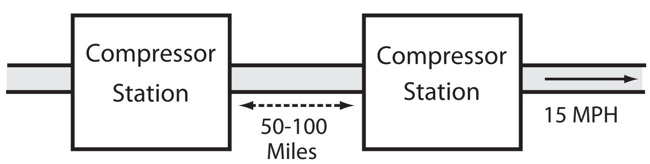
Data: Energy Information Administration

Locations of Natural Gas



Natural Gas Distribution System

Over 300,000 Miles of Pipeline



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

Natural Gas Use

Just about everyone in the United States uses natural gas. Natural gas ranks second in energy consumption, after petroleum. About one-quarter of the energy we use in the United States comes from natural gas.

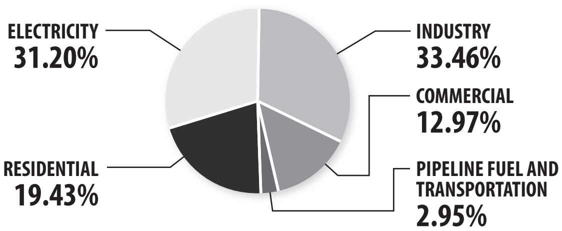
Industry uses one-third of the natural gas consumed in the U.S., mainly as a heat source to manufacture goods. Industry also uses natural gas as an ingredient in fertilizer, photographic film, ink, glue, paint, plastics, laundry detergent, and insect repellents. Synthetic rubber and man-made fibers like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

Homes and businesses—the residential/commercial sector—consume another third of the gas in the country. Over half of 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. 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 second largest producer of electricity after coal. 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 24.76 percent of the electricity in the U.S.

Compressed natural gas is often used as a transportation fuel. Natural gas can be used in any vehicle that has been modified with a special carburetor and fuel tank. Natural gas is cleaner burning than gasoline, costs less, and has a higher octane (power boosting) rating. Today, more than 119,000 vehicles run on natural gas in the United States.

U.S. Natural Gas Consumption by Sector, 2011



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

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.

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 1,023 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 98 cubic feet.

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.

The United States has large reserves of natural gas. Most reserves are in the Gulf of Mexico and in the following states: Texas, Wyoming, Oklahoma, Colorado, Louisiana, New Mexico, Arkansas, and Pennsylvania. If we continue to use natural gas at the same rate as we use it today, the United States has just under a 100 year supply of natural gas.

The U.S. natural gas proved reserves increased by 12 percent in 2010 to 318 trillion cubic feet (Tcf). Since the late 1990s, proved reserves have steadily increased due to improvements in shale gas exploration and production technologies drove the increase in natural gas reserves.

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 varies regionally. It is about two and a half times cheaper than electricity and fuel oil, both of which are common fuels used to heat U.S. homes.

Natural Gas and the Environment

All the fossil fuels—coal, petroleum, propane, 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.

Future of Natural Gas

▪ Shale Gas

Shale gas is natural gas that is trapped in shale formations. Shale is essentially a common form of sedimentary rock. It is formed by the compaction of silt and clay-size mineral particles. Shale formations are found all over the world. The Energy Information Administration projects that by 2035, production of shale gas will make up 49 percent of the U.S. natural gas supply. In 2010, shale gas accounted for 23 percent of U.S. natural gas production.

SHALE GAS PRODUCTION

Horizontal Drilling: A vertical well is drilled to the formation that has been identified as a natural gas reservoir. Then the drill bit can be turned up to a 90 degree angle so that the well parallels the natural gas reservoir. This allows the maximum amount of natural gas to be recovered.

Hydraulic Fracturing: Hydraulic fracturing, or "fracking," uses water, silica (sand), and chemical compounds piped several thousand feet below the Earth's surface, creating cracks or fissures in shale formations. This allows natural gas to be released and flow into the well. Hydraulic fracturing can be used along with horizontal drilling. Once the shale area is reached, the water, chemicals, and sand are pumped in to unlock the hydrocarbons in the shale.

BENEFITS AND CHALLENGES

There are benefits to natural gas development. When burned, it is cleaner than coal or oil, and releases fewer emissions. Advancements in drilling and fracturing techniques have made the extraction of shale gas possible to meet increasing demand for natural gas.

Development of natural gas from shale plays using hydraulic fracturing presents some challenges, including the need for access to water for use in the process, and the need to protect local drinking water and other natural resources. In some areas, development of shale gas brings drilling operations closer to local residential communities too, making land and homeowner cooperation and collaboration a high priority for companies engaged in development of these resources.

Continued technological innovations promise to make shale gas an important part of the United States' energy future.

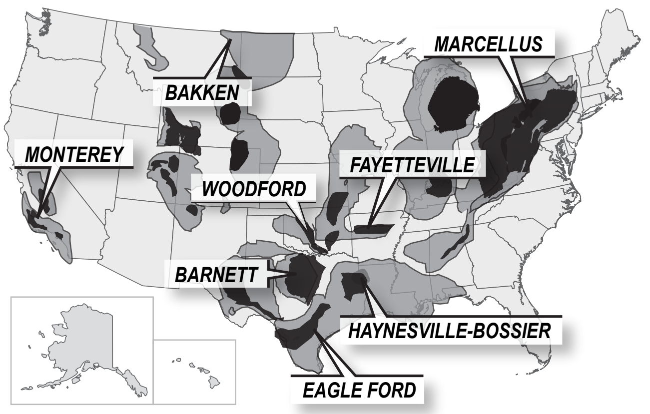
▪ Methane Hydrates

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 pressure 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.

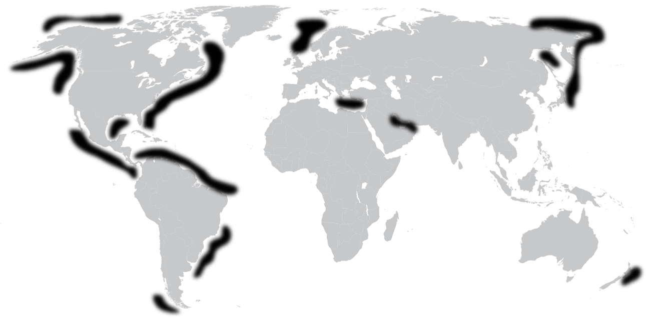
Scientists also suspect that huge deposits of free methane gas are trapped beneath the hydrate layer. Researchers estimate there is more carbon trapped in hydrates than in all the fossil fuels; however, they aren't sure how to capture this methane. When a hydrate breaks down, it loses its solidity and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

Location of Shale Gas Plays

Shale Gas Plays   Major Shale Gas Plays



Likely Methane Hydrate Deposits



▪ Biogases

Depending on how the gas is obtained and used, methane from biogases can be classified as a natural gas. Biogases are fuel sources derived from plant and animal waste (see *Biomass*, page 12).

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. In 2011, landfill gas generated 1,730 megawatts of electricity.

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 -260°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 facilities are operating in the United States.

Petroleum

Petroleum at a Glance, 2011

Classification:
- nonrenewable

Major Uses:
- transportation, industry

U.S. Energy Consumption:
- 33.689 Q
- 34.67%

U.S. Energy Production:
- 14.049 Q
- 17.99%

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 hundreds of millions of years ago, before dinosaurs lived. 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 buried underground does not turn into oil. Certain geological conditions must exist within the rock formations for the transformations to occur. First, there must be a trap of non-porous rock that prevents the material from seeping out, and a seal (such as salt or clay) to keep the material 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

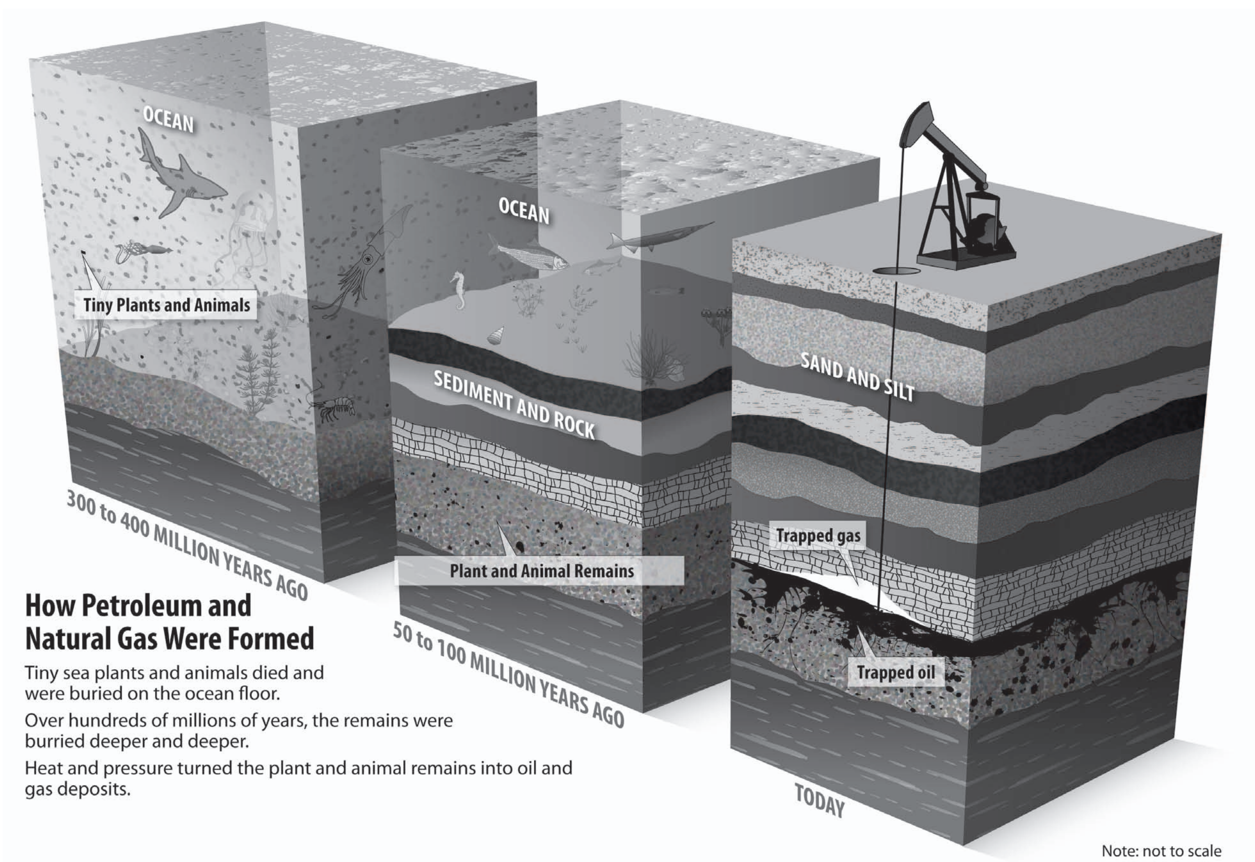
People have used naturally available **crude oil** for thousands of years. The ancient Chinese and Egyptians, for example, burned oil to produce light.

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, PA. 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.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor.

Over hundreds of millions of years, the remains were burried deeper and deeper.

Heat and pressure turned the plant and animal remains into oil and gas deposits.

Producing Oil

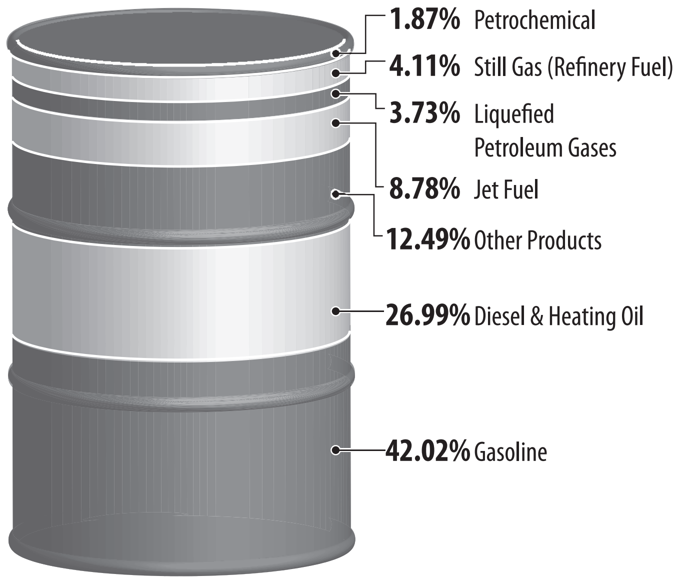
Although research has improved the odds since Edwin Drake's days, petroleum exploration today is still a risky business. Geologists study underground rock formations to find areas that might yield oil. Even with advanced methods, only 61 percent of exploratory wells found oil in 2010. Developmental wells fared much better; 91 percent found oil.

When the potential for oil production is found on shore, 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 over 6,000 feet deep and may sink below 20,000 feet. The average well produces 10.6 barrels of oil a day.

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 sites. Experts believe that much of our remaining oil reserves are on land owned by the federal government. Oil companies lease the land from the federal government, which, in return, receives rental payments for the mineral rights as well as percentage payments from each barrel of oil.

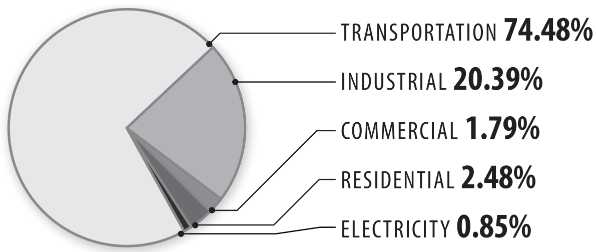
Texas produces more oil than any other state. The other top producing states are Alaska, California, North Dakota, and Oklahoma. These five states account for about 56 percent of all U.S. crude oil production. In all, 31 states produce petroleum.

Products Produced From a Barrel of Oil, 2011



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

Petroleum Consumption by Sector, 2011



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

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. For example, asphalts have a higher boiling point than gasoline, 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.

Not all of the crude oil sent to a refinery is turned into product. Up to nine percent of the energy in the crude oil is used to operate the refinery facility.

Shipping Oil Products

Pipelines are the safest and cheapest way to move large quantities of crude oil or refined petroleum across land. About 95,000 miles of small gathering lines and large trunk lines move crude oil from wells to refineries.

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 two weeks to move a shipment of gasoline from Houston, TX to New York City. Petroleum is transported over water via tanker.

Distribution

Companies called **jobbers** handle the wholesale distribution of oil. 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.

Petroleum

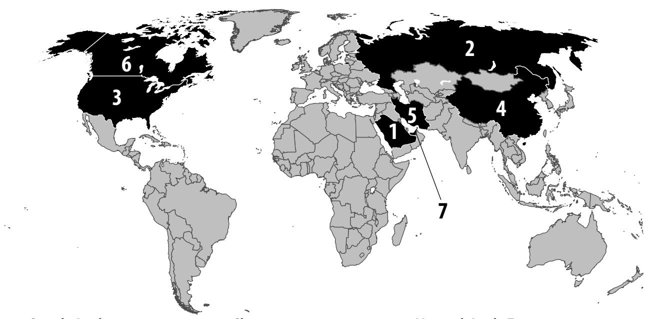
Demand for Oil

Since World War II, petroleum has replaced coal as the leading source of energy consumed in the United States. Petroleum supplies 34.67 percent of the total energy demand. Natural gas supplies 25.57 percent and coal supplies 20.22 percent of our total energy needs.

America uses about 18.8 million barrels of oil (more than 847 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 46 percent more oil than we did in 1973, when the first oil crisis hit the U.S. This is true even though today's vehicles get almost twice as many miles per gallon as their 1970s counterparts, because there are almost twice as many vehicles on the road today than in 1973. Today, 74.48 percent of U.S. oil consumption is used for transportation.

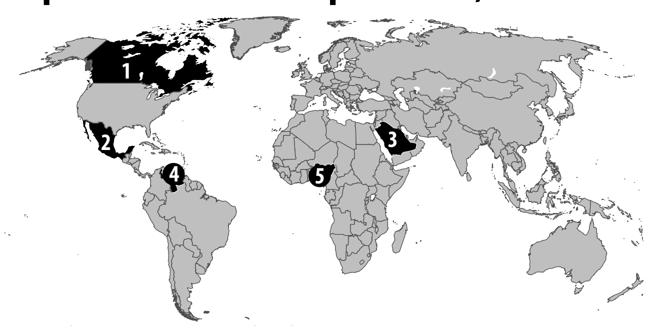
Top Oil Producing Countries, 2011



1. Saudi Arabia
2. Russia
3. United States
4. China
5. Iran
6. Canada
7. United Arab Emirates

Data: Energy Information Administration

Top Sources of U.S. Imported Oil, 2011



1. Canada, non-OPEC
2. Mexico, non-OPEC
3. Saudi Arabia, OPEC
4. Venezuela, OPEC
5. Nigeria, OPEC

Percentage of Imports from Persian Gulf: 16.4%
Percentage of Imports from OPEC Nations: 39.9%

Data: Energy Information Administration

Imported Oil

The United States uses more petroleum than it produces. Today, we import about 45 percent of our crude oil supply from other countries.

Many Americans believe this dependence on imported petroleum is problematic and reduces America's energy security and the ability to withstand disruption of supply. We were first alerted to that reality in 1973 when a group of Arab countries stopped supplying 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 member countries often set production levels for petroleum. As a rule, the less oil they produce, the higher the price of oil on the world market.

The next shock came in 1978–1979 when the Iranian Revolution cut off oil production. Again, world oil prices increased. Another major price increase resulted from the Persian Gulf War in 1990–1991. As many countries in the Middle East and North Africa experience political change, petroleum prices may increase temporarily resulting in higher prices for gasoline and other products. Many people believe that prices are less related to oil supply and more related to how petroleum is traded (bought and sold) as a commodity.

The U.S. continues to work to increase energy security and maintain domestic supplies of petroleum—including the purchase and storage of three months of supply 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 War.

