2020-2021

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:

Secondary

Subject Areas:

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

NEED
National Energy Education Development Project

Teacher Advisory Board

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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.

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Energy Data Used in NEED Materials

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NEED
National Energy Education Development

1.800.875.5029
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Secondary Energy Infobook

Table of Contents

Standards Correlation Information

https://www.need.org/educators/curriculum-correlations/

Next Generation Science Standards

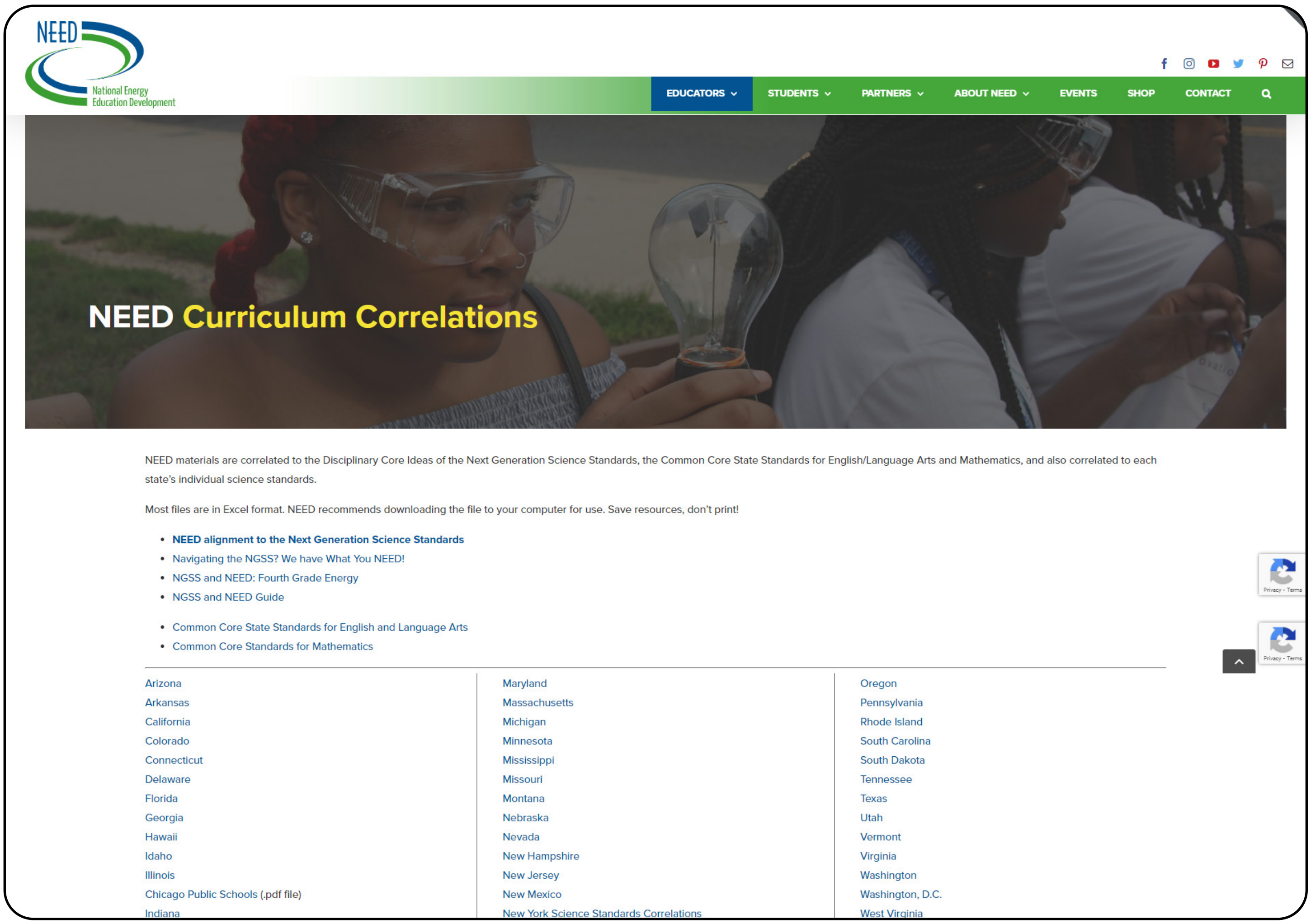
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

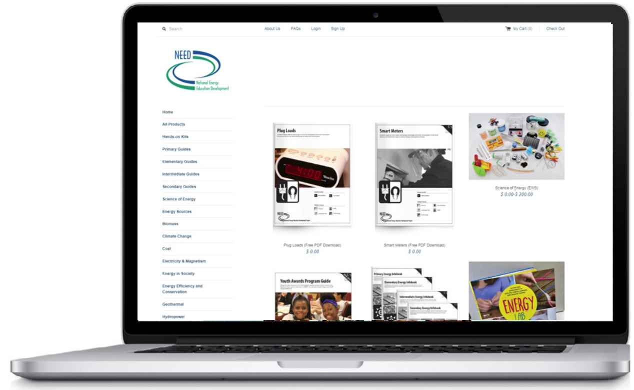
Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.



NEED Secondary Curriculum Resources

For more in-depth information, inquiry investigations, and engaging activities, download these curriculum resources from shop.NEED.org to fit with our eight-step, comprehensive energy unit.



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 Coal Exploring Hydroelectricity Exploring Nuclear Energy Exploring Ocean Energy and Resources Exploring Oil and Natural Gas Exploring Photovoltaics Exploring Wind Energy Fossil Fuels to Products Great Energy Debate H_2 Educate Schools Going Solar Secondary Energy Infobook Activities U.S. Energy Geography Wind for Schools
STEP THREE: Electricity and Magnetism	Current Energy Affair Energy Games and Icebreakers Mission Possible Secondary Energy Infobook Activities
STEP FOUR: Transportation	Energy Expos Energy on the Move Exploring Hybrid Buses H_2 Educate Transportation Fuels Debate Transportation Fuels Enigma Transportation Fuels Live!

STEP FIVE: Efficiency and Conservation	Chemistry and Energy Efficiency Energy Conservation Contract Energy Expos Energy Games and Ice Breakers Energy House Exploring Climate Science Managing Home Energy Use Museum of Solid Waste and Energy Plug Loads School Energy Managers
STEP SIX: Synthesis and Reinforcement	Carbon Capture, Utilization, and Storage Digital Energy Energy Analysis Energy and Our Rivers Energy Around the World Energy Games and Icebreakers Energy Jeopardy Energy Live! Energy Math Challenge Energy on Stage Global Trading Game NEED Songbook
STEP SEVEN: Evaluation	Energy Polls Question Bank
STEP EIGHT: Student Leadership and Outreach	Blueprint for Student Energy Teams Youth Awards Program Guide

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 potential 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. Foods we eat, 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.
- **Elastic energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic 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.