The United States also imports oil from non-OPEC countries. Today, we import more oil from Canada than any other country (24 percent) followed by Mexico (11 percent). The United States is a major consumer in a global energy economy and access to petroleum resources continues to be a high priority for providing the energy resources needed for transportation and for making many of our consumer goods and products. As countries like China and India grow, their demand for petroleum and petroleum products increases as well. Global demand for oil continues.

There are steps we can take to help ensure our energy security and reduce the impact of high oil prices. Some experts believe the most important step is to decrease our demand for oil through increased conservation—reducing the oil we use and increasing the efficiency of our vehicles and transportation.

Some people believe we should increase oil production in the United States, particularly in the Arctic National Wildlife Refuge (ANWR) in northern Alaska and in offshore areas. Others say we should increase our use of other transportation fuels. Many people agree that the United States must increase production from domestic sources, increase efficiency, and continue development of non-petroleum transportation fuels.

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 13 percent of the nation's natural gas production and 33 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.

The U.S. Department of Interior (DOI) grants permission to use offshore lands through lease sales. After companies pay for a lease, they apply for U.S. DOI permits to develop energy resources from the lease. A lease is generally nine square miles. Currently, the entire Pacific Coast, the eastern Gulf of Mexico, the entire Atlantic Coast, and parts of Alaska are restricted from new lease sales, due to a Presidential mandate through 2017. Leases and new production can still occur in unblocked areas.

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.

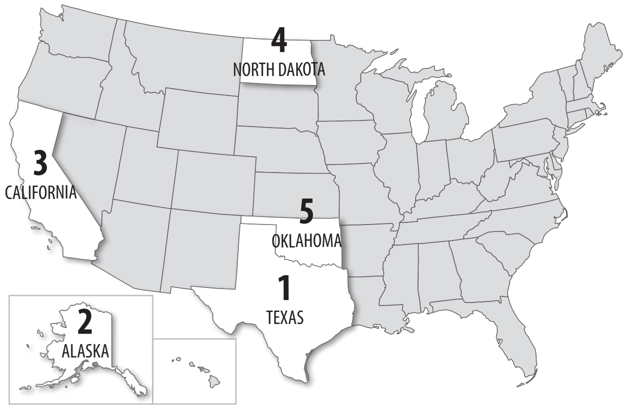
In 2010, the Macondo (Deepwater Horizon) well accident released oil into the Gulf of Mexico for several months. The companies involved in developing Macondo, the Coast Gaurd, and the Bureau of Ocean Energy Management, Regulation and Enforcement quickly began work to determine the cause of the accident and to improve production and safety standards as a result.

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 $11 a barrel; in the spring and summer of 2008, the price shot up to over $130 a barrel, the highest price in history.

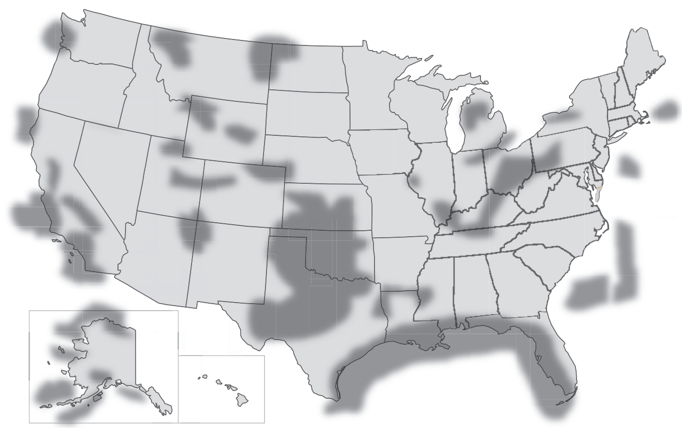
Low oil prices are good for the consumer and the economy, acting as a check on inflation. The oil industry, however, does not prosper during periods of low oil prices. Oil industry workers lose their jobs, many small wells are permanently sealed, and the exploration for new oil sources drops off. Low 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.

Top Petroleum Producing States, 2011



Data: Energy Information Administration

U.S. Oil and Gas Basins



Data: Energy Information Administration

Oil and 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. Petroleum production, distribution, and consumption can also contribute to air and water pollution.

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

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

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 hundreds of 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 gas (LPG)** family. Because propane is the type of LPG most commonly used in the United States, propane and LPG are often used synonymously. The chemical formula for propane is C_3H_8. Butane is another LPG often used in lighters.

Propane at a Glance, 2011

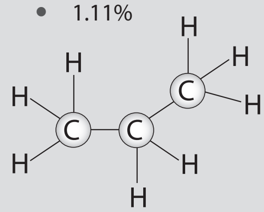
Classification:
- nonrenewable

Major Uses:
- industry, heating, transportation

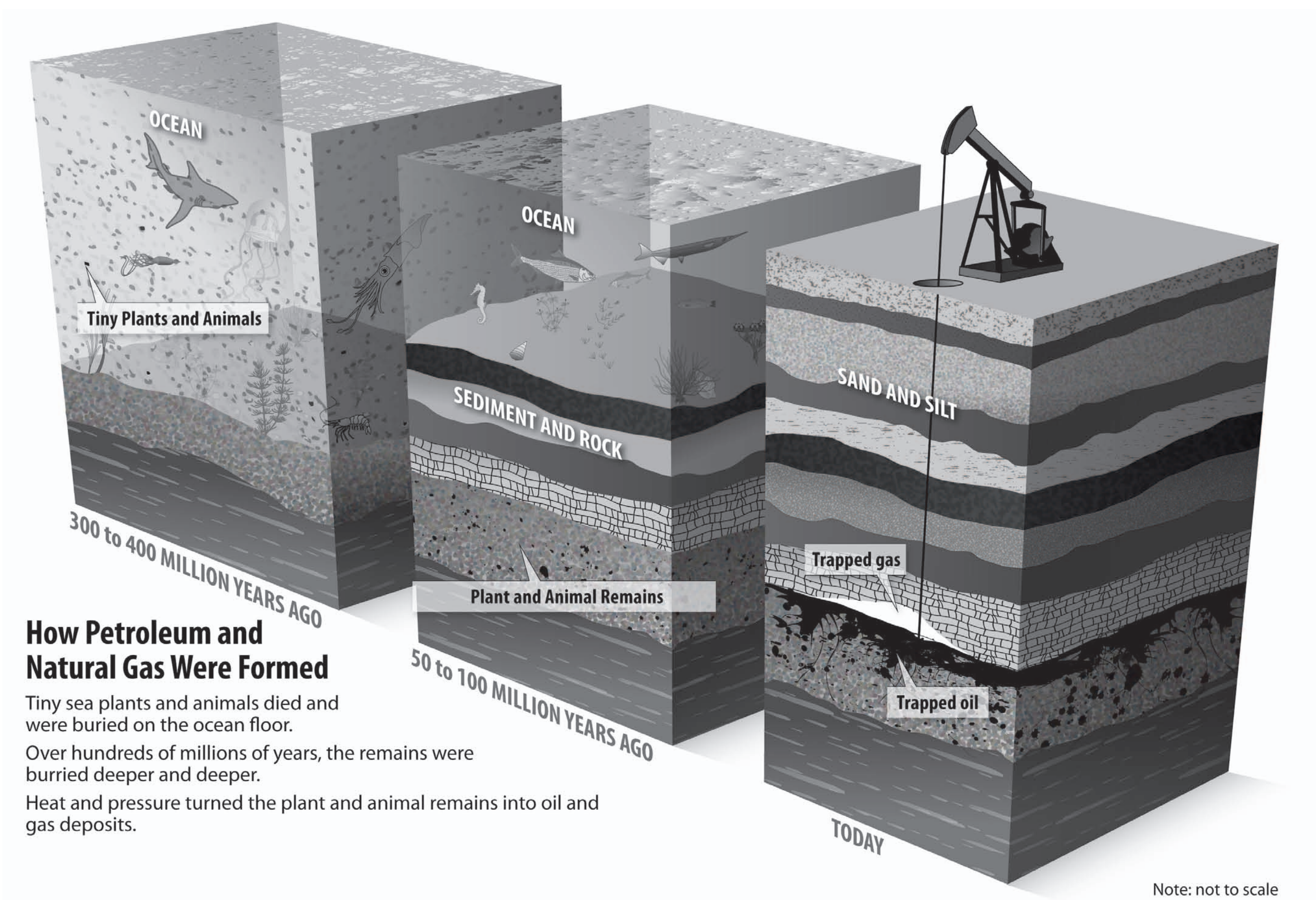
U.S. Energy Consumption:
- 1.594 Q
- 1.64%

U.S. Energy Production:
- 0.865 Q
- 1.11%

PROPANE = 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.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor.

Over hundreds of millions of years, the remains were burried deeper and deeper.

Heat and pressure turned the plant and animal remains into oil and gas deposits.

Note: not to scale

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.

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. About 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.

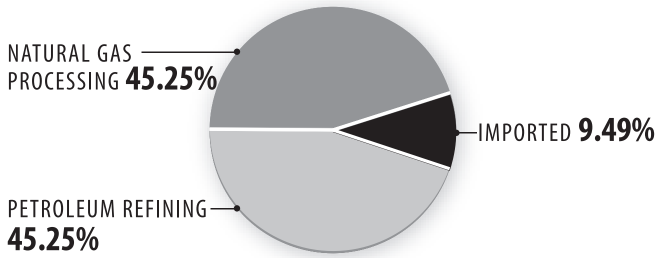
About forty-five percent of the propane is extracted from crude petroleum. Petroleum is separated into its various products at a processing plant called a **refinery**. The other 9.5 percent of the propane we use in the U.S. is imported from other countries, mostly from Canada and Mexico.

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 bulk storage and distribution terminals.

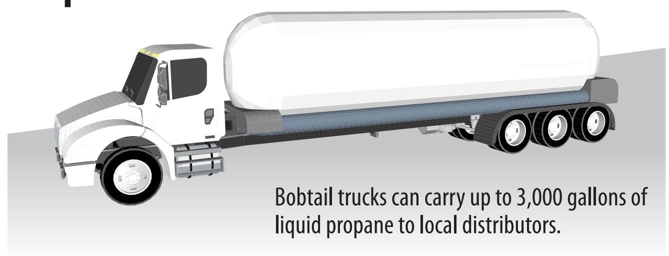
Distribution terminals, which are operated by propane companies, function like warehouses that store merchandise before shipping it to stores and shops. Sometimes, especially in the summer when less energy is needed for heating, propane is stored in large underground storage caverns.

Sources of U.S. Propane



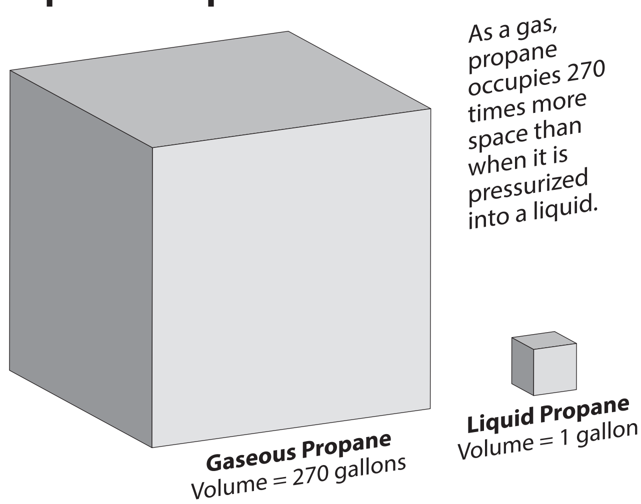
* Total does not equal 100% due to independent rounding.
Data: Energy Information Administration

Propane Truck



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

Liquefied Propane



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 25,000 propane dealers, such as hardware stores and gas stations, in the U.S. today.

Propane

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-quarter 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. Nearly 44 million households use propane to meet some of their energy needs. Nearly six million households use propane as their main heating source. Less than one-sixth 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 and 1,000 gallons of liquid fuel.

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

▪ Farms

Approximately 40 percent of America's farms—865,000—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

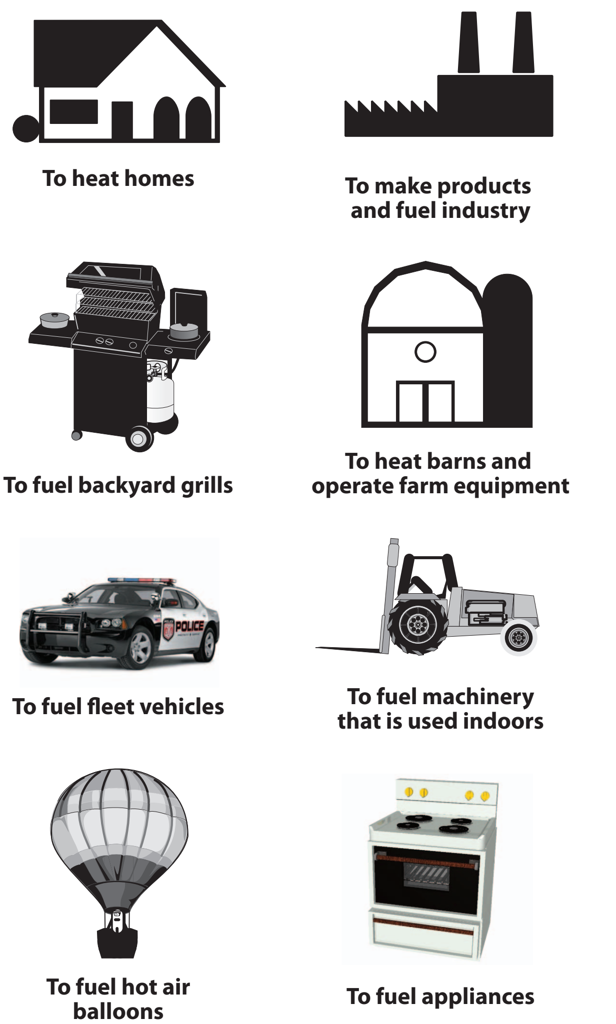
More than one million business and commercial establishments—such as hotels, schools, hospitals, restaurants, and laundromats—use propane for heating and cooling air, cooking and refrigerating food, heating water, and lighting.

▪ Industry

Industry uses three-quarters 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. In 2010, propane supplied about 10 percent of industrial energy needs in the U.S.

RESIDENTIAL TANK

How Propane Is Used



PROPANE POWERED FORKLIFT

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. Almost half of the propane used today is as a raw material for making plastic bags, nylon, and other products.

Propane Today

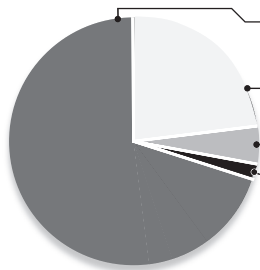
The United States uses more propane gas than any other country in the world. Propane supplies 1.64 percent of our total energy needs and ranks as the seventh most important energy source.

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 45 percent of the petroleum we use, more than 20 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 was approved as an alternative fuel under the Clean Air Act, as well as the National Energy Policy Act of 1992.

U.S. Propane Consumption by Sector, 2011



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

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 one 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.

A delivery van that runs on propane fuel.

Propane-fueled engines produce less air pollution than gasoline engines. Carbon monoxide emissions from engines using propane are 20 to 90 percent lower than emissions from gasoline-fueled engines. Total hydrocarbon emissions are 40 to 80 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 traveled per gallon when propane is used to fuel vehicles.

Solar

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 day than the world uses in one year.

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 nuclei to separate from their electrons. At this extremely energized state, the nuclei are able to fuse, or combine. Hydrogen nuclei fuse to become one helium atom of a higher atomic number and greater mass, and one neutron remains free. This new helium atom, however, contains less mass than the combined masses of the hydrogen isotopes that fused. This transmutation (changing one element to another) of matter results in some mass being lost. The lost matter is emitted into space as **radiant energy.** The process of fusion occurs most commonly with lighter elements like hydrogen, but can also occur with heavier nuclei, until iron (Fe) is formed. Because iron is the lowest energy nucleus, it will neither fuse with other elements, nor can it be fissioned (split) into smaller nuclei.

It can take 150,000 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 (3.0×10^8 meters per second).

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. Each hour the sun provides enough energy to supply our nation's energy needs for one year.

Where does all this energy go? About 30 percent of the sun's energy that hits the Earth is reflected back into space. Another 25 percent is used to evaporate water, which, lifted into the atmosphere, produces rainfall. Solar energy is also 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 seventh 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 solar 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.

Solar at a Glance, 2011

Classification:
- renewable

Major Uses:
- light*, heat*, electricity

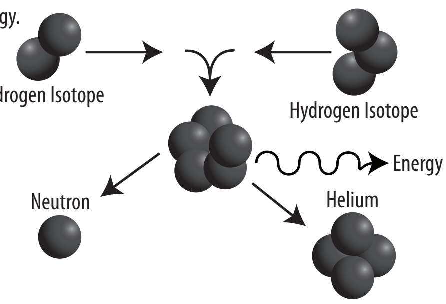
U.S. Energy Consumption:
- 0.158 Q
- 0.16%

U.S. Energy Production:
- 0.158 Q
- 0.20%

*Most of the solar energy we use for light and passive solar heating cannot be measured and is not included in this data. Only harnessed energy is included.

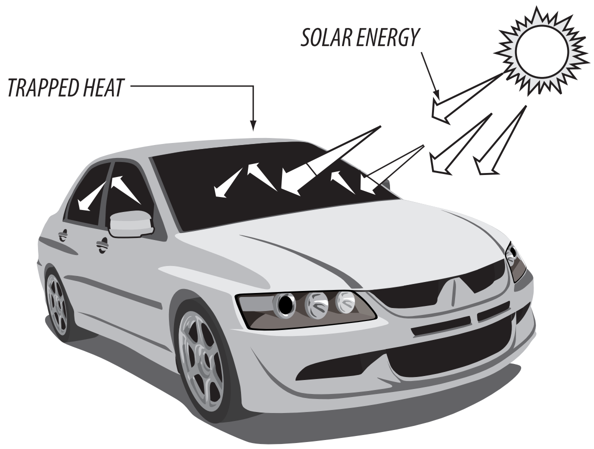
Fusion

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



Solar Collector

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



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 such 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 solar 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 home, 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.