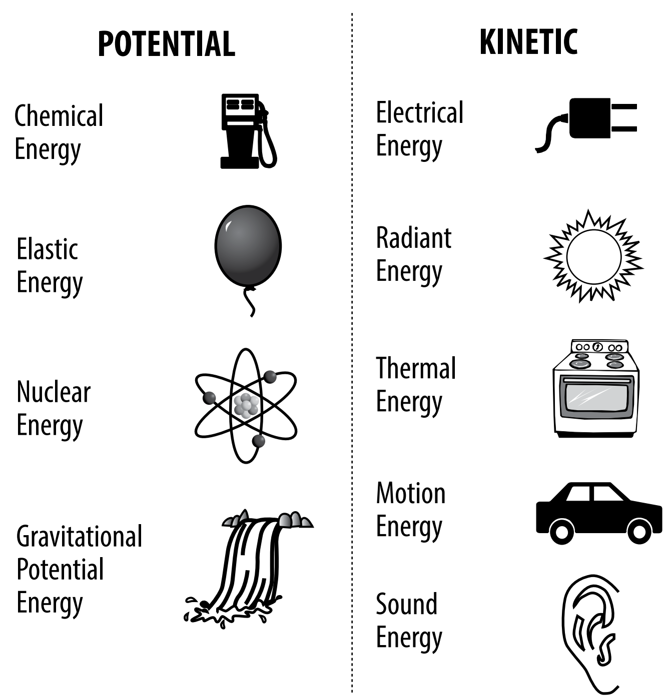
Energy at a Glance, 2018

	2017	2018
World Population	7,530,360,000	7,594,270,000
U.S. Population	325,147,000	327,167,000
World Energy Production	74.894 Q	*
U.S. Energy Production	88.261 Q	95.722 Q
• Renewables	11.301 Q	11.617 Q
• Nonrenewables	76.960 Q	75.667 Q
World Energy Consumption	582.46 Q	*
U.S. Energy Consumption	97.809 Q	100.961 Q
• Renewables	11.181 Q	11.301 Q
• Nonrenewables	84.464 Q	89.660 Q

Q = Quad (10^{15} Btu), see Measuring Energy on page 8.
* 2018 world energy figures not available at time of print.
Data: Energy Information Administration

**Totals may not equal sum of parts due to rounding of figures by EIA.

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**, which is often described as 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** or mechanical 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.

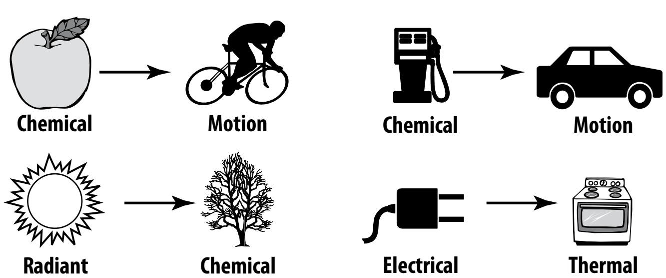
Conservation of Energy

Your parents may tell you to conserve energy. "Turn off 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.

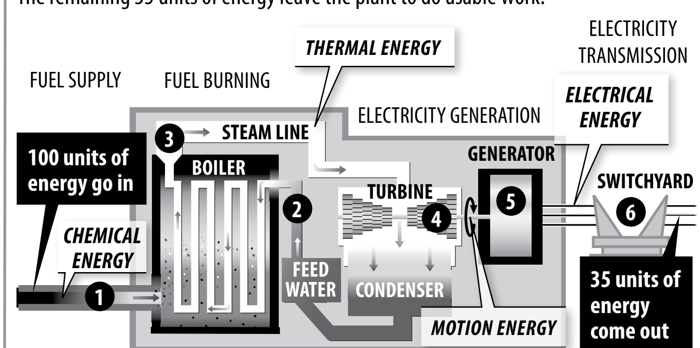
In fact, most energy transformations are not very efficient. The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. Your body is very inefficient at converting food into useful work. Most of the energy in your body is released as thermal energy.

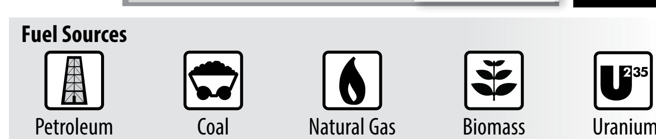
A traditional incandescent light bulb isn't efficient either. This type of light bulb converts only ten percent of the electrical energy into light and the rest (90 percent) is converted into thermal energy. That's why these light bulbs are so hot to the touch. Their inefficiency is also why these bulbs are no longer sold for use in homes, and why many consumers use LEDs for lighting.

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

Efficiency of a Thermal Power Plant

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





How a Thermal Power Plant Works

1. Fuel is fed into a boiler, where it is burned to release thermal energy. Nuclear plants are thermal plants but the fuel is not burned, however, and undergoes a nuclear fission reaction to heat water.
2. Water is piped into the boiler and heated, turning it into steam.
3. The steam travels at high pressure through a steam line.
4. The high pressure steam turns a turbine, which spins a shaft.
5. Inside the generator, the shaft spins a ring of magnets inside coils of copper wire. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage,

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. More than one hundred thirty-five 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, natural gas, petroleum, 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 cell phones.

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.

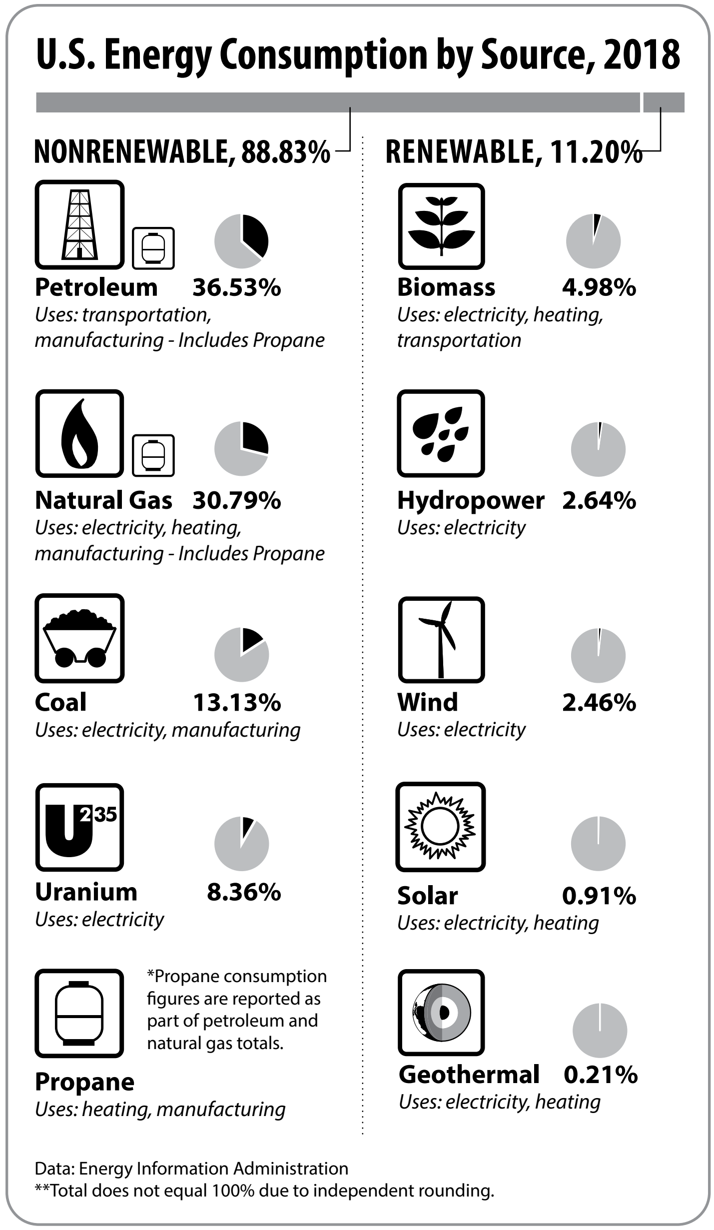
Is electricity a renewable or nonrenewable source of energy? The answer is neither. Electricity is different from the other energy sources because it is a **secondary source of energy**. That means we have to use another energy source to make it. In the United States, natural gas is the number one fuel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

Measuring Energy

"You can't compare apples and oranges," the old saying goes. That holds true for energy sources. We buy gasoline in gallons, wood in cords, and natural gas in cubic feet. How can we compare them? With **British thermal units (Btu)**, 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 846.819 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 approximately every 3.61 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high. However, 2018 was not too far off with 100.961 quads consumed.



Energy Use

Imagine how much energy you use every day. You wake up to an electric alarm clock or the vibration from your cell phone. You take a shower with water warmed by a water heater using electricity or natural gas.

You listen to music on your smart phone as 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 a little more than seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to a little more than 2,300 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, electric power,** 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 often 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 11.58 percent of the primary energy supply in 2018, with a total of 11.689 quads. The residential sector consumed 6.901 quads and the commercial sector consumed 4.788 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 22.940 quads of energy in 2018, which accounted for 22.72 percent of total consumption.

▪ Electric Power

The electric power sector includes electricity generation facilities and power plants. All of the other sectors consume electricity generated by the electric power sector. The electric power sector consumed 37.81 percent of the total energy supply in 2018 more than any of the other sectors, with a total of 38.170 quads.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2018, the U.S. consumed 28.401 quads of energy for transportation, which accounted for 28.13 percent of total consumption. 91.68 percent of this energy was from petroleum products such as gasoline, diesel, and jet fuel.

Energy Use and Prices

Several decades ago, 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.

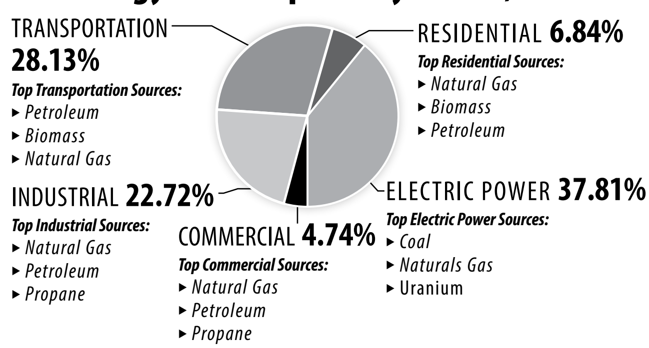
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

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 2018, the United States used 33 percent more energy than it did in 1973. That might sound like a lot, but the population has increased by over 54 percent and the nation's **gross domestic product** was 3.182 times that of 1973.

You may wonder why the 1970s are important—it was so long ago. However, the energy crisis during this decade taught us a valuable lesson. 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, 2018



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

Data: Energy Information Administration

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

Biomass

Biomass at a Glance, 2018

Classification:
- renewable

Major Uses:
- industry, transportation fuel, electricity

U.S. Energy Consumption:
- 5.031 Q
- 4.98%

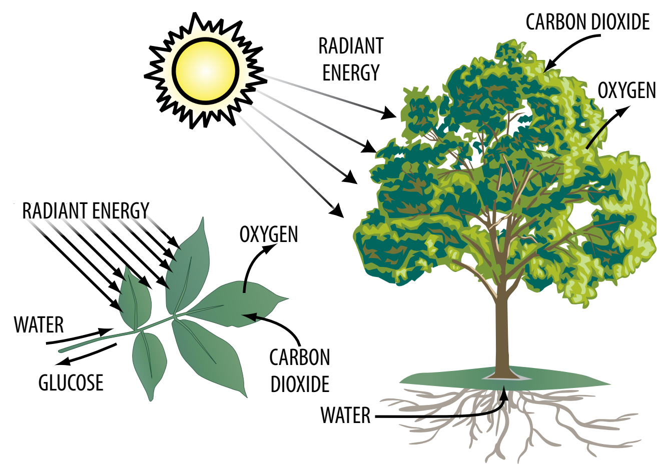
U.S. Energy Production:
- 5.338 Q
- 5.58%

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

Data: Energy Information Administration

Photosynthesis

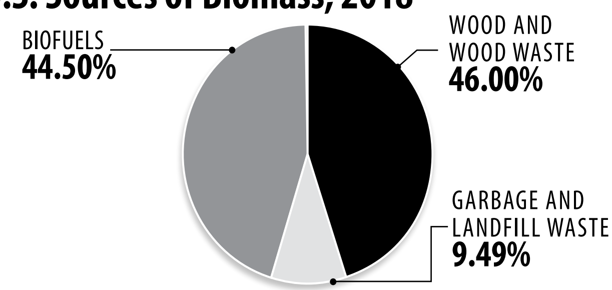
In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



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, 2018



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

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 46 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 a process called **cogeneration**. 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 for well over half of their energy needs. Other industries that use biomass include lumber producers, furniture manufacturers, agricultural businesses like nut and rice growers, and liquor producers.

▪ Solid Waste

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 just 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.

- **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 to generate electricity.

Methane, the main ingredient in natural gas, is a good energy source. Most gas stoves and furnaces 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 more than 8,000 Kentucky homes. More than 500 facilities across the country use their landfill gas for electricity.

However, still only 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 less economical to collect. Methane, however, is a more powerful greenhouse gas than carbon dioxide. It is better for the environment 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 present 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 can 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. In 2018, biomass provided 4.98 percent of the total energy we consumed. Biomass has largely been replaced by coal, natural gas, and petroleum.

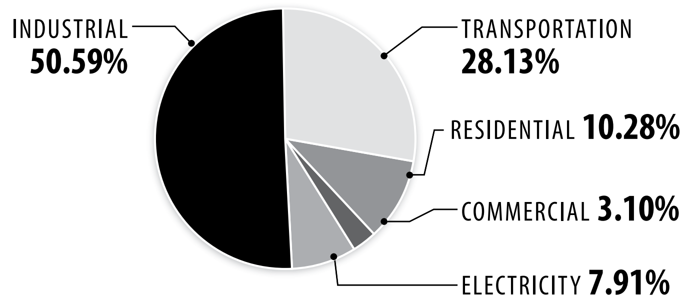
Forty-six percent of the biomass used today comes from burning wood and wood scraps such as saw dust. About 45 percent is from **biofuels**, principally ethanol, that are used as a gasoline additive. The rest comes from crops, garbage, and landfill gas.

Industry is the biggest user of biomass. Fifty percent of biomass is used by industry. Electric utilities use 10 percent of biomass for power generation. In turn, biomass produces 1.49 percent of the electricity we use.

Transportation is the next biggest user of biomass; about 28 percent of biomass is used by the transportation sector to produce biofuels like **ethanol** and **biodiesel** (see pages 12-13).

The residential sector uses about 10 percent of the biomass supply. The most recently reported data showed about three percent of American homes use wood as the only source of heat. Most of these homes burn wood in fireplaces and wood stoves for heat.

U.S. Biomass Consumption by Sector, 2018



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

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. Landfills can recover and use 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 type of alcohol made from fermenting wood. Methane and methanol each have only one carbon atom.

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**. Burning biomass releases carbon dioxide, but growing plants for use as biomass fuels may also help keep carbon dioxide levels balanced. Plants remove carbon dioxide—a **greenhouse gas**—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 around 10 percent ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency (EPA) 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. As of 2017, more than 21 million flexible fuel vehicles (FFV) have been on the road with the ability to run efficiently on E85 or E10. However, it is estimated that only a small percentage of these vehicles use E85 regularly.

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 cruising 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

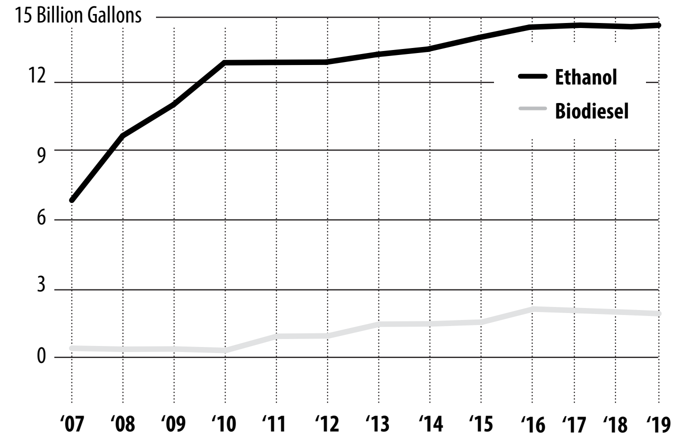
In 2019, ethanol plants in the U.S. produced more than 16.5 billion gallons of ethanol. There are 200 plants operating nationwide. These plants are located mostly in the Midwest. Many new plants are in the planning stages. There are currently over 3,600 E85 fueling stations in 44 states. Ethanol fuels 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 exceeding this mark, producing over 16 billion gallons of ethanol alone in 2019. For comparison, however, the U.S. consumed over 125 billion gallons of gasoline in 2019. 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, 2019



Data: Energy Information Administration

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. However, 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 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.