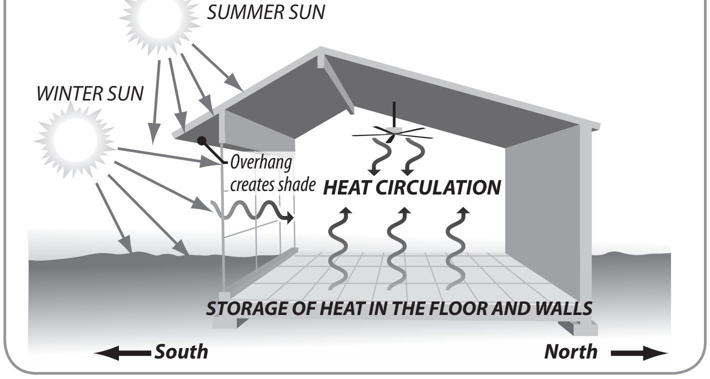
In the summer, awnings or roof overhangs help to cool the house by shading the windows from the high summer sun.

Heating a house by warming the walls or floors is more comfortable than heating the air inside a house. It is not so drafty. Passive buildings are quiet, peaceful places to live. A passive solar home can get 30 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 solar 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.

Passive Solar Home



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 second leading home energy expense, costing the average family about $360 per year.

Depending on where you live, and how much hot water your family uses, a solar water heater can reduce your water heating bill 50 to 80 percent. A well-maintained system can last 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.

SOLAR WATER HEATER

Solar

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.

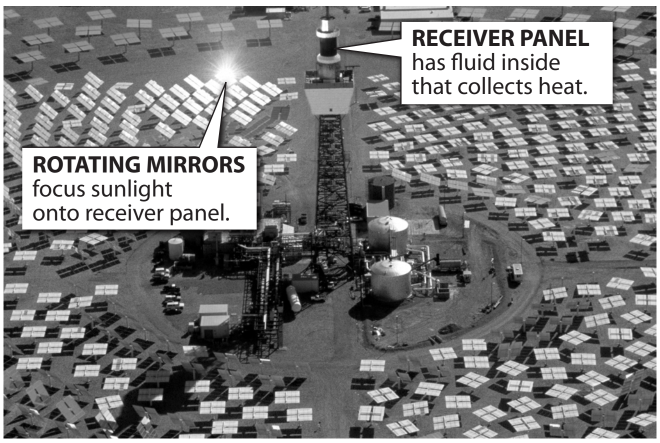
Photovoltaic Cells

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.

There are four major steps involved in generating electricity from the silicon in PV cells (see page 43). Current PV cell technology is not very efficient. Today's PV cells convert only about 11–29 percent of the radiant energy into electrical energy. Fossil fuel plants, on the other hand, convert about 35 percent of their fuel's chemical energy into electrical energy.

The cost per kilowatt-hour to produce electricity from PV cells is currently about three 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.

Solar Power Tower



SOLAR HOUSE

Concentrated Solar Power

Like solar cells, solar thermal systems use solar energy to make electricity. **Concentrated solar power (CSP)** technologies focus heat in one area to produce the high temperatures required 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 several types of technologies that use mirrors or other reflecting surfaces to concentrate the sun's energy up to 2,000 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 turbine. The world's largest parabolic trough power plant 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.

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

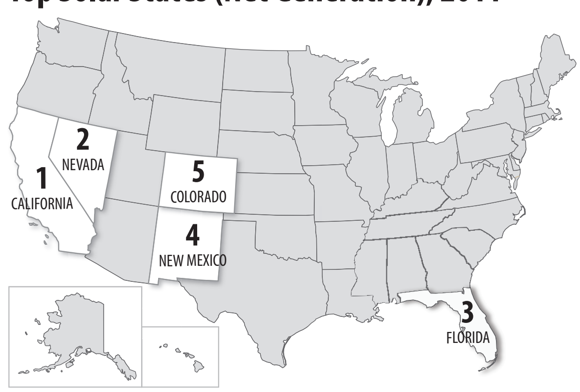
Dish/engine systems are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators are small mobile units that can be operated individually or in clusters, in urban and remote locations.

Concentrated solar power 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.

Top Solar States (Net Generation), 2011



Data: Energy Information Administration

How a Photovoltaic Cell Works

▪ Step 1

A slab (or wafer) of pure silicon is used to make a PV cell. The top of the slab is very thinly diffused with an "n" **dopant** such as phosphorous. On the base of the slab a small amount of a "p" dopant, typically boron, is diffused. The boron side of the slab is 1,000 times thicker than the phosphorous side. Dopants are similar in atomic structure to the primary material. The phosphorous has one more electron in its outer shell than silicon, and the boron has one less. These dopants help create the electric field that motivates the energetic electrons out of the cell created when light strikes the PV cell.

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

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

▪ Step 2

Where the n-type silicon and p-type silicon meet, 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 the two sides. This point of contact and barrier is called the **p-n junction**.

When both sides of the silicon slab are doped, there is a negative charge in the p-type section of the junction and a positive charge in the n-type section of the junction due to movement of the electrons and "holes" at the junction of the two types of materials. This imbalance in electrical charge at the p-n junction produces an electric field between the p-type and n-type silicon.

▪ Step 3

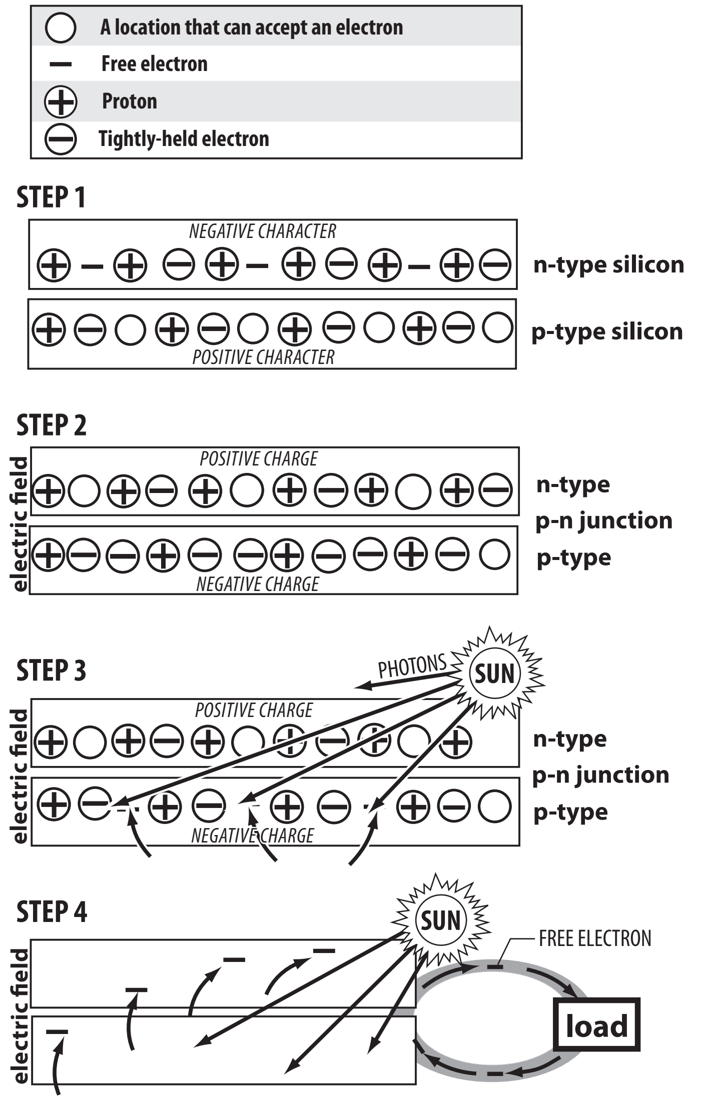
If the PV cell is placed in the sun, **photons** of light strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-type silicon and repelled by the negative charge in the p-type silicon. Most photon-electron collisions actually occur in the silicon base.

▪ Step 4

A conducting wire connects the p-type silicon to an electrical load, such as a light or battery, and then back to the n-type silicon, forming a complete circuit. As the free electrons are pushed into the n-type silicon they repel each other because they are of like charge. The wire provides a path for the electrons to move away from each other. This flow of electrons is an electric current that travels through the circuit from the n-type to the p-type silicon.

In addition to the semiconducting materials, solar cells consist of a top metallic grid or other electrical contact to collect electrons from the semiconductor and transfer them to the external load, and a back contact layer to complete the electrical circuit.

From Silicon to Electricity



PHOTOVOLTAIC CELLS

Uranium (Nuclear)

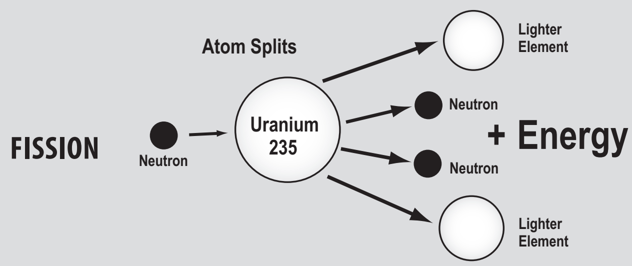
Uranium at a Glance, 2011

Classification:
- nonrenewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 8.259 Q
- 8.50%

U.S. Energy Production:
- 8.259 Q
- 10.58%



What Is Uranium?

Uranium is a naturally occurring radioactive element, that is very hard and heavy and is classified as a metal. It is also one of the few elements that is easily fissioned. It is the fuel used by nuclear power plants.

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.

Three **isotopes** of uranium are found in nature, uranium-234, 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 the other isotopes, the nucleus splits easily when bombarded by a neutron. During fission, the uranium-235 atom absorbs a bombarding neutron, causing its nucleus to split apart into two atoms of lighter mass.

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** 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 (see *Solar*, page 40).

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.

During 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, PA 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, were ordered after the 1970s until recently, 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 and plans for new plants are underway.

Uranium Fuel Cycle

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

▪ Mining

Uranium ore can be mined using conventional surface and underground mining methods. Uranium can also be mined using solution mining techniques. **In situ leaching** dissolves uranium ore while it is still in the ground using a weak chemical solution. The chemical-ore solution is then pumped to the surface. In 2011, five underground mines and five in situ leach mines produced uranium in the U.S.

▪ Milling

At the mill, conventionally mined ore is crushed and treated with an acid that separates the uranium ore from the rock. If in situ mining is used, the uranium is already dissolved in solution. The chemical-ore solution undergoes further treatments to separate the uranium as a precipitate. Uranium is collected and dried as uranium oxide (U_3O_8) concentrate. The concentrate is a powder called **yellowcake**. 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 UF_6. 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 its concentration. This process—called enrichment—increases the percentage of uranium-235 from 0.7 to five percent, required for reactor fuel. 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. This method increases the percentage of uranium-235 as the gas passes through thousands of filters. The enriched fuel is then converted into uranium dioxide (UO_2) in the form of a black powder.

▪ 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 a pencil eraser, yet each one can produce as much energy as 149 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**. The reactor is the center of the nuclear power plant. 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.

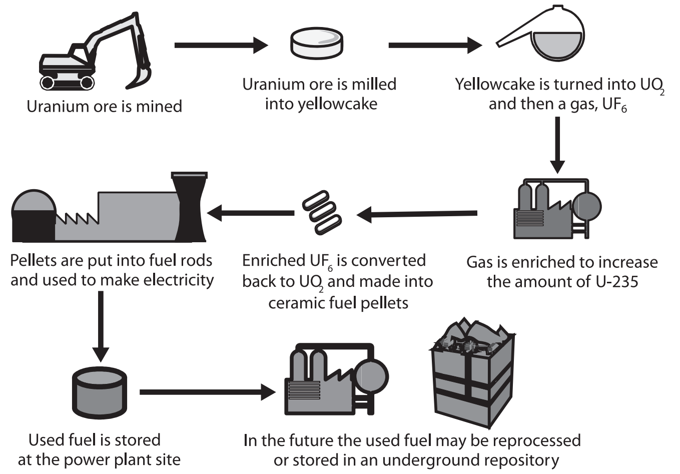
The reactor core houses about 200 fuel assemblies. Spaced between the fuel assemblies are movable **control rods**. Control rods absorb neutrons and slow down the nuclear reaction. Water also flows through the fuel assemblies and control rods to remove some of the heat from the chain reaction.

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 **steam 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**.

▪ Spent (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 to carry out. Utility companies generally replace one-third of the fuel rods every 12 to 18 months to keep power plants in continuous operation.

Uranium Fuel Cycle



The fuel that is taken out of the reactor is called **spent fuel**. This used fuel contains both radioactive waste products and unused fuel. The spent fuel is usually stored near the reactor in a deep pool of water called the spent fuel pool. The spent fuel cools and loses most of its radioactivity through radioactive decay. In three months, the spent fuel will lose 50 percent of its radiation; in one year, 80 percent; in 10 years, 90 percent. The spent fuel pool was intended as a temporary method for storing used nuclear fuel. However, there is no permanent storage solution yet for spent nuclear fuel, and fuel pools space is running out. The nuclear industry has designed dry cask storage as another temporary solution. Now, the spent fuel stays in the pool for five to seven years. Then, it is moved elsewhere on the nuclear power plant site to be stored in vaults or dry casks. Each of these methods for managing spent nuclear fuel puts the fuel into airtight, steel and concrete structures. The U.S. Nuclear Regulatory Commission has stated that it is safe to store spent fuel on site for at least 120 years. Eventually, the spent fuel will be reprocessed and/or transported to a permanent federal disposal site, although no permanent facilities exist at this time.

▪ Reprocessing

Spent fuel contains both radioactive waste products and unused nuclear fuel. In fact, the vast majority 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 spent fuel in spent fuel pools—without reprocessing. 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. Other countries, like France, reprocess some of their spent nuclear fuel.

Spent Fuel 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 did not happen.

Uranium (Nuclear)

What Is Radiation?

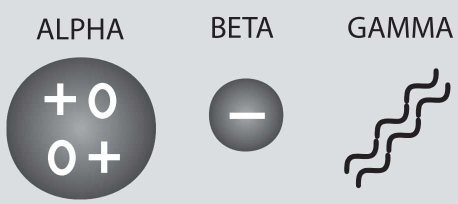
Radiation is energy released by atoms. It is very powerful and moves very fast. Not all atoms are radioactive. Some atoms—the radioactive ones—have more neutrons than protons, making them unstable. In a natural process called **radioactive decay**, these atoms give up their energy and nuclear particles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

Radiation cannot be touched, seen, or heard, but it is around us all the time. Natural sources of radiation include cosmic rays from outer space, minerals in the ground, and radon in the air. Man-made sources of radiation include the x-ray equipment used by doctors, smoke detectors, 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 0.01 millirem of exposure per year.



The same law also established the Nuclear Waste Fund to pay for a permanent 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 11,300 kilowatt-hours a year, contributes $11.30 a year to the fund.

The Department of Energy (DOE) originally looked at Yucca Mountain, Nevada to be the site of a national used nuclear fuel repository.

In 2010, the DOE withdrew its Yucca Mountain application with the intention of pursuing new long-term storage solutions. A Blue Ribbon Commission was formed in January 2010. The commission's job is to provide recommendations for managing used nuclear fuel in the United States. Until a final storage solution is found, nuclear power plants will continue storing used fuel at their sites in spent fuel pools or dry cask storage.

Nuclear Energy Use

Nuclear energy is an important source of electricity—third after coal and natural gas—providing 19.25 percent of the electricity in the U.S. today. There are 104 nuclear reactors in operation at 65 power plants in 31 states. Four new reactors are expected to come online by 2017.

Worldwide, nuclear energy is a growing source of electrical power. New plants are going online each year with many more under construction. Nuclear energy now provides about 13 percent of the world's electricity. The U.S., France, Russia, and Japan are world leaders. France generates almost 80 percent of its electricity with nuclear power.

Licensing Nuclear Power Plants

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

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

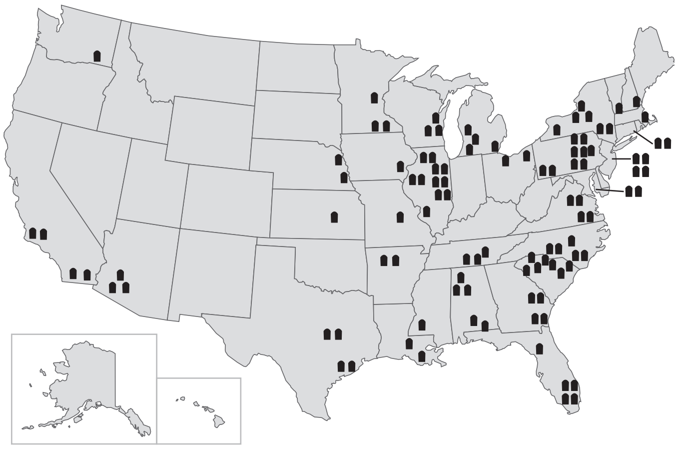
Economics of Nuclear Energy

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

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

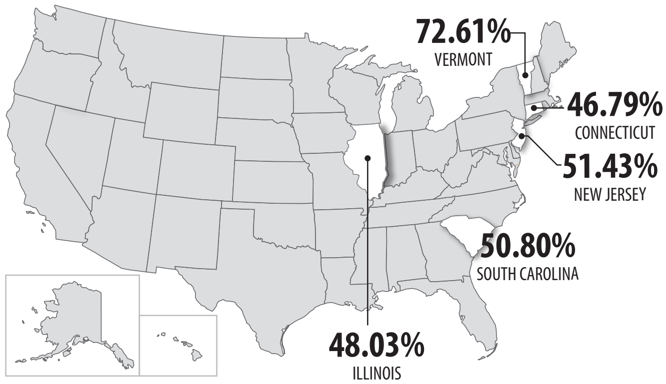
Uranium is an abundant natural resource that is found all over the world. Because uranium is an extremely concentrated fuel source, it requires far less mining and transportation than other fuel sources for

U.S. Nuclear Power Reactors, 2011



Data: Energy Information Administration

States with the Largest Percentage of Electricity Generated by Nuclear Energy, 2011



Data: Energy Information Administration

the energy it furnishes. At current rates of use, uranium resources could last over 100 years. A process called breeding, which converts uranium into plutonium—an even better fuel—could extend uranium reserves for thousands of years. Breeder reactors were tested in France, but they are not planned for use in this country.