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 have switched from diesel to biodiesel blends to reduce emissions and improve air quality.

Characteristics of Biodiesel

Biodiesel exceeds diesel in cetane number, resulting in superior ignition. The cetane number is the performance rating of diesel fuel. Biodiesel also has a higher flash point, or ignition temperature, 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. There are relatively few public pumps that offer biodiesel. With over 300 biodiesel fueling stations, it is a more practical fuel for fleets with their own fueling facilities. Availability for consumers is steadily expanding as demand grows.

BIODIESEL FUELING STATION

Photo courtesy of Elly Jonez via wikimedia commons

Economics of Biodiesel

Today, B99-B100 costs about $3.72 a gallon, but costs can vary depending on region, the base crop, purchase volume, and delivery costs. Historically, all biodiesel blends cost more than diesel. In 2005, a Biodiesel Excise Tax Credit went into effect, but these credits have expired, eliminating incentives for biodiesel use.

Because it is stored in existing infrastructure and can fuel vehicles without modification, biodiesel has emerged as a popular 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.

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.

Like other transportation fuels, when biodiesel is burned it releases CO_2. CO_2 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.

WASTE OIL

Photo courtesy of Joe Mabel via wikimedia commons

SOYBEAN FIELD

Coal

Coal at a Glance, 2018

Classification:
- nonrenewable

Major Uses:
- electricity, industry

U.S. Energy Consumption:
- 13.252 Q
- 13.13%

U.S. Energy Production:
- 15.36 Q
- 16.05%

Data: Energy Information Administration

What Is Coal?

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

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

Millions to 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.

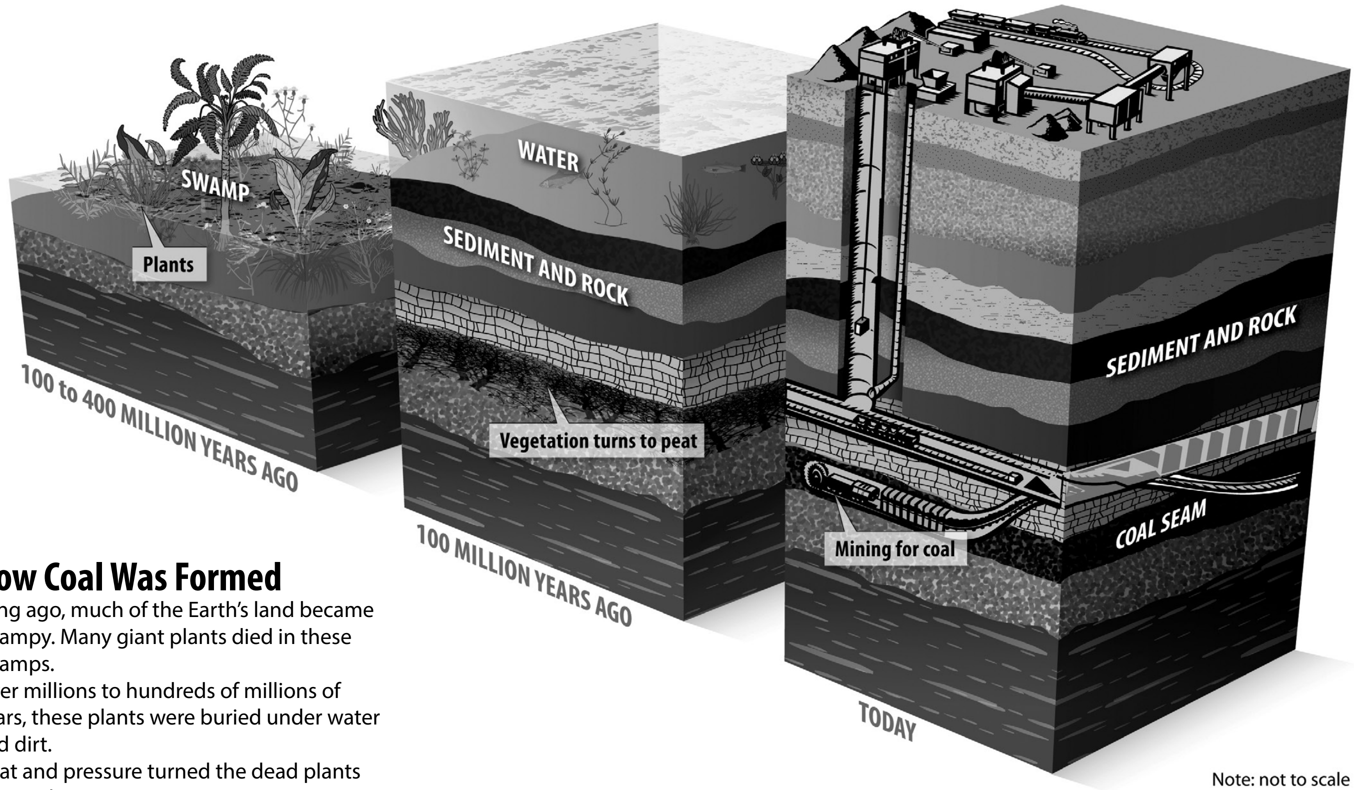
Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

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 natural gas furnaces instead.



How Coal Was Formed

Long ago, much of the Earth's land became swampy. Many giant plants died in these swamps.
Over millions to hundreds of millions of years, these plants were buried under water and dirt.
Heat and pressure turned the dead plants into coal.

Coal

Coal production reached its low point in 1961. Since 1970, coal production reached high points where coal production was up by as much as 48%. Today, coal supplies about 13 percent of the nation's total energy needs, mostly for electricity production, but has seen a decline in recent years.

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.

About 64 percent of the nation's coal is obtained through surface mining. Surface mining is typically much less expensive than underground mining. With new technologies, surface mining productivity has more than doubled since 1970.

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

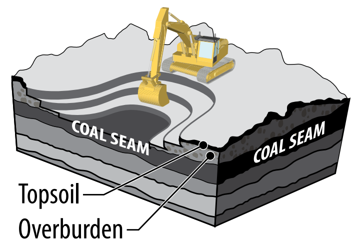
After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other impurities, increasing the heating value of the coal.

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.

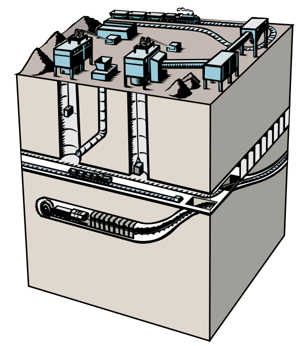
Underground pipelines can easily move petroleum and natural gas to market. But that's not so for coal. Huge trains transport more than two thirds of U.S. coal for some or all of its journey to market.

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 eight percent of the coal mined in 2018 in the U.S. was lignite.

Subbituminous coal typically contains less heating value (8,300 to 13,000 Btu per pound) than bituminous coal and more moisture. It contains 35 to 45 percent carbon. 45 percent of the coal mined in 2018 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. 47 percent of the coal mined in 2018 in the U.S. 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 2018 in the U.S. was anthracite.

Coal Reserves

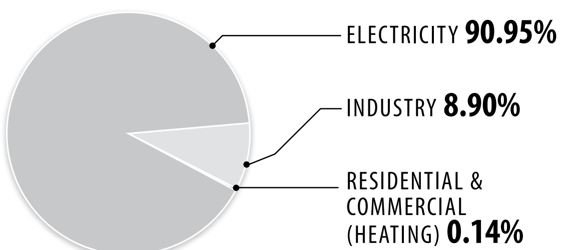
When scientists estimate how much coal, petroleum, natural gas, or other energy sources there are in the United States, they use the term **reserves**. Reserves are deposits that can be harvested using today's methods and technology.

Experts estimate that the United States has over 253 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 over 325 years. 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. Coal is also found in large quantities in Illinois, Wyoming, West Virginia, Kentucky, Ohio, and Pennsylvania. Western coal generally contains less sulfur than eastern coal.

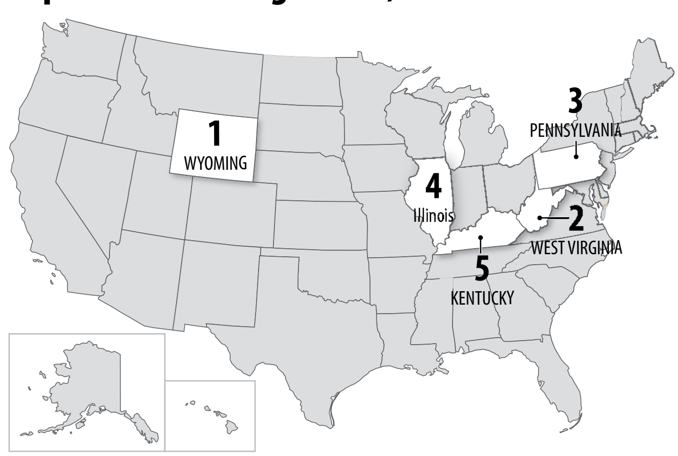
The Federal Government is by far the largest owner of the nation's coalbeds. In the West, the Federal Government owns approximately 60 percent of the coal and indirectly controls another 20 percent. Coal companies must lease the land from the Federal Government in order to mine this coal.

U.S. Coal Consumption by Sector, 2018



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

Top Coal Producing States, 2018



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 24 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 2018, the West provided 59 percent of total production, and states east of the Mississippi River provided 41 percent.

Total U.S. coal production was 756 million short tons in 2018. The leading coal states are Wyoming, West Virginia, Pennsylvania, Illinois, and Kentucky. These five states produce over 72 percent of the coal in the U.S.

Some coal produced in the United States is exported to other countries. In 2018, foreign countries bought about 15.29 percent of all the coal produced in the U.S. The biggest foreign markets for U.S. coal are the Netherlands, South Korea, India, Brazil, Japan, and Canada.

How Coal Is Used

The main use of coal in the United States is to generate electricity. In 2018, 91 percent of all the coal in the United States was used for electricity production. Coal generates about 27.5 percent of the electricity used in the U.S. Other energy sources used to generate electricity include natural gas, uranium (nuclear power), hydropower, 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. A very, very small amount 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 works 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 by modernizing their plants.

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 (CO_2) 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 agreement among scientists 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.

Most 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 and how these atmospheric concentrations affect the oceans, ice sheets, and ecosystems. 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, 2018

Classification:
- renewable

Major Uses:
- electricity, heating

U.S. Energy Consumption:
- 0.209 Q
- 0.21%

U.S. Energy Production:
- 0.209 Q
- 0.22%

Data: Energy Information Administration

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).

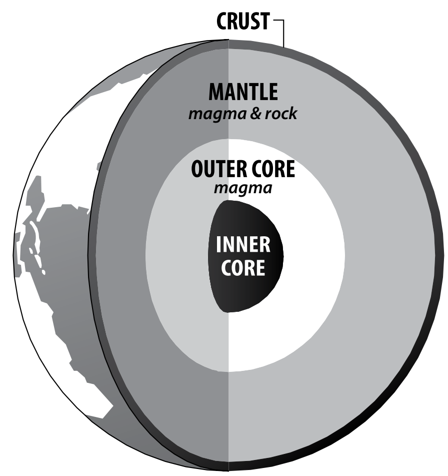
Surrounding the Earth's core is the **mantle**, thought to be partly rock and partly **magma**. The mantle is about 1,800 miles thick. The outermost layer of the Earth, the insulating **crust**, is not one continuous sheet of rock, like the shell of an egg, but is broken into pieces called plates.

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** (see page 20), which rims the Pacific Ocean and is bounded by Indonesia, the Philippines, Japan, the Aleutian Islands, North America, Central America, and South America.

Geothermal

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 (150 - 370ºC)—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 one of two dry steam field resources in the world and, after more than 50 years, still produces enough electricity to supply a city the size of San Francisco.

▪ Binary Cycle Power Plants

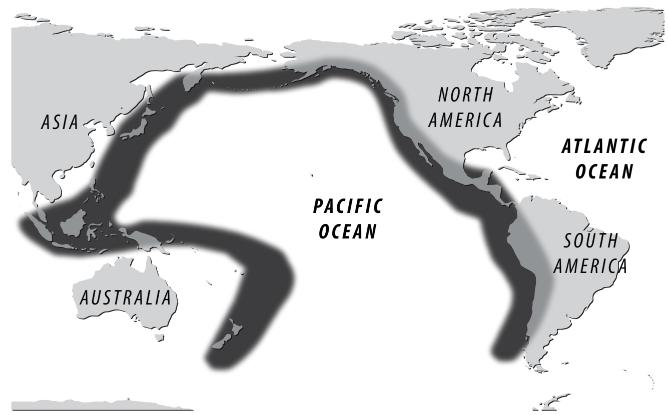
Binary cycle plants transfer the thermal energy from geothermal hot water to other liquids to produce electricity. The geothermal water is passed through a **heat exchanger** in a closed pipe system, and then reinjected into the reservoir. The heat exchanger transfers the heat to a working fluid—usually 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 (PGV) in Hawaii had the capacity to produce 38 megawatts of power, but the Kilauea volcanic eruption in 2018 forced PGV to cap the wells and cease production. The facility was providing 30 percent of the power consumed on the Big Island. The Big Island is using petroleum and renewables to make up for this loss until the facility is reopened in 2020.

Ring of Fire



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, Oregon, 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.

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 below ground 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 pipe buried in the ground. This liquid absorbs heat from the ground and carries it into the building. It also absorbs heat from the building during warmer months, and carries it out of the building, reducing the load of an air conditioner.

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

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

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

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

Geothermal systems cost more to install than conventional heating and cooling systems. Over the life of the system, however, they can produce significant cost savings. They can reduce heating costs by 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.

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.

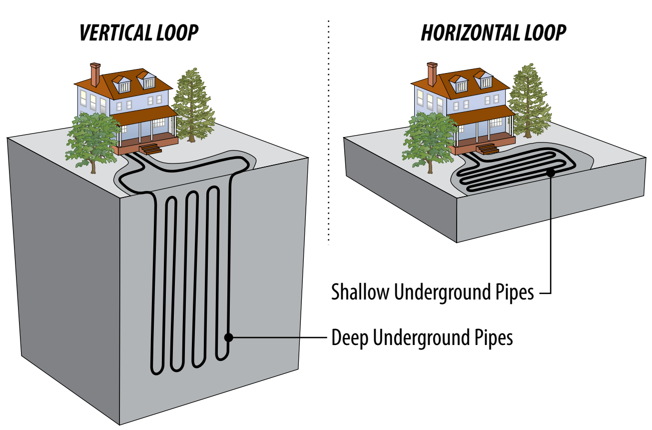
Geothermal Production

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.