Nuclear Energy and the Environment

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

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

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

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

Nuclear Safety

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

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

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

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

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

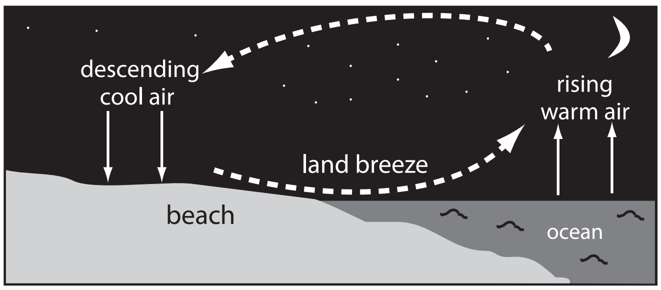
Wind

What Is Wind?

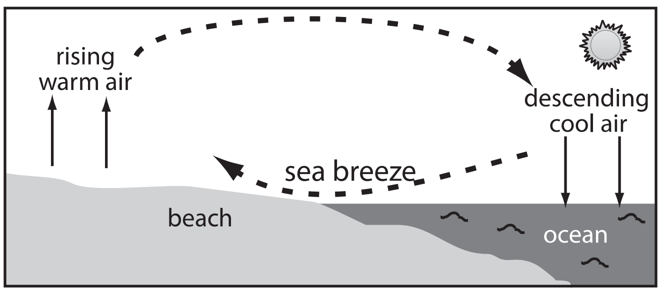
Wind is simply air in motion. It is produced by the uneven heating of the Earth's surface by energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's radiant energy at different rates. Much of this energy is converted into heat as it is absorbed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

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

Land Breeze

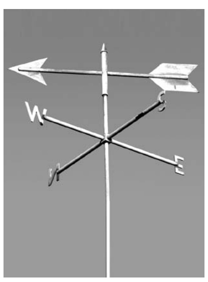


Sea Breeze



Windmill

Weather Vane



Anemometer

Wind at a Glance, 2011

Classification:
- renewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 1.168 Q
- 1.20%

U.S. Energy Production:
- 1.168 Q
- 1.50%

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

The History of Wind

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

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

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

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

Monitoring Wind Direction

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

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

Wind Velocity

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

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

Modern Wind Machines

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

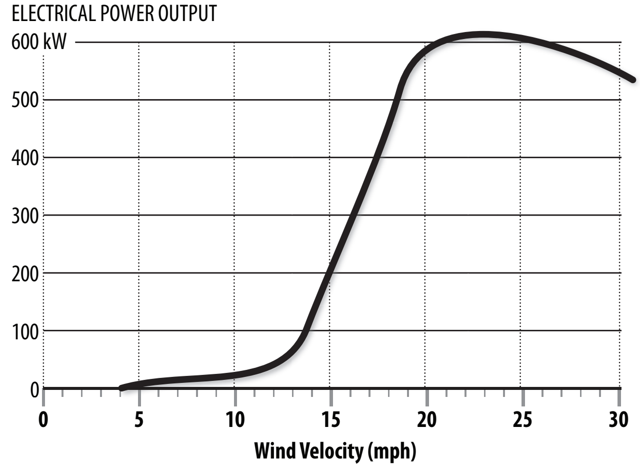
1. The moving air spins the turbine blades.
2. The blades are connected to a low-speed shaft. When the blades spin, the shaft turns.
3. The low-speed shaft is connected to a gear box. Inside, a large slow-moving gear turns a small gear quickly.
4. The small gear turns another shaft at high speed.
5. 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. Wind turbines today are typically placed on top of towers that are about 80 meters (260 feet) tall.

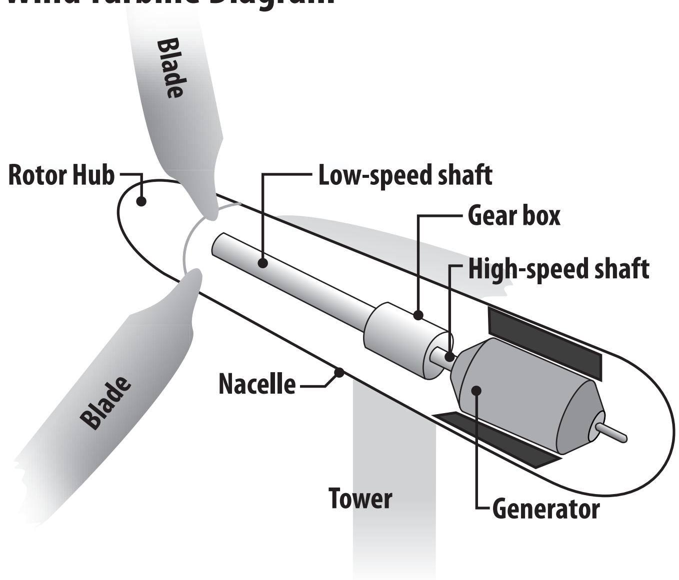
There are many different types of wind turbines with different blade shapes. Different types of turbines operate most efficiently at different wind speeds. While one turbine might operate efficiently in winds as low as five miles per hour, another may need winds up to 45 miles per hour.

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 a few appliances in 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 1.5 to 7.5 megawatts (MW), enough electricity to power 375 to 1,875 homes. Large turbines are grouped together into **wind farms**, which provide bulk power to the electrical grid.

Sample Power Curve of a Wind Turbine



Wind Turbine Diagram



Wind Power Plants

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

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

Wind

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

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

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

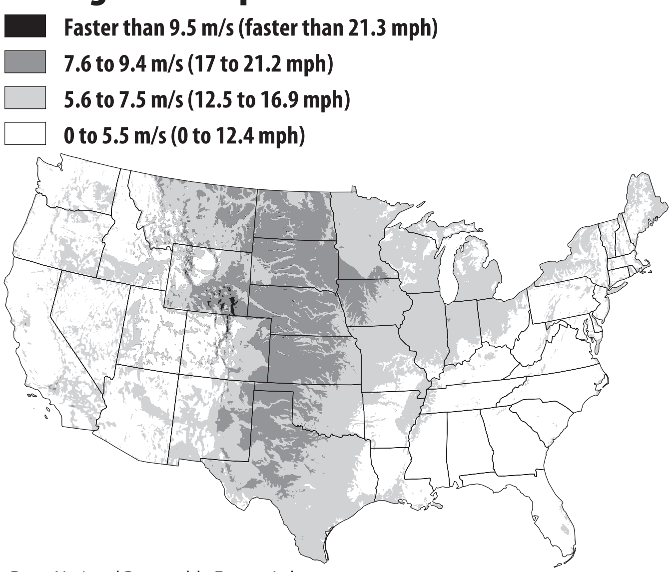
Can the site be connected to the power grid? It is expensive to lay long-distance transmission lines to get electricity to where people live, so wind farms should be located near the areas where electricity is needed.

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

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

OFFSHORE WIND FARM

Average Wind Speed at 80 Meters Altitude



Data: National Renewable Energy Laboratory

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. Offshore construction is difficult and expensive. The cables that carry the electricity must be buried deep under the water.

The first offshore wind farm in the U.S., Cape Wind Energy Project, received final approval from the Bureau of Ocean Energy Management, Regulation and Enforcement in April 2011. Construction is expected to begin in 2013 off the coast of Cape Cod, Massachusetts.

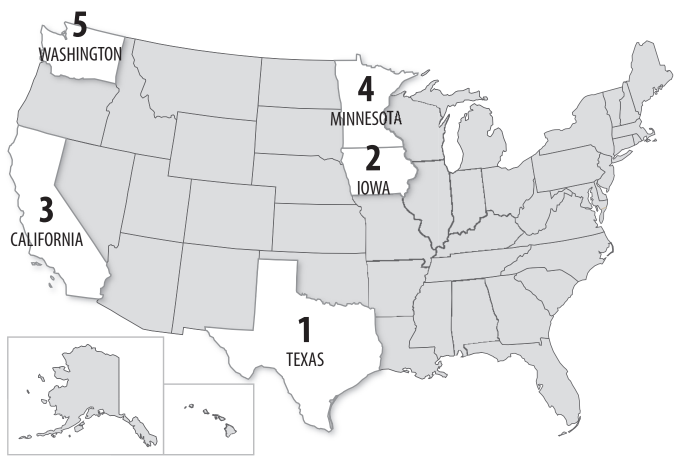
After a plant has been built, there are ongoing maintenance costs. In some states, these costs are offset by tax breaks given to power plants that use renewable energy sources.

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. An average wind speed of 13 miles per hour (mph) is needed to convert wind energy into electricity economically. Currently, wind generates electricity in 38 states. Texas leads the nation producing over one-quarter of the wind-generated electricity in the country.

Top Wind States (Net Electricity Generation), 2011



Data: Energy Information Administration

Wind Production

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

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

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

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

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

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

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

One 2.5 megawatt turbine can produce about 7.7 million kilowatt-hours (kWh) of electricity a year. That is enough electricity for more than 650 homes per year. In this country, wind turbines produce 119.7 billion kWh of energy a year. Wind energy provides about 2.92 percent of the nation's electricity, which is enough electricity to serve over 10.4 million households.

Wind is the fastest growing energy technology in the world today. In the last three years, wind capacity worldwide has doubled. In 2011, China, the United States, and India installed the most new wind capacity.

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

Small Wind Systems

Wind turbines are not only on wind farms or offshore, they can also be found on the property of private residences, small businesses, and schools. A typical home uses approximately 958 kilowatt-hours (kWh) of electricity each month. Many people are choosing to install small wind turbines to lower or eliminate their electricity bills.

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

Wind Economics

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

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

Installing a wind turbine on a residential property can be expensive. The Emergency Economic Stabilization Act of 2008 created energy tax incentives to encourage large and small companies, along with individuals, to make energy improvements and invest in renewable energy. Included in this bill is an extension and modification to the Residential Energy Efficient Property Credit. Through December 31, 2016, individuals can receive a 30 percent tax credit for installing a small wind system, up to 100 kilowatts. Some states and utilities offer additional incentives to residents to install renewable energy systems.

Wind Energy and the Environment

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

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

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

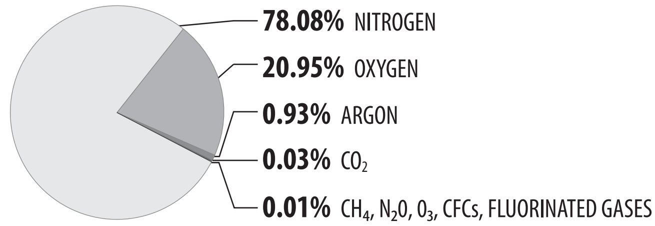
Climate Change

Earth's Atmosphere

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

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

Major Gases in the Atmosphere (Dry)



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

- Water vapor (H_2O) is produced naturally through evaporation. It is the most abundant and important GHG. Human activities have little influence on the concentration of water vapor in the atmosphere. However, a warmer climate increases evaporation and allows the atmosphere to hold higher concentrations of water vapor.
- **Carbon dioxide** (CO_2) is produced naturally through plant, animal, and human respiration and volcanic eruptions. Carbon dioxide is mostly produced through human activities such as **combustion** of fossil fuels and biomass, industrial processes, and deforestation.
- **Methane** (CH_4) is produced naturally when organic matter decays during wildfires, and from animals. Human activities are responsible for methane emissions from the production and transport of fossil fuels, managing livestock waste, and landfill decay.
- Nitrous Oxide (N_2O) comes from the bacterial breakdown of nitrogen in soil and the oceans. Human activities contribute to nitrous oxide emissions through agricultural and industrial activities, the combustion of fossil fuels, and sewage treatment.
- Tropospheric, or ground-level, **ozone** (O_3) is produced in the atmosphere when chemicals from human activities interact with sunlight. These emissions are from automobiles, power plants, and other industrial sources.
- **F-gases** are synthetically sourced substances, also known as flourinated gases. This group of chemicals is made of bonded halogen and carbon atoms and depending on the combination, can have a variety of uses, including insecticides, coolants, solvents, propellants, and electricity production. The presence of F-gases in the atmosphere is due to human activities. Certain types of F-gases (CFCs and HCFCs) have been or will be phased out internationally, due to their long atmospheric lifetimes and their role in ozone depletion in the stratosphere.

GREENHOUSE

Sunlight and the Atmosphere

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

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

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

The Greenhouse Effect

We call the trapping of 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, and it turns into heat when it hits objects inside. The heat becomes trapped. The **radiant energy** can pass through the glass; the **thermal energy** cannot.

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

According to studies conducted by NASA, the National Aeronautics and Space Administration, and many other researchers around the world, the concentration of carbon dioxide has increased about 40 percent since the Industrial Revolution in the late 18th century. Climate change experts have concluded that this increase is due primarily to the expanding use of fossil fuels.

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

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

Global Climate Change

Increased levels of greenhouse gases are trapping more heat in the atmosphere. This phenomenon is called global **climate change** or **global warming**. According to NASA the average temperature of the Earth has risen by about 1.5 degrees Fahrenheit since 1880. This increase in average temperature has been the major cause of a 17 centimeter rise in sea level over that time period, as well as an increase in extreme precipitation events. Sea levels are rising because sea water expands as it warms and land-based ice is melting in the Arctic, Antarctic, and in glaciers. Regions such as the Gulf Coast of the United States and several Pacific islands have already experienced losses to their coastlines. Recent research has also linked the increased severity of hurricanes and typhoons to global warming.

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

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

The Greenhouse Effect

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

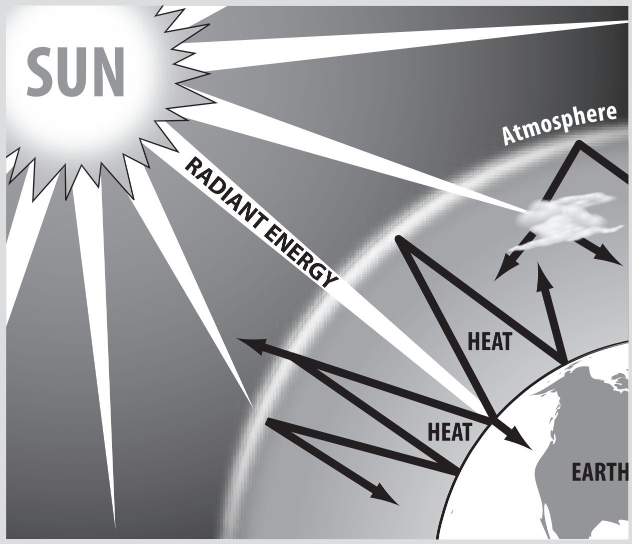
Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into heat.

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 toward the Earth.



International Awareness

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

This agreement expired in 2012 and, in an attempt to continue international efforts, world leaders are meeting periodically. One of the main roadblocks is regulating GHG emissions from developing countries. These nations argue that since current climate change was primarily caused by emissions from the developed, industrialized countries, those countries should bear the responsibility of lowering emissions. They see limits on GHGs as a limit to their development and their efforts to bring millions of their citizens out of poverty. While the developed nations accept that they need to curb their emissions, they feel that developing nations will have an unfair economic advantage if they are not regulated. An international conference in Copenhagen, Denmark in 2009 ended without a strong agreement on how to regulate emissions globally. Many, but not all, countries made commitments to specific GHG targets, but there is no international system to monitor or regulate their efforts. Meetings are continuing in hopes of crafting a strong international treaty. In 2011, the United Nations hosted climate talks in Durban, South Africa. Participating countries agreed to come to a legally binding agreement by 2015.

Hydrogen

What Is Hydrogen?

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

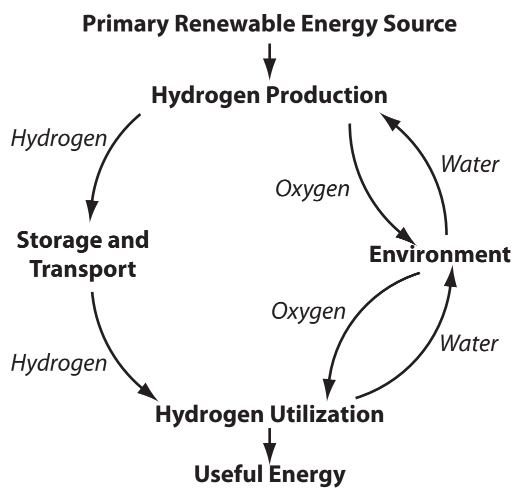
Hydrogen is also the most abundant gas in the universe, and the source of all the energy we receive from the sun. The sun is basically a giant ball of hydrogen and helium gases. In a process called **fusion**, hydrogen nuclei combine to form one helium atom, releasing energy as radiation.

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

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

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

Hydrogen Life Cycle



Every day we use more 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 an easily usable form. We convert energy to electricity because it is easier for us to transport and use. Try splitting an atom, building a dam, or burning coal to run your television. Energy carriers make life easier.