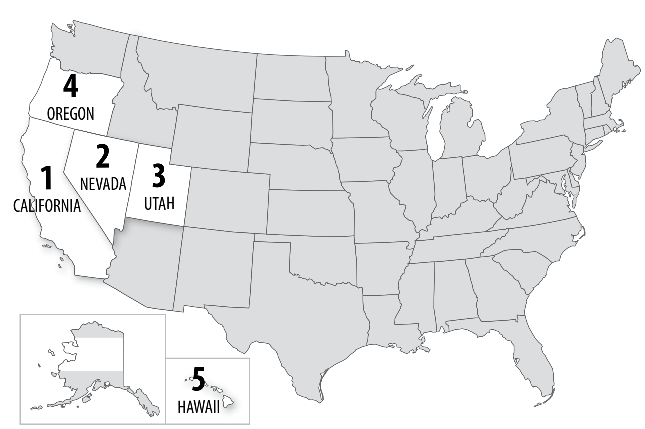
Geothermal power plants operate in California, Hawaii, Idaho, Nevada, New Mexico, Oregon, and Utah. Today, the total installed capacity of geothermal power plants in the United States is around 3,800 megawatts (MW). An additional 1,250 MW is proposed or under development. Since 2005, 38 projects have added 700 MW generating capacity.

In 2018, geothermal energy produced about 15.967 billion kilowatt-hours (kWh) of electricity, or 0.38 percent of the electricity used in this country. This is enough to serve the electricity needs of more than one and a half million households. California generates more electricity from geothermal energy than any other state.

Residential Geoexchange Units



Top Geothermal Producing States, 2018



Data: Energy Information Administration
*Hawaii plant not operational in part of 2018 and beyond.

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 kWh at a geothermal power plant, while the electric power generated sells for about five cents per kWh. In comparison, new 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 **baseload power**. Baseload power is power that electric utility companies must deliver all day long. Baseload geothermal plants can sell electricity any hour, day or night.

Geothermal Energy and the Environment

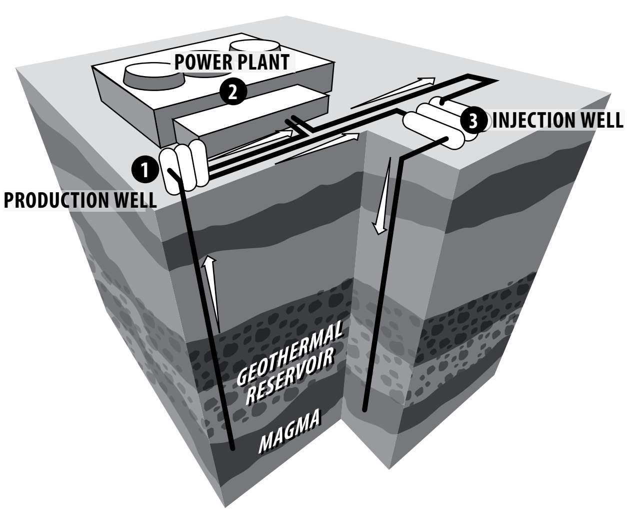
Geothermal energy is a renewable energy source that does little damage to the environment. Geothermal steam and hot water do contain naturally occurring traces of hydrogen sulfide (a gas that smells like rotten eggs) and other gases and chemicals that can be harmful in high concentrations.

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 spin 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.

Hydrothermal 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 2018, there were geothermal power plants in 22 countries, generating more than 82 billion kilowatt-hours of electricity. Direct uses of geothermal reservoirs provides thermal enegry in even more 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.

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

Hydropower

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 potential 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 powered multiple homes and businesses. It 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 the U.S. and Canada have hydropower plants at Niagara Falls. Dams, which create 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 91,000 dams in the United States, but only around 2,500 were built specifically for electricity generation. Most dams were built for recreation, flood control, fire protection, and irrigation.

Hydropower at a Glance, 2018

Classification:
- renewable

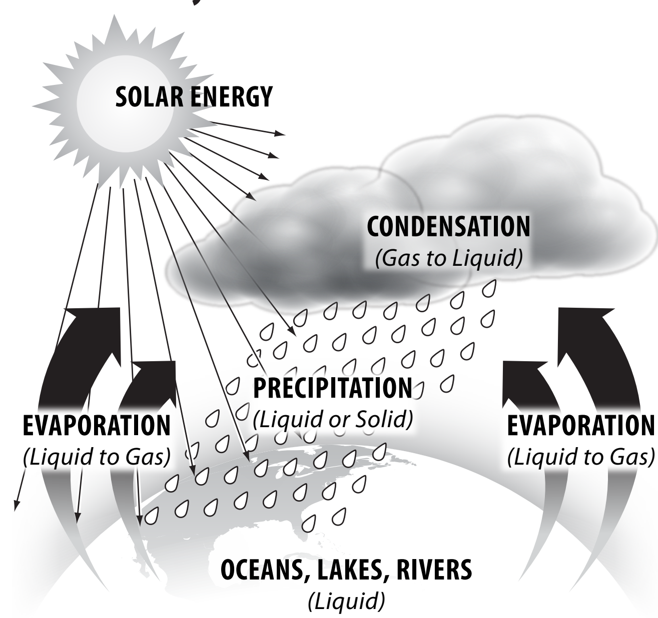
Major Uses:
- electricity

U.S. Energy Consumption:
- 2.663 Q
- 2.64%

U.S. Energy Production:
- 2.667 Q
- 2.79%

Data: Energy Information Administration

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 power 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.

Hydropower

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.

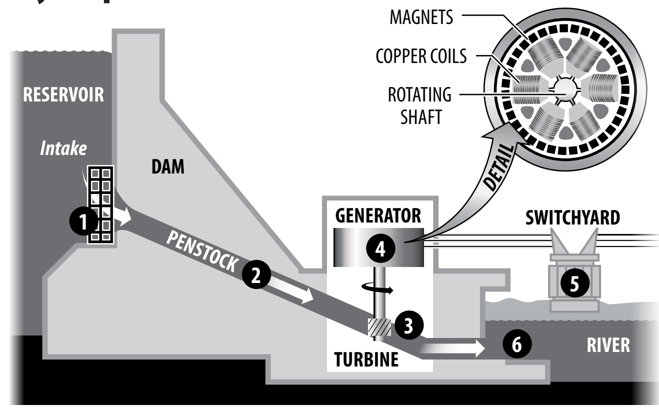
Pumped Storage Systems

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. In 1997, 10.21 percent of electricity came from hydropower—a historical high. However, in the last 15 years, U.S. hydroelectricity has ranged as low as 5.81 percent in 2001 to 7.79 percent in 2011, a recent high. In some states like Oregon, Washington, and Idaho, hydropower can account for more than half (55 to 69 percent) of each state's electricity generation.

Today, there is over 79,900 megawatts of conventional hydro generating capacity in the United States, and almost 102,000 megawatts when including pumped storage. That's equivalent to the generating capacity of 80 large nuclear power plants. In 2018, hydropower accounted for 6.89% of U.S. electricity. 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 new, large hydro plants is unlikely.

Existing plants can 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.

Hydropower for Baseload Power

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

Electric utility companies have to produce electricity to meet these changing demands. **Baseload power** is the electricity that utilities have to generate all the time. For that reason, baseload power should be cheap and reliable. Hydropower meets both of these requirements. Generating electricity with hydropower is one of the cheapest ways 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

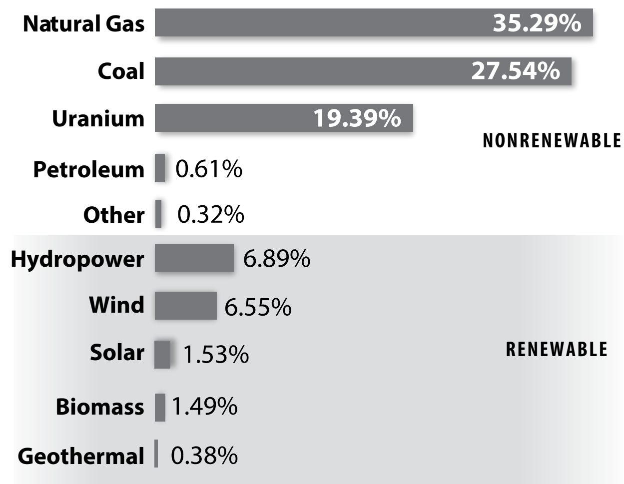
Hydropower is the cheapest way to generate electricity today. No other energy source, renewable or nonrenewable, can match it. It costs about one cent per kilowatt-hour (kWh) to produce electricity at a typical hydro plant. In comparison, it costs coal plants about four cents per kWh and nuclear plants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