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

How Is Hydrogen Made?

Since hydrogen gas is not found on Earth, it must be manufactured. There are several ways to do this. Industry produces the hydrogen it needs by a process called **steam reforming**. High-temperature steam separates hydrogen from the carbon atoms in methane (CH_4). The hydrogen produced by this method isn't used as a fuel, but for industrial processes. This is the most cost-effective way to produce hydrogen today, but it uses fossil fuels both in the manufacturing process and as the heat source.

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

Hydrogen produced by electrolysis is extremely pure, and electricity from renewable sources can power the process, but it is very expensive at this time. Today, hydrogen from electrolysis is 12 times more costly than natural gas and 1.5 times more costly than gasoline per Btu.

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

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

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

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

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

Hydrogen Uses

The U.S. hydrogen industry currently produces twenty million metric tons of hydrogen a year. Most of this hydrogen is used for industrial applications such as refining, treating metals, and food processing.

Liquid hydrogen is the fuel that has propelled the space shuttle and other rockets since the 1970s. Hydrogen fuel cells powered the shuttle's electrical systems, producing pure water, which was used by the crew as drinking water.

In the future, however, hydrogen will join electricity as an important energy carrier, since it can be made safely from renewable energy sources and is virtually non-polluting. It 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 compressed natural gas (CNG) to increase performance and reduce pollution. Adding 20 percent hydrogen to CNG can reduce **nitrogen oxide (NO_X)** emissions by 50 percent in today's engines. An engine converted to burn pure hydrogen produces only water and minor amounts of NO_X as exhaust.

A few hydrogen-powered vehicles are on the road today, but it will be some time before you can walk into your local car dealer and drive away in one. Today 58 hydrogen fuel stations are operating in 17 states, but not all are open to the public. With 24 stations, California has 41 percent of the nation's hydrogen fuel stations.

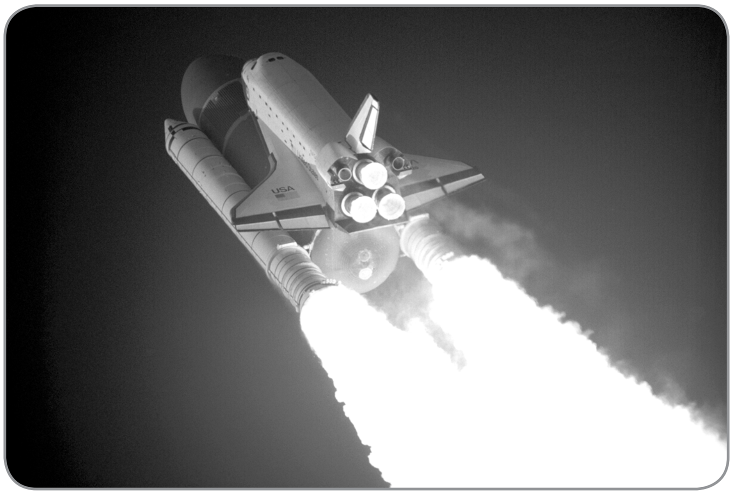
Can you imagine how huge the task would be to quickly change the gasoline-powered transportation system we have today? (Just think of the thousands of filling stations across the country and the production and distribution systems that serve them.) Change will come slowly to this industry, but hydrogen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

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

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

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

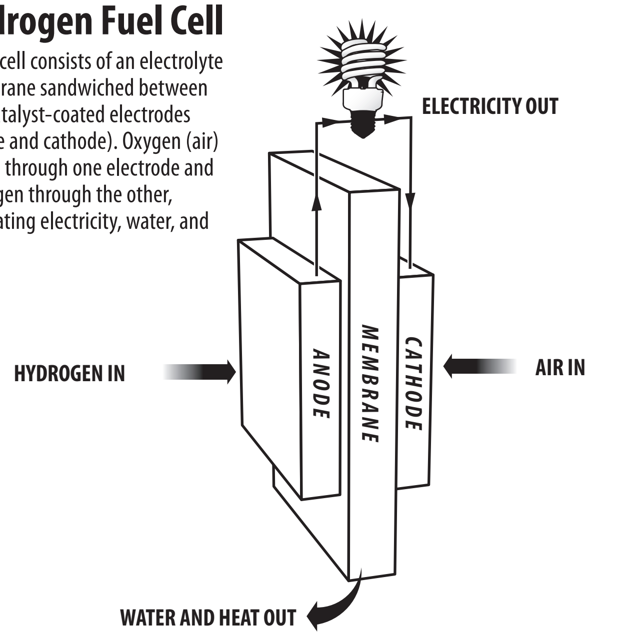
SPACE SHUTTLE



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

Hydrogen Fuel Cell

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



Future of Hydrogen

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

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

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

Electricity

Electricity at a Glance, 2011

Secondary Source of Energy, Energy Carrier

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

U.S. Energy Consumption:
- 40.44%

Net U.S. Electricity Generation:
- 4,105.70 billion kWh

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.

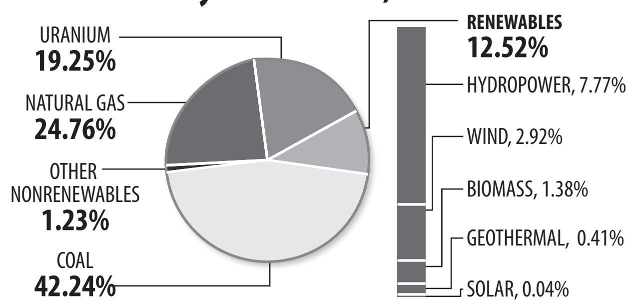
Making Electricity

Almost all electricity made in the United States is generated by large, central power plants. There are about 5,800 power plants in the U.S. Most power plants 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 coiled copper wire. The blades spin the magnet rapidly, rotating the magnet inside the coil producing an **electric current**.

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

Not all power plants use thermal energy to generate electricity. Hydropower plants and wind farms use motion energy to turn turbines, turning a generator, which produces electricity. Photovoltaic plants use radiant energy to generate electricity directly.

U.S. Electricity Production, 2011



Data: Energy Information Administration

Moving Electricity

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

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

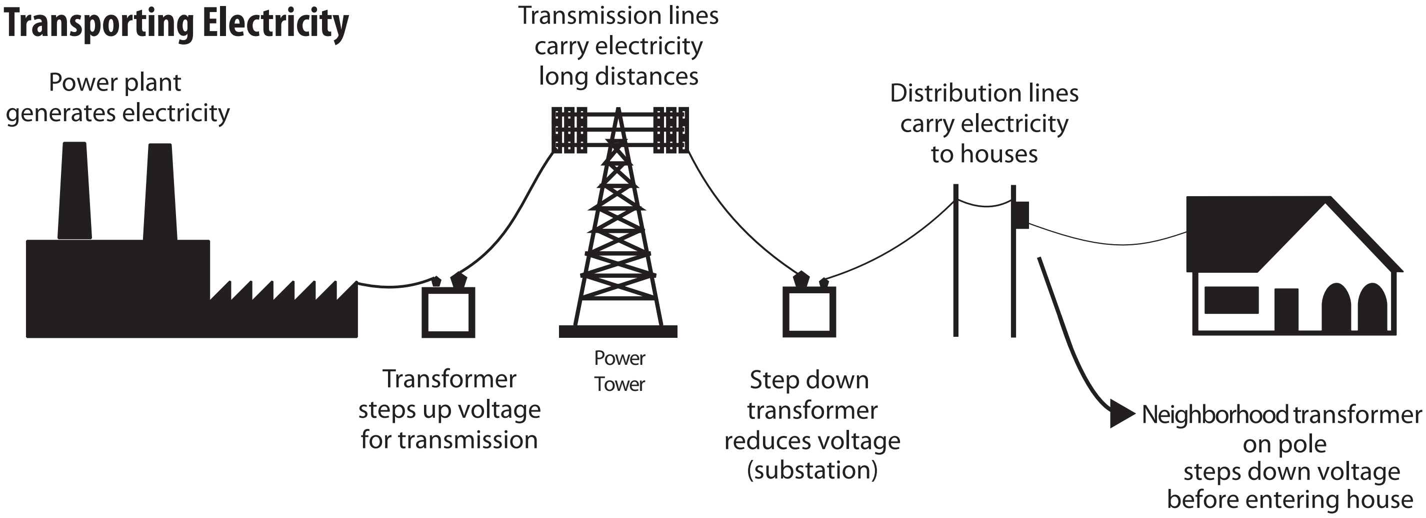
The electricity is then sent on a nationwide network of **transmission lines** made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway connected by tall power towers. The lines are interconnected, so should one line fail, another will take over the load.

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

Before electricity enters your house, the voltage is reduced again at another transformer, usually a large gray can mounted on an electric pole. This neighborhood transformer reduces the electricity to 240 and 120 volts, the amount needed to run the appliances in your home.

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

Transporting Electricity



Power to the People

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

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

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

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

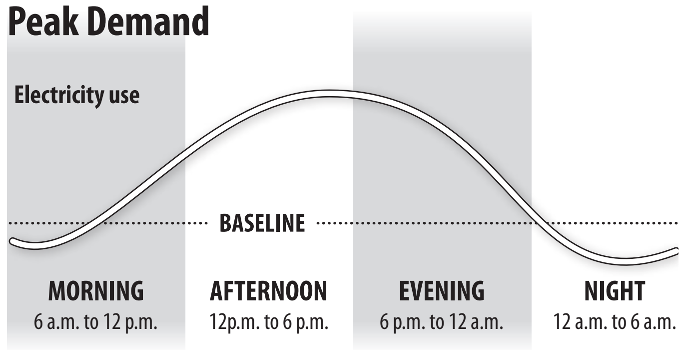
Base load power is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Base load power stations usually run at full or near capacity.

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 hydropower 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 eight regional power pool networks in North America. The key is to share power rather than lose it.

The reliability of U.S. electric service is excellent, usually better than 98 percent. In some countries, electric power may go out several times a day for several minutes or several hours at a time. Power outages in the United States are usually caused by such random occurrences as lightning, a tree limb falling on electric wires, or a fallen utility pole.

Peak Demand



Peak demand, also called peak load, is the maximum load during a specified period of time.

Demand-Side Management

Demand-side management is all the things a utility company does to affect how much people use electricity and when. It's one way electric companies manage peak load periods. In 2011, through energy efficiency and load management, electric utilities saved over 121.21 billion kilowatt-hours.

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

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

Demand-side management can also affect the timing of electrical demand. Some utility companies give rebates to customers who allow the utility company to turn off their hot water heaters or set their thermostats (via radio transmitters) during extreme peak demand periods, which occur perhaps 12 times a year.

America's Electric Grid

When you walk into a room and flip the switch on the wall, the lights come right on, just as you expected. But did you ever think how the electricity got to your house to give you the power for those lights and the many electrical appliances and products you use at home, ranging from your DVD player to your refrigerator?

Today there are more than 3,200 electric distribution utilities and about 18,000 generating units all over America that produce and distribute electricity to homes, businesses, and other energy users.

To get electricity to its users, there are more than 160,000 miles of high-voltage electric transmission lines across the U.S. They take the electricity produced at power plants to transformers that step up the voltage to reduce energy loss while it travels along the grid to where it is going to be used.

Generating Electricity

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

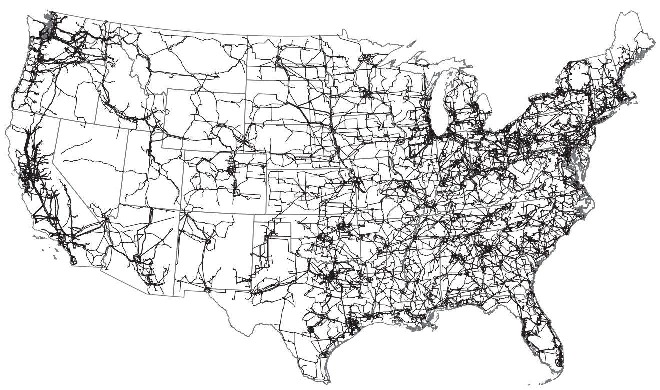
Fossil Fuel Power Plants: Fossil fuel plants burn coal, natural gas, or petroleum. These plants use the chemical energy in fossil fuels to superheat water into steam, which drives a **steam generator**. Fossil fuel plants are sometimes called thermal power plants because they use heat to generate electricity. Coal is the fossil fuel of choice for most electric companies, producing 42.24 percent of total U.S. electricity. Natural gas plants produce 24.76 percent. Petroleum produces 0.69 percent of the electricity in the U.S.

Nuclear Power Plants: Nuclear plants generate electricity much as fossil fuel plants do, except that the furnace is a **reactor** and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller elements, producing a great amount of heat in the process. The heat is used to superheat water into high-pressure steam, which drives a turbine generator. Like fossil fuel plants, nuclear power plants are thermal plants because they use heat to generate electricity. Nuclear energy produces 19.25 percent of the electricity in the U.S.

Hydropower Plants: Hydropower plants use the gravitational force of falling water to generate electricity. Hydropower is the cheapest way to produce electricity in this country, but there are few places where new dams can be built economically. There are many existing dams that could be retrofitted with turbines and generators. Hydropower is called a renewable energy source because it is renewed continuously during the natural water cycle. Hydropower produces five to ten percent of the electricity in the U.S., depending upon the amount of precipitation. In 2011, hydropower generated 7.77 percent of U.S. electricity.

TRANSMISSION LINES

The Continental U.S. Electric Grid



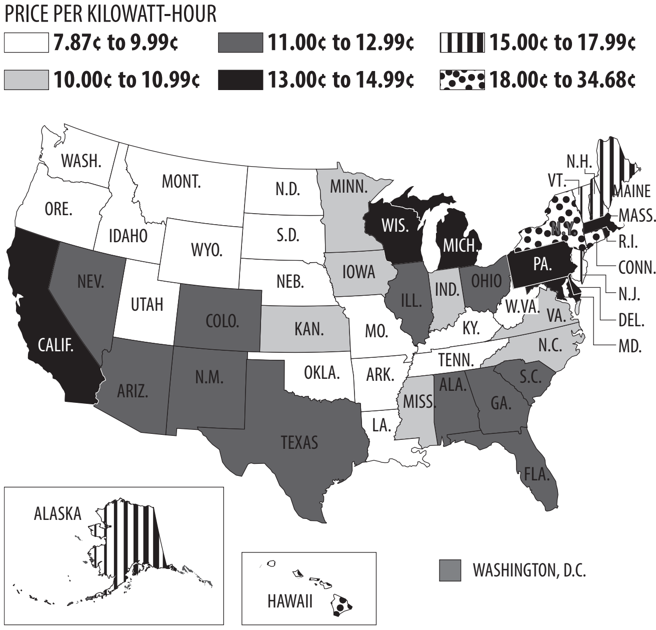
These transmission lines—whether they are located on poles above ground or buried underground—make up the most visible part of what is called the electric **grid**. The grid consists of the power generators, the power lines that transmit electricity to your home, the needed components that make it all work, your family, and the other homes and businesses in your community that use electricity.

The process starts at the power plant that serves your community, and ends with wires running from the distribution lines into your home. Outside your home is a meter with a digital read-out or an analog series of dials that measure the flow of energy to determine how much electricity you are using. Of course, there are many more parts to this process, ranging from substations and wires for different phases of current to safety devices and redundant lines along the grid to ensure that power is available at all times. You can see why the U.S. National Academy of Engineering has called America's electric grid "the greatest engineering achievement of the 20th century."

While this basic system of electricity transmission has worked well since the late 1880s, the increase in electric use in recent years has put a strain on the country's electric grid. The grid we use today was designed and put into place in the 1950s and 1960s, with much of the equipment planned to handle far smaller electrical use. More than 50 years later, a great deal of the equipment is reaching the end of its lifespan. At the same time, our electricity use has increased tremendously, putting a huge load on the system. Just look around your home at the TV sets, CD and DVD players, computers, gaming consoles, lamps, air conditioners, and all the other appliances found in the typical home today, and you'll see a tremendous demand for electricity far above the basic lights and products used in homes back when today's system was set up.

The surge in demand for electricity has far exceeded the creation of new transmission facilities and equipment over the years. Compounding the problem is the fact that about two-thirds of the electricity produced in our power plants never reaches potential users because of losses in energy conversion and transmission. Because of the complexity and importance of the country's electric grid, many new governmental regulations increase the time needed to plan and install additional equipment to meet today's demands.

Average Residential Price for Electricity, 2011



Data: Energy Information Administration

In the past few years, many parts of the country have experienced brief "brown-outs" or longer periods of power outages, increasing public concern about the future of the system we use today. Think about this: right now, our electric grid is actually 98 percent reliable, meaning the power is usually there when we want it. But that very tiny percentage of time when the grid isn't working at its full capability costs consumers an estimated $119 billion each year, including stoppages in automated equipment, computers that crash, and even the brief interruptions in the flow of energy and information in today's digital world that affect our work and our leisure activities.

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

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (58 percent), the cost of transmission (11 percent), and local distribution (31 percent). The average cost of electricity is twelve cents per kWh for residential customers and a little under 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 uranium or hydropower.

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

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

In 1900, most power plants were only four percent efficient. That means they wasted 96 percent of the fuel used to generate electricity. Today's thermal power plants are over eight times more efficient with efficiency ratings around 35 percent. Still, this means 65 percent of the initial thermal energy used to make electricity is lost. You can see this waste heat in the clouds of steam pouring out of giant cooling towers on newer power plants. A modern coal plant burns about 4,500 tons of coal each day, and about two-thirds of this is lost when the chemical energy in coal is converted into thermal energy, then into electrical energy. A hydropower plant, on the other hand, is about 90 percent efficient at converting the kinetic energy of moving water into electricity.

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

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

Deregulation and Competition

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

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

Measuring Electricity

Power is the rate (time) of doing work. A **watt** is a measure of the electric power an electrical device uses. Most electrical devices require a certain number of watts to work correctly. Light bulbs, for example, are rated by watts (13, 32, 60, 75, 100 watts), as are appliances, such as a 1500-watt hairdryer.

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

Just as we buy gasoline in gallons or wood in cords, we buy electricity in kilowatt-hours. Utility companies charge us for the kilowatt-hours we use during a month. If an average family of four uses 950 kilowatt-hours in one month, and the utility company charges 12 cents per kilowatt-hour, the family will receive a bill for $114.00. (950 x $0.12 = $114.00)

Electric utilities use **megawatts (MW)** and **gigawatts** to measure large amounts of electricity. Power plant capacity is usually measured in megawatts. One megawatt is equal to one million watts or one thousand kilowatts.

Gigawatts are often used to measure the electricity produced in an entire state or in the United States. One gigawatt is equal to one billion watts, one million kilowatts, or one thousand megawatts.

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

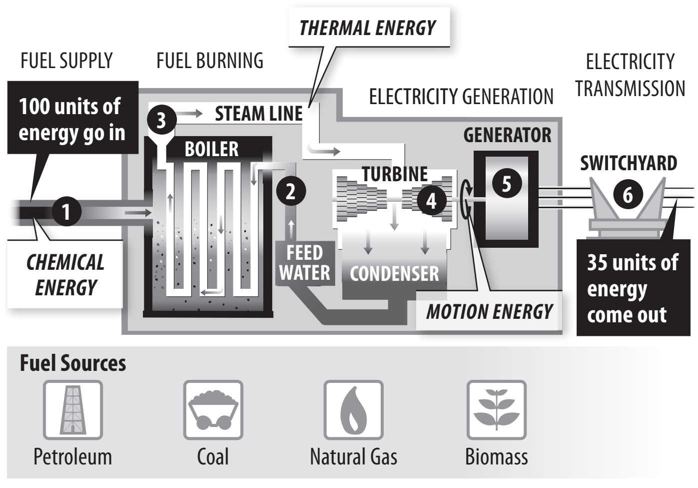
In the 1970s, the energy business changed dramatically in the aftermath of the Arab **oil embargos**, the advent of nuclear power, and stricter environmental regulations. Independent power producers and **cogenerators** began making a major impact on the industry. Large consumers began demanding more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

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

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

Efficiency of a Power Plant

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



How a Thermal Power Plant Works

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

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

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

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

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

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

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

Many states now have competition in the electric power industry. This competition can take many forms, including allowing large consumers to choose their provider and allowing smaller consumers to join together to buy power.

In some states, individual consumers have the option of choosing their electric utility, much like people can choose their telephone carrier or internet service provider. Their local utility would distribute the power to the consumer.

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

Future Demand

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

The U. S. Department of Energy predicts the nation will need to increase its current generating capacity of 1,054,800 megawatts by a fifth in the next 20 years. Demand for electricity is projected to increase in the future despite technological energy efficiency improvements in electric devices and appliances.

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

Conserving electricity and using it more efficiently will help, but everyone agrees we need more power plants now. That's where the challenge begins. Should we use 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.

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

Independent Power Producers

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

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

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

For different reasons, some environmentalists also worry that IPPs may not be subject to the same pollution control laws as public utilities. In reality, the opposite is true. Because they are generally the newest plants, IPPs are subject to the most stringent environmental controls. In any case, most experts predict that IPPs will produce more and more electricity. Today, IPPs generate 32.07 percent of the nation's electricity.

A special independent power producer is a **cogenerator** (combined heat and power, CHP)—a plant that produces electricity and uses the waste heat to manufacture products. Industrial plants, paper mills, and fast-food chains can all be cogenerators. These types of plants are not new. Thomas Edison's plant was a cogenerator. Plants generate their own electricity to save money and ensure they have a reliable source of energy that they can control. Now, some cogenerators are selling the electricity they do not use to utilities. The electric utilities supply that energy to their customers. So, even though your family's electric bill comes from a utility company, your electricity may have been made by a local factory. Today, 3.76 percent of the electricity produced in the U.S. is cogenerated.

Smart Grids

Another way to meet future demand is to update the electric grid and create a smart grid. The existing electric grid has worked well for many years, but developing a new, more efficient grid will help meet growing electricity demand. Updating the current grid and transmission lines would not only improve current operations, but would also open new markets for electricity generated by renewable energy sources.

Research and Development

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

Superconductivity was discovered in the laboratory about 100 years ago, long before there was any adequate theory to explain it. Superconductivity is the loss of virtually all resistance to the passage of electricity through some materials. Scientists found that as some conducting materials are cooled, the frictional forces that cause resistance to electric flow suddenly drop to almost nothing at a particular temperature. In other words, electricity remains flowing without noticeable energy loss even after the voltage is removed.

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

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

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

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

Monitoring Electricity Use

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

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

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

Smart meters allow customers to more closely monitor their energy usage and make changes to conserve energy. In 2011, more than 23 percent of all U.S. electric customers had smart meters.

History of Electricity

Starting with Ben

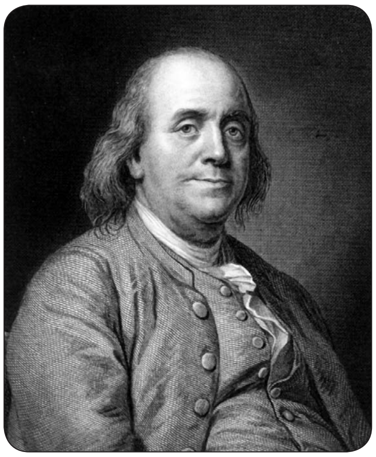


Image courtesy of NOAA Photo Library

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.

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


Image courtesy of Teylers Museum

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

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

A Current Began

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

Mr. Edison and His Light

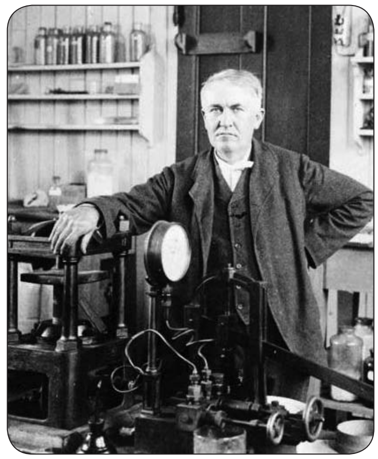


Image courtesy of U.S. Library of Congress

Thomas Edison in his lab in 1901.

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

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

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

Edison's Pearl Street Power Station started up its generator on September 4, 1882, in New York City. About 85 customers in lower Manhattan received enough power to light 5,000 lamps. His customers paid a lot for their electricity. In today's dollars, the electricity cost $5 per kilowatt-hour! Today's electricity costs about twelve 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 2011, with the increasing use of technologies powered by electricity, it was 40 percent.

Measuring Electricity

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

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

Voltage

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

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

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

Current

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

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

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

Resistance

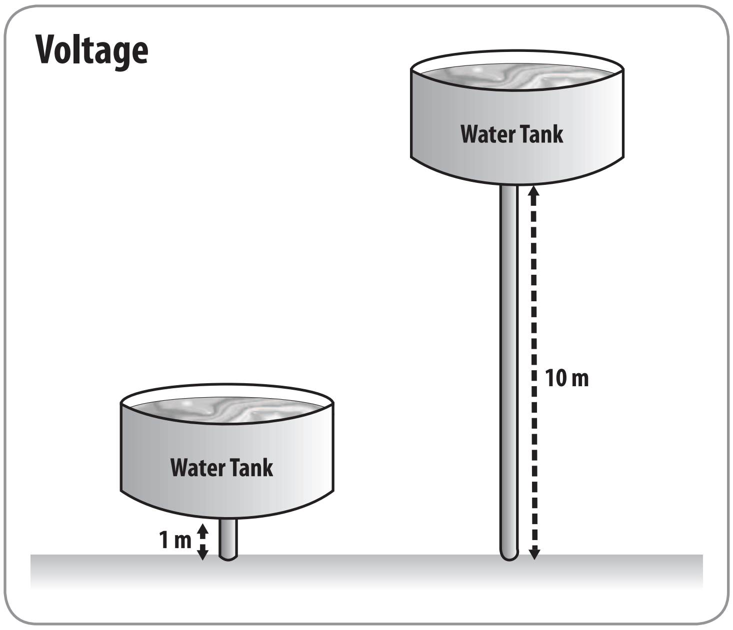
Resistance (R) is a property that slows the flow of electrons. Using the water analogy, resistance is anything that slows water flow, such as a smaller pipe or fins on the inside of a pipe.

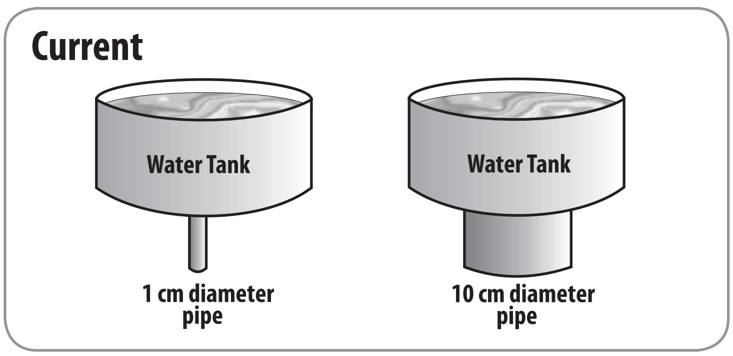
In electrical terms, the resistance of a conducting wire depends on the properties of the metal used to make the wire and the wire's diameter. Copper, aluminum, and silver—metals used in conducting wires—have different resistance.

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

Ohm's Law

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





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

voltage = current x resistance
V = I x R or V = A x Ω

Electric Power

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

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

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

power = voltage x current
P = V x I or W = V x A

Electrical Energy

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

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

energy = power x time
E = P x t or E = W x h = Wh

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

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

distance = 40 mph x 1 hour = 40 miles

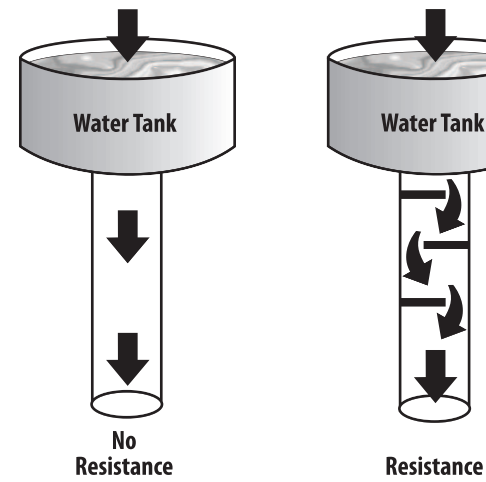
If a car travels for 3 hours at 40 miles per hour, it would travel 120 miles.

distance = 40 mph x 3 hours = 120 miles

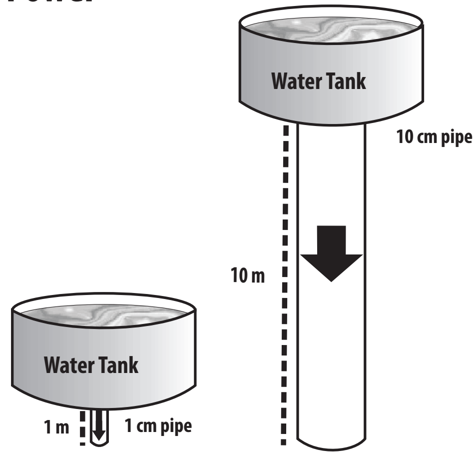
The distance traveled represents the work done by the car. When we look at power, we are talking about the rate that electrical energy is being produced or consumed. Energy is analogous to the distance traveled or the work done by the car.

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

Resistance



Electric Power



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

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

energy = power x time (E = P x t)
energy = 100 W x 5 hour = 500 Wh

One watt-hour is a very small amount of electrical energy. Usually, we measure electrical power in larger units called **kilowatt-hours (kWh)** or 1,000 watt-hours (kilo = thousand). A kilowatt-hour is the unit that utilities use when billing most customers. The average cost of a kilowatt-hour of electricity for residential customers is about $0.12.

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

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

$$0.5\text{ kWh} \times \$0.12/\text{kWh} = \$0.06$$

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

Energy Consumption

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

Residential and Commercial Sector

The residential and commercial sector—homes and buildings—consumes 40.74 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 35 years, Americans have significantly reduced the amount of energy we use to perform these tasks, mostly through technological improvements in the systems we use, as well as in the manufacturing processes to make those systems.

Heating and Cooling

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

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

The three fuels used most often for heating are natural gas, electricity, and heating oil. Today, 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 a clean-burning fuel. Most natural gas furnaces used in the 1970s and 1980s were about 60 percent efficient—they converted 60 percent of the energy in the natural gas into usable heat. Some of these furnaces might still be in use today. Depending on maintenance and homeowner use, these furnaces could last for over 20 years.

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

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

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

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

Heating oil is the third leading fuel for home heating and is widely used in northeastern states. In 1973, the average home used 1,294 gallons of oil a year. Today, that figure is 551 gallons, an almost 60 percent decrease.

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

Saving Energy on Heating and Cooling

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

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

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

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

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

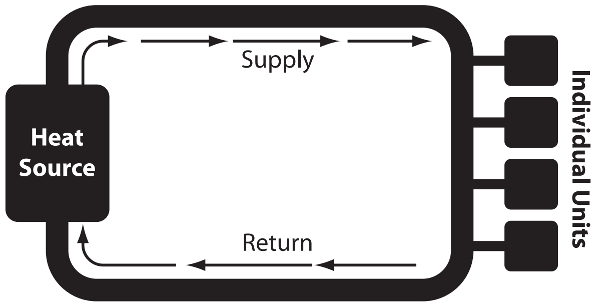
District Energy Systems

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

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

If the district energy system uses a renewable energy source, such as geothermal energy or waste heat, emission levels can be reduced even more. A major benefit of district heating is its ability to use materials as

District Heating System



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.

Geoexchange Systems

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

Geothermal systems cost more to install than conventional systems, but over the life of the system, they can save a significant amount of money and energy. They can reduce heating costs by 30-70 percent and cooling costs by 20-50 percent. Until 2016, there is a federal tax credit of up to 30 percent of the cost of the system. Today, there are more than one million geothermal systems in homes and buildings.

Building Design

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

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

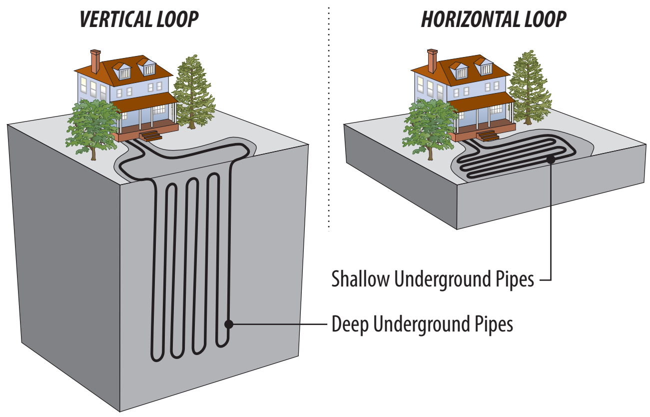
The Department of Energy's National Renewable Energy Lab has developed computer programs to design energy efficient buildings for any area of the country, taking into account the local climate and availability of building materials.

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.

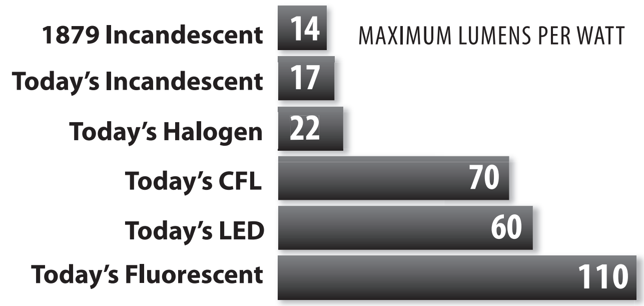
Lighting

Lighting is essential to a modern society. Lights have revolutionized the way we live, work, and play. Lighting accounts for about six percent of the average home's energy bill, but for stores, schools, and businesses, the figure is much higher. On average, the commercial sector uses about 20 percent of its energy for lighting.

Residential Geoexchange Units



Lighting Efficiency



Many homes still use the traditional **incandescent light bulbs** invented by Thomas Edison. These bulbs convert only 10 percent of the electricity they use to produce light; the other 90 percent is converted into heat. With new technologies, such as better filament designs and gas mixtures, these bulbs are more efficient than they used to be. In 1879, the average bulb produced 14 lumens per watt, compared to up to 17 lumens per watt today. By adding halogen gases, this efficiency can be increased to 22 lumens per watt.

Compact fluorescent light bulbs (CFL) are more common in homes now. 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 70 lumens per watt.

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

Light emitting diodes (LED) are another efficient lighting choice. Even more efficient than CFLs, these bulbs last twenty-five times longer than CFLs and have many tech-friendly applications.