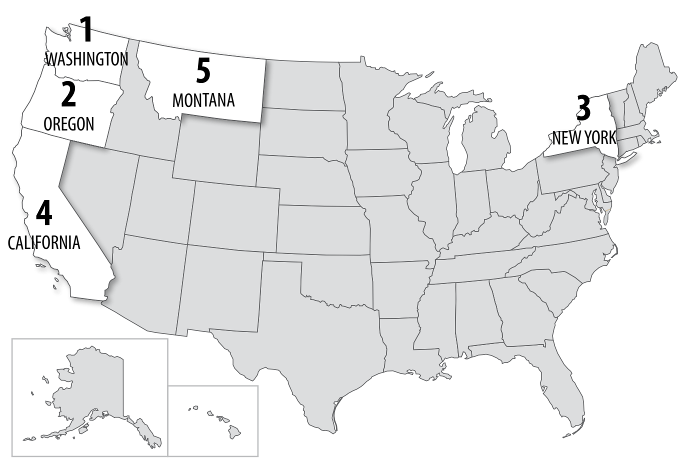
One requirement may increase hydropower's costs in the future. The procedure for licensing and relicensing dams has become a lengthy and expensive process. Many environmental impact studies must be undertaken and multiple state and federal agencies must be consulted. It takes up to seven years to get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

U.S. Electricity Net Generation, 2018



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

Top Hydropower Producing States, 2018



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 change 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 called 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. Though they produce no air pollution, the plants do affect the environment. 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.

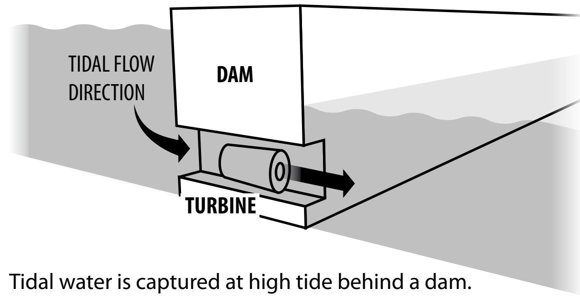
The United States has only a few sites where tidal energy could be produced economically. In 2012, Maine deployed the country's first commercial tidal power system connected to the grid. It is located in the Bay of Fundy and has the capacity to power up to 2,000 homes. France, England, Canada, and Russia have much more potential for tidal energy. The keys to a successful tidal energy project 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. Wave-energy devices 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 has an active wave-energy program. Currently, the only wave power projects in the U.S. are those in experimental studies.

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. A small, grid-connected facility was inaugurated in Hawaii in 2015. The facility can power up to 120 homes and has received expansion funding.

Today, there are several OTEC plants in design, development, and research phases across the globe. However, none of these plants are operating as large-scale, commercialized power production facilities at this time. OTEC has 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 fact sheet.*) 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 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

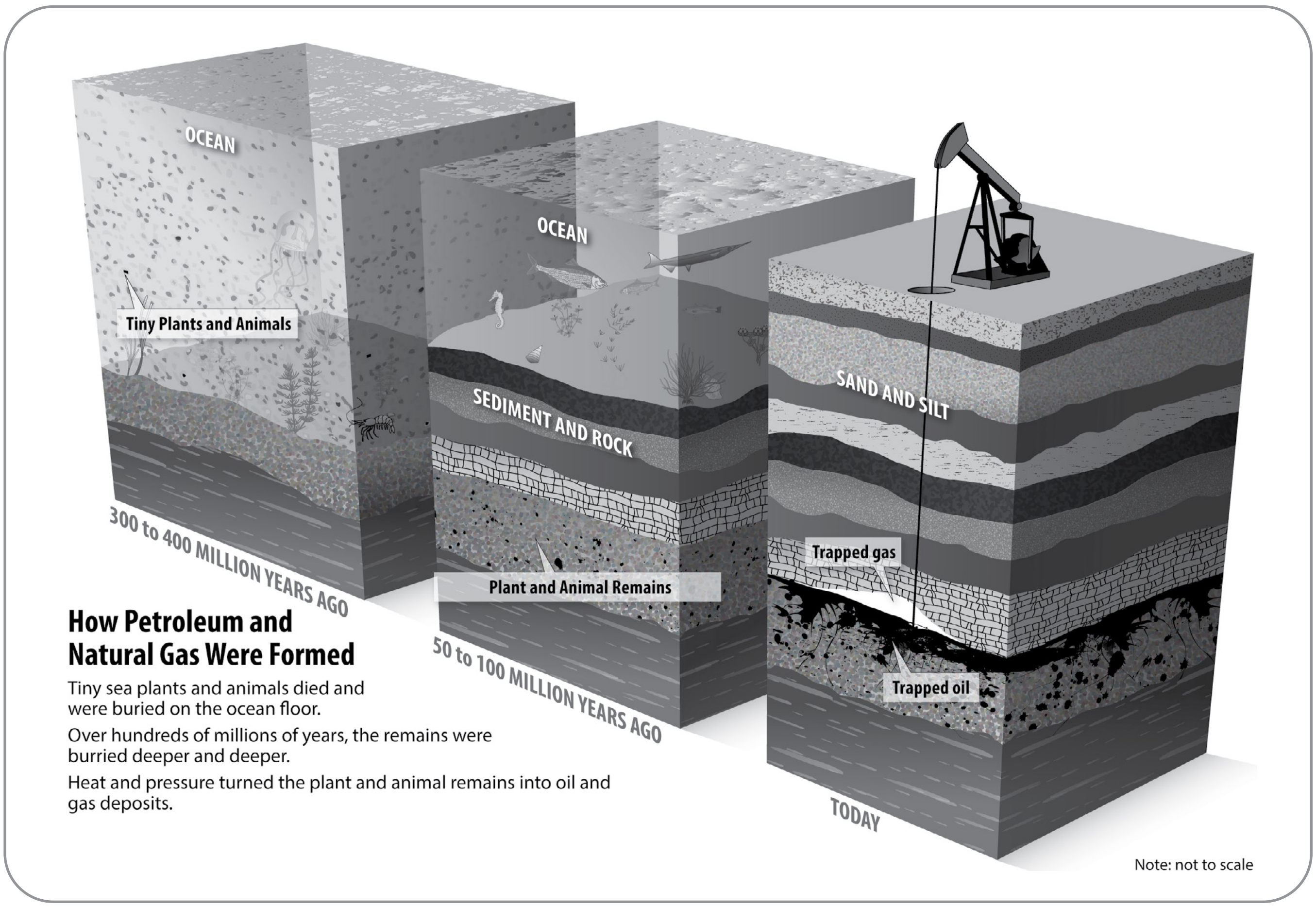
The ancient peoples of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeping from cracks in the ground was ignited by lightning. They sometimes built temples around these eternal flames so they could worship 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 over 30 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.

Natural Gas

Natural Gas at a Glance, 2018

Classification:
- nonrenewable

Major Uses:
- heating, industry, electricity

U.S. Energy Consumption:
- 31.088 Q
- 30.79%

U.S. Energy Production:
- 31.69 Q
- 33.11%

Data: Energy Information Administration

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 more than 8,600 feet deep and can cost hundreds of dollars per foot to drill, so it's important to choose sites carefully.

In the past few years, around 60 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. Over 90 percent of the developmental wells drilled recently yield gas. Natural gas can be found in pockets by itself or in petroleum deposits.