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

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

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

Appliances

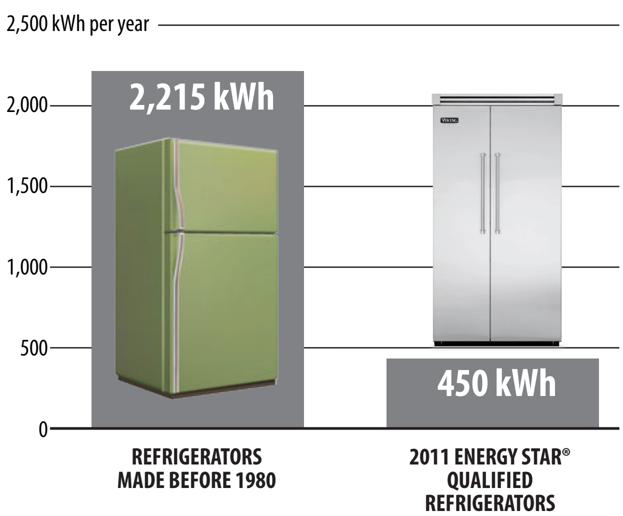
In the last 100 years, appliances have revolutionized the way we spend our time at home. Tasks that used to take hours are now accomplished in minutes, using electricity most of the time instead of human energy. In 1990, Congress passed the National Appliance Energy Conservation Act, which requires appliances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

▪ Water Heating

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

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

Refrigerator Efficiency



Data: ENERGY STAR®

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

▪ Refrigerators

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

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

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

▪ Washers and Dryers

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

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

▪ Appliance Efficiency Ratings

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

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

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

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

Industrial Sector

The United States is a highly industrialized society. We use a lot of energy. Industry consumed 31.44 percent of the energy in 2011, but U.S. industry produces about 20 percent of the world's manufacturing output. Advanced technologies have allowed industry to do more with less. Industry has also been a leader in developing cogeneration technology. Cogenerators produce electricity and use the waste heat for manufacturing, increasing overall energy efficiency by 35 percent.

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

Petroleum Refining

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

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

Steel Manufacturing

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

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

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

Aluminum Manufacturing

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

Today, it requires 20 percent less energy to produce a pound of aluminum than it did 20 years ago, mostly because of the growth of recycling. Aluminum recycling has quadrupled 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. Paper and paper products manufacturing is the third largest energy consumer in the industrial sector.

PETROLEUM REFINERY

Photo courtesy of BP

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

Chemical Manufacturing

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

Improved technology has made the chemical industry about 50 percent more energy efficient today than it was in 1974. Technology has allowed the industry to use less energy, as well as produce more product from an equivalent amount of feedstock.

Cement Manufacturing

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

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

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

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

Energy Consumption

Transportation Sector

America is a nation on the move. Almost 28 percent of the energy we use every day goes to transporting people and goods from one place to another.

The Automobile

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

In 1973, there were 125 million vehicles on the road, driving an average of 10,000 miles a year. Today, there are more than 241 million vehicles, driving 12,000 miles a year. Even with the scares of the oil embargoes, we are driving more cars, more miles. It's a good thing we're doing it more efficiently and cleanly.

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

All of these improvements have resulted in almost doubling the fuel efficiency for vehicles since the 1970s.

▪ Mileage Requirements

Most of the improvements in automobile efficiency have been the result of mandates by the federal government such as CAFE standards. First enacted by Congress in 1965, the purpose of Corporate Average Fuel Economy (CAFE) standards is to reduce energy consumption by increasing the fuel economy of cars and light trucks. The National Highway Traffic Safety Administration (NHTSA) sets fuel economy standards for cars and light trucks sold in the U.S., while the U.S. Environmental Protection Agency (EPA) calculates the average fuel economy for each manufacturer. Today, passenger cars are required to achieve a combined city and highway mileage of 30.2 **miles per gallon (mpg)**.

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 SUVs and light trucks made up half of total passenger vehicle sales.

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

NHTSA has proposed CAFE standards for 2017-2025 for passenger cars and light trucks (including subcompact cars, large sedans, station wagons, crossover utility vehicles, SUVs, minivans, and pickup trucks). The proposed standards require 41.0 miles per gallon in model year 2021, and 49.7 mpg in model year 2025.

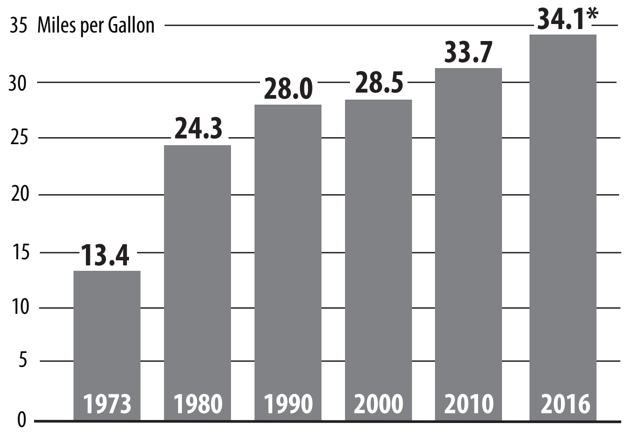
As the nation's automakers re-invent themselves, energy efficiency is a major consideration of future auto makes and models.

▪ Alternative Fuels

There is also a push to develop vehicles that run on fuels other than petroleum products or on blended fuels. Today, there are vehicles that run on electricity, natural gas, propane, biodiesel, ethanol, and hydrogen. In the 1970s, there were only a few vehicles that ran on alternative fuels. Today, there are more than 938,000 in the United States, and that figure is increasing by over nine 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.

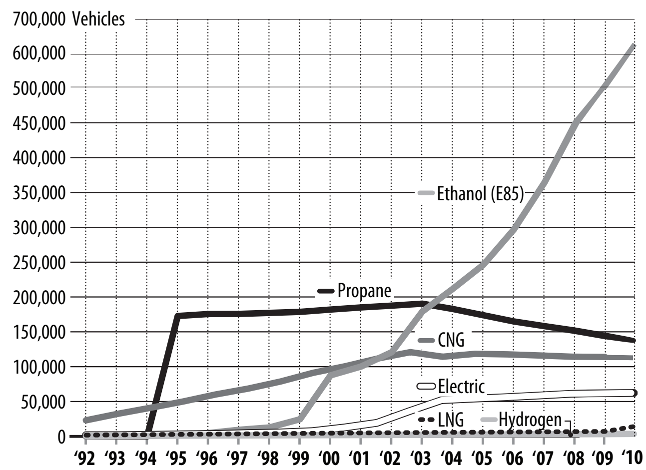
Average Fuel Economy of New Passenger Cars and Light Trucks



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

Data: U.S. Department of Energy

Alternative Fuel Fleet Vehicles in Use Since 1992



Data: Energy Information Administration

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

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

Commercial Transportation

The United States is a large country. We use a lot of energy moving goods and groups of people from one place to another. Passenger vehicles consume about 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 40 years, as well as the number of miles traveled.

▪ Trucks

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

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

▪ Planes

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

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

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

▪ Railroads

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

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

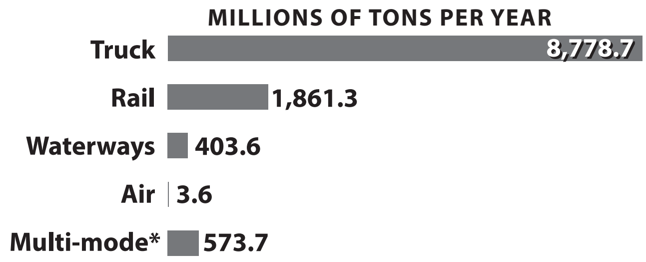
In the future, there will be an increase in the use of AC motors on diesel electric engines on locomotives. With AC motors, there are fewer moving parts, so less heat is generated, resulting in more efficient use of fuel. A train that today requires six locomotives might require only four with this new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

▪ Mass Transit: Public Transportation

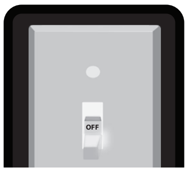
Mass transit is the system of public transportation for moving people on buses, trains, light rail, and subways. In 1970, nine percent of workers who traveled to work used public transit systems, two-thirds on buses. Today, only five percent of commuters use public transportation, half on buses. Why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

The average American spends 38 hours each year delayed by traffic congestion. Building more roads isn't the only answer, especially with environmental concerns over vehicle emissions and the higher cost of transportation fuels.

U.S. Freight, by Mode of Transportation



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



Efficiency and Conservation

Introduction

The United States uses a lot of energy— over two 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 about one-fifth (19 percent) of the world's energy. We are not alone among industrialized nations; average-world energy use per person continues to grow at a rate of approximately 10% per year, while population also continues to increase.

The average American consumes 4.32 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.

Selected Countries and Energy Consumption

Country	Population in in millions (2011)	Consumption quads Btu (2011)
China	1,344.13	109.620
India	1,241.49	23.611
United States	311.59	97.301
Indonesia	242.33	6.055 (2010)
Brazil	196.66	11.657
Pakistan	176.75	2.560 (2010)
Nigeria	162.47	0.730 (2010)
Russia	142.96	32.771
Japan	127.82	20.823
Mexico	114.79	7.808
Germany	81.80	13.082
Iran	74.80	9.108 (2010)
Thailand	69.52	4.325
France	65.43	10.781
Untied Kingdom	62.74	8.518
South Africa	50.59	5.593 (2010)
South Korea	49.78	11.161
Canada	34.48	13.495
Saudi Arabia	28.08	8.758
Australia	22.32	5.601
Netherlands	16.69	4.079
Chile	17.27	1.358
Honduras	7.75	0.132 (2010)

Data: Energy Information Administration, The World Bank

Energy Efficiency and Conservation

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

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

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

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

Residential/Commercial

Households use about one-fifth of the total energy consumed in the United States each year. The typical U.S. family spends $2,000 a year on utility bills. About 70 percent is in the form of electricity, the remainder is mostly 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.

The residential and commercial sectors generates 11 percent of greenhouse gas emissions that contribute to global climate change. The three main sources of greenhouse gas emissions from homes are electricity use, space heating, and waste. Using a few inexpensive, energy efficient measures can reduce your energy bill and, at the same time, reduce air pollution.

Window Ratings

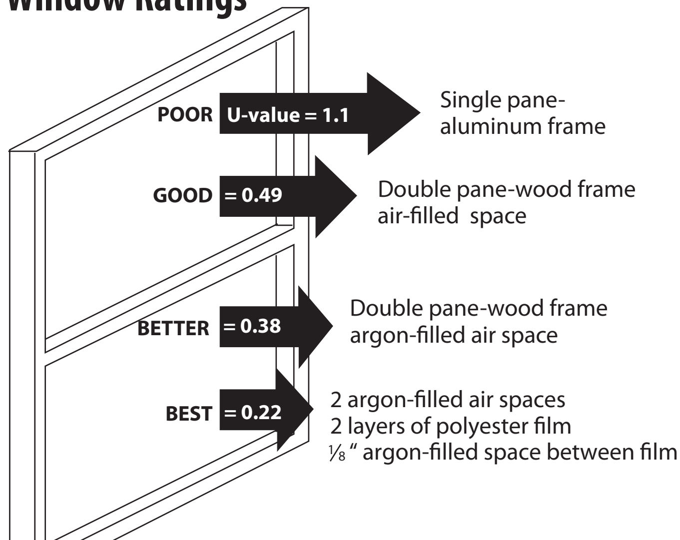
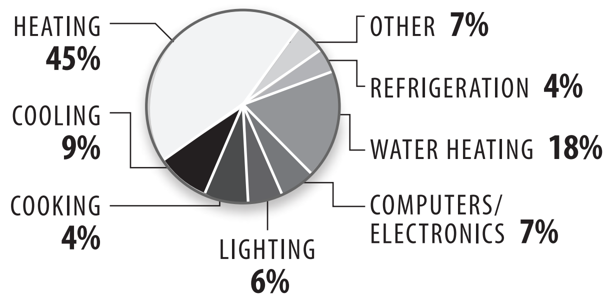


Diagram from the Consumer Guide to Home Energy Savings by the American Council for an Energy-Efficient Economy.

Home Energy Usage, 2011



Data: U.S. Department of Energy

▪ 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, 54 percent of the average family's utility bills goes to keeping homes at a comfortable temperature.

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

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

▪ Insulation and Weatherization

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

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

▪ Doors and Windows

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

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

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

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.

Efficiency and Conservation

Appliance Energy Consumption

Appliance	Average Yearly Usage in kWh	Annual Cost*
Coffee Maker	54	$6.48
Clothes Dryer	898	$107.70
Hair Dryer	80	$9.60
Refrigerator	525	$63.00
Television, Digital HD <40”	110	$13.20
DVR/Cable Box	387	$46.41
Microwave	126	$15.16
Laptop PC	149	$17.85
Video Game Console	32	$3.87

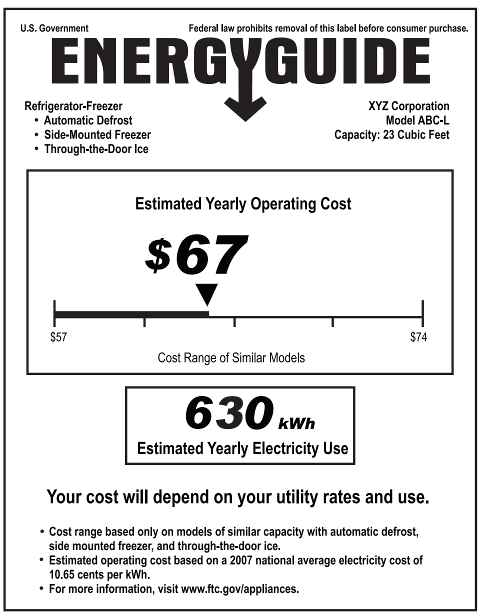
Data: U.S. Department of Energy: Buildings Energy Data Book, and Energy Savers Book
Lawrence Berkeley National Laboratory
ENERGY STAR®
*Average yearly consumption data accounts for devices used in different modes, i.e. idle, charging, etc.

ENERGY STAR® Logo

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

CHANGE FOR THE BETTER WITH ENERGY STAR

EnergyGuide Label


U.S. Government
Federal law prohibits removal of this label before consumer purchase.
ENERGYGUIDE
Refrigerator-Freezer
• Automatic Defrost
• Side-Mounted Freezer
• Through-the-Door Ice
XYZ Corporation
Model ABC-L
Capacity: 23 Cubic Feet
Estimated Yearly Operating Cost
$67
$57
$74
Cost Range of Similar Models
630 kWh
Estimated Yearly Electricity Use
Your cost will depend on your utility rates and use.
• Cost range based only on models of similar capacity with automatic defrost, side mounted freezer, and through-the-door ice.
• Estimated operating cost based on a 2007 national average electricity cost of 10.65 cents per kWh.
• For more information, visit www.ftc.gov/appliances.

▪ Appliances

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. Appliances that contribute significantly to a typical household’s energy consumption, are refrigerators, laundry machines, and cooking appliances.

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

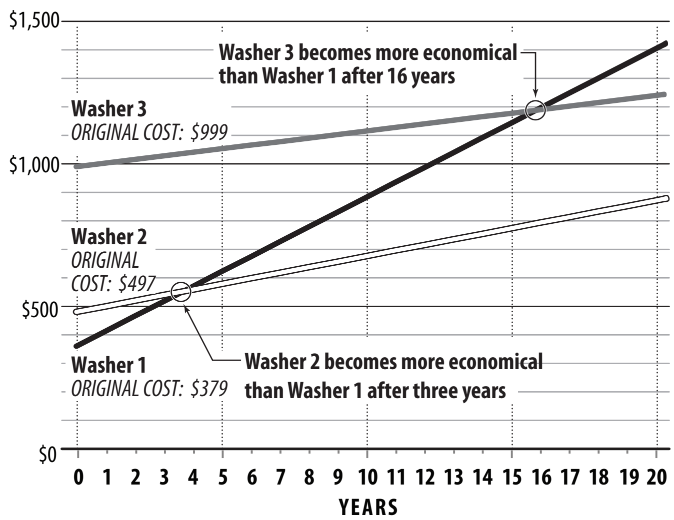
When you shop for a new appliance, look for the ENERGY STAR® logo—your assurance that the product saves energy. ENERGY STAR® appliances have been identified by the Environmental Protection Agency and U.S.

Washing Machine Payback Period

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

	WASHER 1	WASHER 2	WASHER 3
Original Cost	$379	$497	$999
Estimated Annual Electricity Use	427 kWh	160 kWh	102 kWh
Price of Electricity (per kWh)	$0.12	$0.12	$0.12
Operating Cost per Year	$51.24	$19.20	$12.24

COST OVER THE LIFETIME OF THE MACHINE



Data: NEED analysis of washing machine EnergyGuide labels

Department of Energy as the most energy efficient products in their classes. These appliances incorporate advanced technologies that use 10-50 percent less energy and water than standard models. A list of these appliances can be found on the ENERGY STAR® web site at *www.energystar.gov*.

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

Refrigerators, for example, account for about four 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 five degrees, and making sure that the energy saver switch is operational and in use.

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

▪ Lighting

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

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

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

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

Compact fluorescent light bulbs (CFLs) provide an equivalent amount of light as incandescents. Although CFLs cost more initially, they save money in the long run because they use only one-quarter of the energy of an equivalent incandescent bulb and last 10 times longer.

If every American household replaced one of its incandescent light bulbs with an ENERGY STAR® CFL, it would save enough energy to light three million homes for a year, save about $600 million, and prevent nine billion pounds of greenhouse emissions per year.

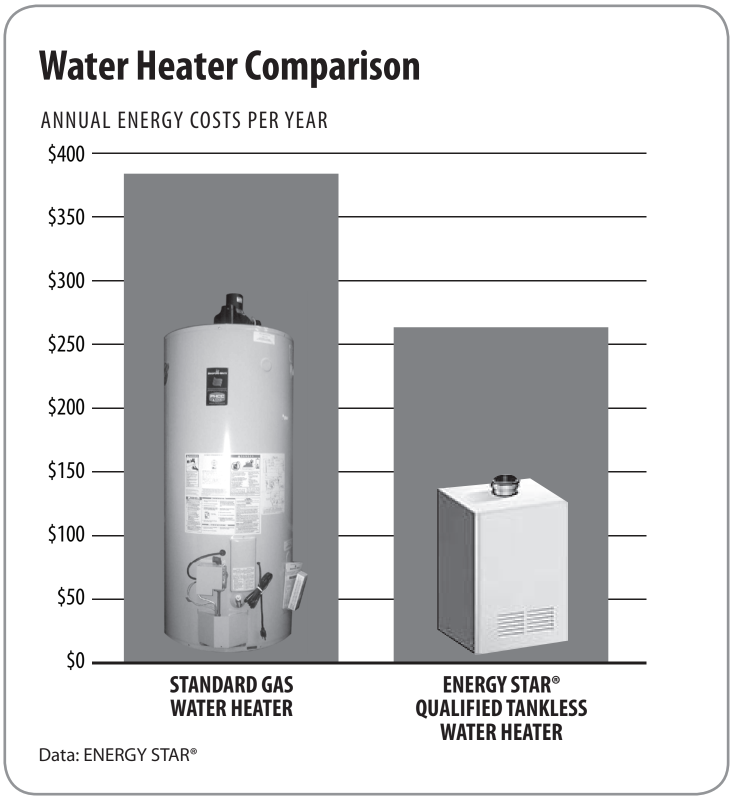
Light emitting diodes (LEDs) are one of the most energy efficient lighting choices available today. They use even less energy than a CFL and last 25 times longer than traditional incandescent bulbs. This means life cycle emissions for an LED will be far fewer than any other type of bulb. LEDs are also the most expensive lighting technology today. As with other electronics, prices are expected to come down as more products enter the market.

▪ Water Heating

Water heating is the largest energy expense in your home after space heating and cooling. It typically accounts for about 18 percent of your utility bill. Heated water is used for showers, baths, laundry, dishwashing, and general cleaning. There are four ways to cut your water heating bills—use less hot water, turn down the thermostat on your water heater, insulate your water heater and pipes, and buy a new, more efficient water heater.

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

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



Efficiency and Conservation

Transportation

Americans own one-sixth of the world's automobiles. The transportation sector of the U.S. economy accounts for 27.83 percent of total energy consumption and 74.48 percent of petroleum consumption each year. America is a country on the move; we love the freedom provided by our vehicles. The average American uses 670 gallons of gasoline every year, driving each vehicle about 12,000 miles. At the 2011 price of $3.53 per gallon, that equals $2,375 in fuel costs alone.

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.

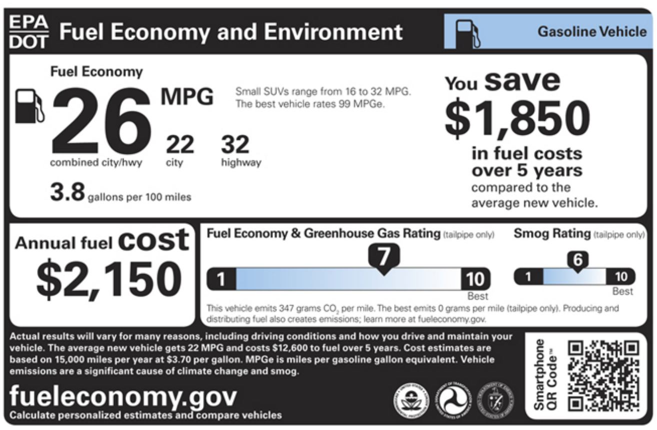
Improvements in the average fuel economy of new cars and light trucks from the mid-1970s through the mid-1980s were significant. The average fuel economy of cars almost doubled in that time period and for trucks it increased by more than 50 percent. These improvements were due mainly to the Corporate 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.

Today CAFE standards are set at 30.2 miles per gallon for passenger cars, which is double the fuel economy of 1974 passenger vehicles. Standards for light trucks are lower at 24.2 mpg. Many manufacturers are exceeding these standards. In fact, the average fuel economy of new cars today is 33.7 mpg. Despite this, not all cars meet these standards. Manufacturers must pay a fine for each model that does not meet CAFE standards.

Recently, the National Highway Traffic Safety Administration (NHTSA) announced that the CAFE standard for 2016 will be an average of 34.1 mpg for passenger cars and light trucks. By 2021, the standard will be 41 mpg, and nearing 50 by 2025. The U.S. imports about 45 percent of the oil we use. Our dependence on foreign oil for gasoline will be greatly lessened by these new standards.

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

Fuel Economy Estimate



Label source: www.fueleconomy.gov

Fuel Economy

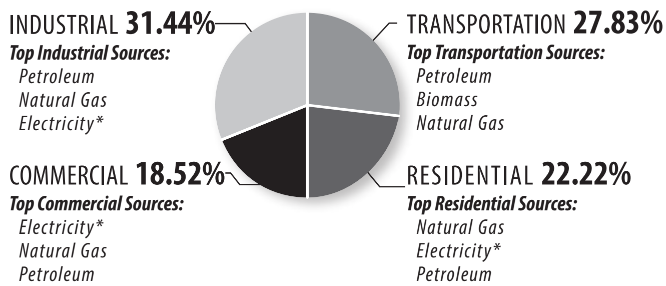
Follow these tips to increase fuel economy:

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

These behaviors lower fuel economy:

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

U.S. Energy Consumption by Sector, 2011



*Electricity is an energy carrier, not a primary energy source.
Note: Figures are independently rounded, and do not add up to 100%.
Data: Energy Information Administration

Industry

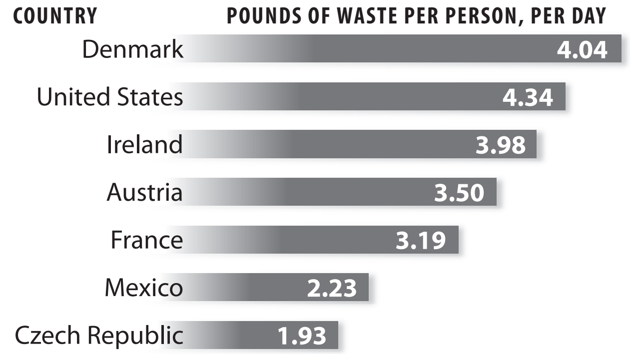
Manufacturing the goods we use every day consumes an enormous amount of energy. The industrial sector of the U.S. economy consumes almost one-third of the nation's total energy demand.

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.

Waste Generation Around the World



Data: Organisation for Economic Co-operation and Development

A Consumer Society

Not only is America a consumer society, it is also a 'throw away' society. In 2010, the U.S. produced 249.86 million tons of solid waste. The average citizen generates more than 1,600 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 whenever possible. Purchasing only those items that are necessary, as well as reusing and recycling products wherever possible, can significantly reduce energy use in the industrial sector.

The three "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 1.25 pounds of iron ore. Recycling one glass bottle saves enough energy to power a computer for 30 minutes. Recycling aluminum cans saves 95 percent of the energy required to produce aluminum from bauxite. Recycling paper cuts energy usage by 60 percent.

Energy Sustainability

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

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

Glossary

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

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

d

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

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

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

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

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

porous	having tiny openings or spaces in a material that can hold fluid
potential energy	the energy stored within a body, due to place or position
power	the rate at which energy is transferred; electrical energy is usually measured in watts; also used for a measurement of capacity
power plant	a facility where power is generated
power pool	a group of electric utilities able to share power as needed
propane	a normally gaseous straight-chain hydrocarbon; it is a colorless paraffinic gas that boils at a temperature of -43.67 degrees Fahrenheit; it is extracted from natural gas or refinery gas streams
pump stations	stations located along pipelines that monitor and control the movement of petroleum and natural gas products
pumped storage system	a method of storing and producing electricity to supply high peak demands by moving water between reservoirs at different elevations

q

quadrillion Btu (Q)	one quadrillion (1015= 10 to the 15th power) British thermal units (Btu), often referred to as a quad

r

R-value	a measure of a material's resistance to heat flow in units of Fahrenheit degrees x hours x square feet per Btu; the higher the R-value of a material, the greater its insulating capability
radiant energy	any form of energy radiating from a source in electromagnetic waves
radiation	any high-speed transmission of energy in the form of particles or electromagnetic waves
radioactive decay	a natural process where atoms give up energy and particles become stable; radioactive waste from a power plant has not yet become stable and, thus, can be harmful
reactor	part of a nuclear power station
recycling	the process of converting materials that are no longer useful as designed or intended into a new product
refinery	an industrial plant that heats crude oil (petroleum) so that is separates into chemical components, which are then made into more useful substances
reliability	the ability of a utility provider to provide electricity to customers without disruption
renewable	fuels that can be easily made or replenished; we can never use up renewable fuels; types of renewable fuels are hydropower (water), solar, wind, geothermal, and biomass
repository	a site for storage
reserves	natural resources that are technically and economically recoverable
reservoir	natural or artificial storage facility
residential sector (of the economy)	the part of the economy having to do with the places people stay or live; the residential sector is made up of homes, apartments, condominiums, etc.
resistance (R)	a measure of the amount of energy per charge needed to move a charge through an electric circuit, usually measured in ohms
Ring of Fire	a region of high geothermal activity in the Pacific Ocean, located along several plate boundaries
rock-catcher	implement used to separate steam and rocks from a geothermal reservoir
room-and-pillar mining	method of coal mining where coal is left behind in column formations to prevent the mine from collapsing

s

scrubber	air pollution control device that power plants use to remove particulate matter and gases from their emissions
Seasonal Energy Efficiency Ratio (SEER)	rating system used to compare efficiency of heat pumps and cooling systems (see also *EER*)
secondary source of energy	also known as energy carriers, these sources require another source of energy to be created; electricity is an example of a secondary source of energy
sedimentary	a type of rock formed by deposits of earth materials, or within bodies of water; oil and gas formations, as well as fossils are found within sedimentary rock formations; coal is a sedimentary rock
semiconductor	any material that has a limited capacity for conducting an electric current; semiconductors are crystalline solids, such as silicon, that have an electrical conductivity between that of a conductor and an insulator

	smelting	producing a metal from its ore, separating the metallic parts of an ore
	solar cell	an electric cell that changes radiant energy from the sun into electrical energy by the photovoltaic process
	solar energy	the radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity
	solar power tower	the conceptual method of producing electrical energy from solar rays; involves the focusing of a large number of solar rays on a single source (boiler), usually located on an elevated tower, to produce high temperatures; a fluid located in or passed through the source changes into steam and is used in a turbine generator to produce electrical energy
	smart meters	digital two-way electric meters that allow for communication between the meter (consumer) and the utility
	sound energy	energy that travels in longitudinal waves
	spent fuel	irradiated fuel that is permanently discharged from a nuclear reactor
	spillway gate	a gate or apparatus at a dam that helps to control the water level of a reservoir; gates release excess water following heavy rainfall
	steam generator	a generator in which the prime movers (turbines) are powered by steam
	steam reforming	a process to create hydrogen through the heating of a fuel (typically fossil fuels)
	stored mechanical energy	energy stored through the application of a force to stretch or compress an item
	superconductivity	having little to almost no electrical resistance
	surface mining	takes place within a few hundred feet of the surface; earth above or around the coal (overburden) is removed to expose the coal bed, which is then mined with surface excavation equipment
	sustainable	describing a behavior or practice that is capable of being continued with minimal effects on the environment
t	tank farm	an installation used by trunk and gathering pipeline companies, crude oil producers, and terminal operators (except refineries) to store crude oil
	thermal energy	the total potential and kinetic energy associated with the random motions of the atoms and molecules of a material; the more the molecules move and vibrate the more energy they possess
	thermostat	a device that adjusts the amount of heating and cooling produced and/or distributed by automatically responding to the temperature in the environment
	tide	rising and falling of sea level due to the gravitational force of the moon and sun, as well as the rotation of the Earth
	transformer	a device that converts the generator's low-voltage electricity to higher-voltage levels for transmission to the load center, such as a city or factory
	transmission line	a set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points
	transportation sector (of the economy)	the part of the economy having to do with how people and goods are transported (moved) from place to place; the transportation sector is made up of automobiles, airplanes, trucks, ships, trains, etc.
	turbine	a device with blades, which is turned by a force, such as that of wind, water, or high pressure steam; the mechanical energy of the spinning turbine is converted into electricity by a generator
u	underground (deep) mining	coal mining that takes place several hundred feet below the surface of the Earth; workers and coal enter and exit through a vertical shaft; see *longwall mining* or *room-and-pillar mining*
	uranium	a heavy, naturally-occurring, radioactive element
	uranium fuel cycle	the series of steps involved in supplying fuel for nuclear power reactors; it includes mining, refining, the making of fuel elements, their use in a reactor, chemical processing to recover spent (used) fuel, re-enrichment of the fuel material, and remaking into new fuel elements
v	volt (V)	the International System of Units (SI) measure of electric potential or electromotive force; a potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance; reduced to SI base units, 1 V = 1 kg times m2 times s-3 times A-1 (kilogram meter squared per second cubed per ampere)

	voltage	the difference in electrical potential between any two conductors or between a conductor and the ground; it is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors
w	waste-to-energy plant	a power plant that generates electricity by burning garbage
	water cycle	water constantly moves through a vast global cycle, in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, then flows back to the ocean; the energy of this water cycle, which is driven by the sun, is tapped most efficiently with hydropower
	watt	a metric unit of power, usually used in electric measurements, which gives the rate at which work is done or energy is used
	well	a hole drilled in the Earth for the purpose of (1) finding or producing crude oil or natural gas; or (2) producing services related to the production of crude oil or natural gas
	wind	the term given to any natural movement of air in the atmosphere; a renewable source of energy used to turn turbines to generate electricity
	wind farm	a series or group of wind turbines in the same location
	wind turbine	device powered by the wind that produces mechanical or electrical power
y	yellowcake	a natural uranium concentrate that takes its name from its color and texture; yellowcake typically contains 70 to 90 percent U_3O_8 (uranium oxide) by weight; it is used as feedstock for uranium fuel enrichment and fuel pellet fabrication

Index

2014 Youth Awards for Energy Achievement

All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.

This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

What's involved?

Students and teachers set goals and objectives, and keep a record of their activities. In April, students combine their materials into scrapbooks and send them in and write summaries of their projects for inclusion in the Annual Report.

Want more info? Check out **www.NEED.org/Youth-Awards** for more application and program information, previous winners, and photos of past events.

NEED's Online Resources

ENERGY EXCHANGE AND CAREER CURRENTS NEWSLETTERS

NEED publishes two newsletters. *Energy Exchange* is published to keep teachers and partners informed about new curriculum materials, current energy issues, and opportunities available for teachers and students. *Career Currents* is published to provide students with information about a variety of careers in the energy industry. The newsletters are distributed to all NEED teachers, partners, and sponsors. The latest edition of each newsletter and archived editions are available on the NEED web site at www.NEED.org.

NEED'S SMUGMUG GALLERY

http://need-media.smugmug.com/

You can find pictures of NEED students learning and teaching about energy. You can also find pictures from NEED workshops, and photos of energy from around the country that were submitted for the Great American Energy Scavenger Hunt. Would you like to submit images or videos to NEED's gallery?

E-mail info@NEED.org for more information.

Use SmugMug for the following resources:

Videos

Need a refresher on how to use *Science of Energy* with your students? Watch the *Science of Energy* videos. Also check out our *Energy Chants* videos!

Find videos produced by NEED students teaching their peers and community members about energy.

Online Graphics Library

Would you like to use NEED's graphics in your own classroom presentations, or allow students to use them in their presentations? Download graphics for easy use in your classroom.

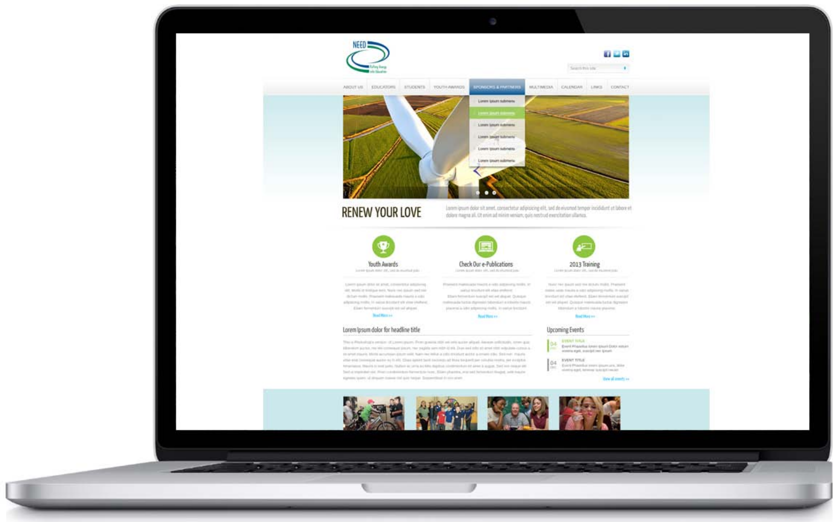
NEED Energy Booklist

Looking for cross-curricular connections, or extra background reading for your students? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org.

U.S. Energy Geography

Maps are a great way for students to visualize the energy picture in the United States. This set of maps will support your energy discussion and multi-disciplinary energy activities.

Go to www.NEED.org/maps to see energy production, consumption, and reserves all over the country!



E-PUBLICATIONS

The NEED Project now offers e-publication versions of various guides for in-classroom use. Go to www.NEED.org/. Don't see what you're looking for? Check back often, as new e-pubs will be added throughout the year.

SOCIAL MEDIA

Stay up-to-date with NEED, "like" us on Facebook! Search for The NEED Project.

Follow us on Twitter. We share the latest energy news from around the country, @NEED_Project.

Read the latest from the NEED family in our blog! Visit it at www.NEED.org.

NEED ANNUAL REPORT

NEED's Annual Report gives summaries of the best state and national Youth Awards projects for 2012–2013, as well as information about The NEED Project and our state programs.

Annual Report	Upon Request

Online at www.NEED.org

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New Mexico Landman's Association
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