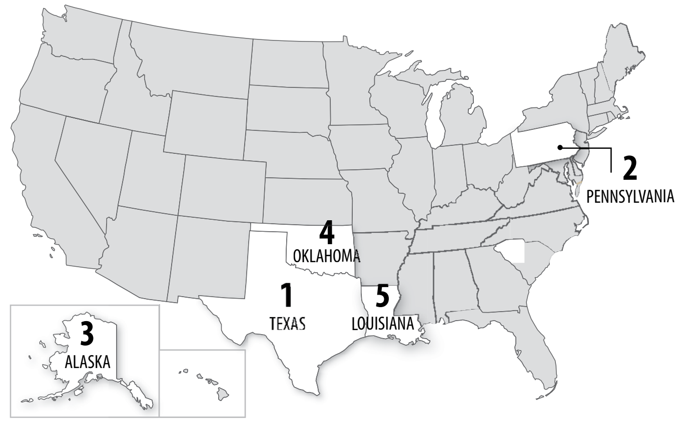
After natural gas comes out of the ground, it goes to a processing plant where it is cleaned of impurities and separated into its various components. Approximately 90 percent of natural gas is composed of methane, but it also contains other gases such as propane and butane.

Natural gas may also come from several other sources. One source is coalbed methane, natural gas found in 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. Just under three percent of the total natural gas produced in the last few years 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.

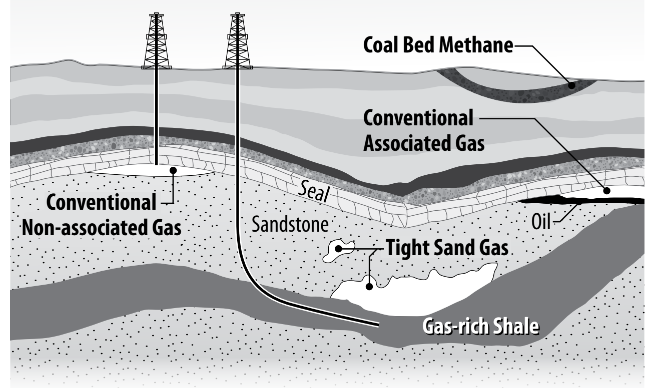
Today, natural gas is produced in 33 states, but the top five states—Texas, Pennsylvania, Alaska, Oklahoma, and Louisiana—produce 65 percent of the total. Natural gas is also produced offshore. A little less than five percent of U.S. natural gas comes from offshore wells. Altogether, the U.S. produces about one-fifth of the world's natural gas each year.

Top Natural Gas Producing States, 2018

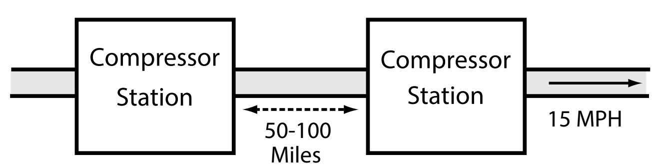


Data: Energy Information Administration

Locations of Natural Gas



Natural Gas Distribution System



Transporting and Storing Natural Gas

How does natural gas get to you? Usually by pipeline. Over 2.4 million miles of underground **pipelines** link natural gas wells to cleaning plants to major cities across the United States. Natural gas is sometimes transported thousands of miles by pipeline to its final destination.

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

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

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

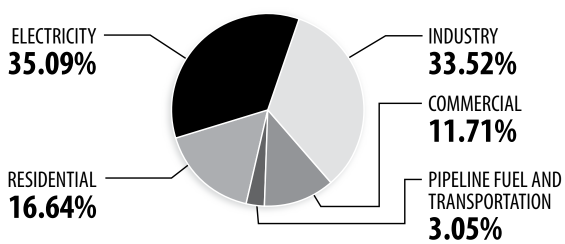
Natural Gas Use

Just about everyone in the United States uses natural gas. Natural gas ranks second in energy consumption, after petroleum, with 30.79 percent of the energy we use in the United States coming from natural gas.

Industry uses about 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 a little more than one quarter of the natural gas in the country. Approximately half of homes use natural gas for heating and cooking. Many homes also use gas water heaters 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.

U.S. Natural Gas Consumption by Sector, 2018



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

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 1,037 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 96 cubic feet.

Over 35 percent of natural gas consumed is used to make electricity. For many years, coal was the top fuel used to generate electricity in the U.S. However, in 2016, natural gas became the largest electricity producer, and remains as such. Natural gas power plants are cleaner than coal plants and can be brought online very quickly. Natural gas plants produce electricity more efficiently than new coal plants and produce it with fewer **emissions**. Many coal plants in the U.S. have, in fact, been converted to natural gas plants to meet the higher **EPA** air quality standards. Today, natural gas generates 35.29 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, over 150,000 vehicles run on natural gas in the United States.

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: Colorado, Louisiana, New Mexico, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming. If we continue to use natural gas at the same rate as we use it today, the United States has a 90-100 year supply.

The U.S. natural gas proved reserves increased in 2018 to its highest level ever, 474 trillion cubic feet (Tcf). Starting in the late 1990s, proved reserves increased steadily almost every year due to improvements in shale gas exploration and production technologies.

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 times cheaper than fuel or heating oil and more than four times cheaper than electricity, 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, however, burning natural gas produces carbon dioxide, a greenhouse gas. The majority of 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 the global climate.

Future of Natural Gas

Shale Gas

Shale gas is natural gas that is trapped in shale formations. Shale is 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 had projected that 53 percent of the U.S. natural gas would come from shale gas by 2040. However, in 2018, shale gas accounted for 59 percent of U.S. natural gas production, and those numbers will likely continue to rise.

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.

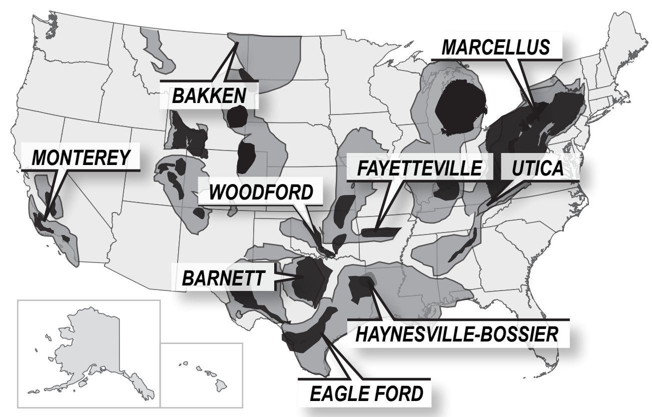
Continued technological innovations promise to make shale gas an important part of the United States' energy future.

Methane Hydrates

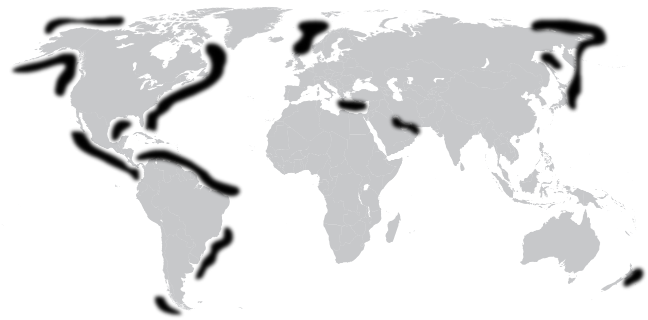
Buried in the sediments of the ocean floor is a reserve of methane so vast it could possibly fuel the entire world. In sediments on the ocean floor, tiny bacteria continuously break down the remains of sea animals and plants, producing methane gas. Under the enormous pressure and cold temperatures at 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



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 10).

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 2018, landfill gas generated 11 billion kilowatt-hours 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 110 LNG facilities are operating in the United States.

Petroleum

Petroleum at a Glance, 2018

Classification:
- nonrenewable

Major Uses:
- transportation, industry

U.S. Energy Consumption:
- 36.882 Q
- 36.53%

U.S. Energy Production:
- 22.89 Q
- 23.91%

Data: Energy Information Administration

What Is Petroleum?

Petroleum, often known as **oil**, 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 hundreds of millions of years to form. We cannot make more oil in a short time.

History of Oil

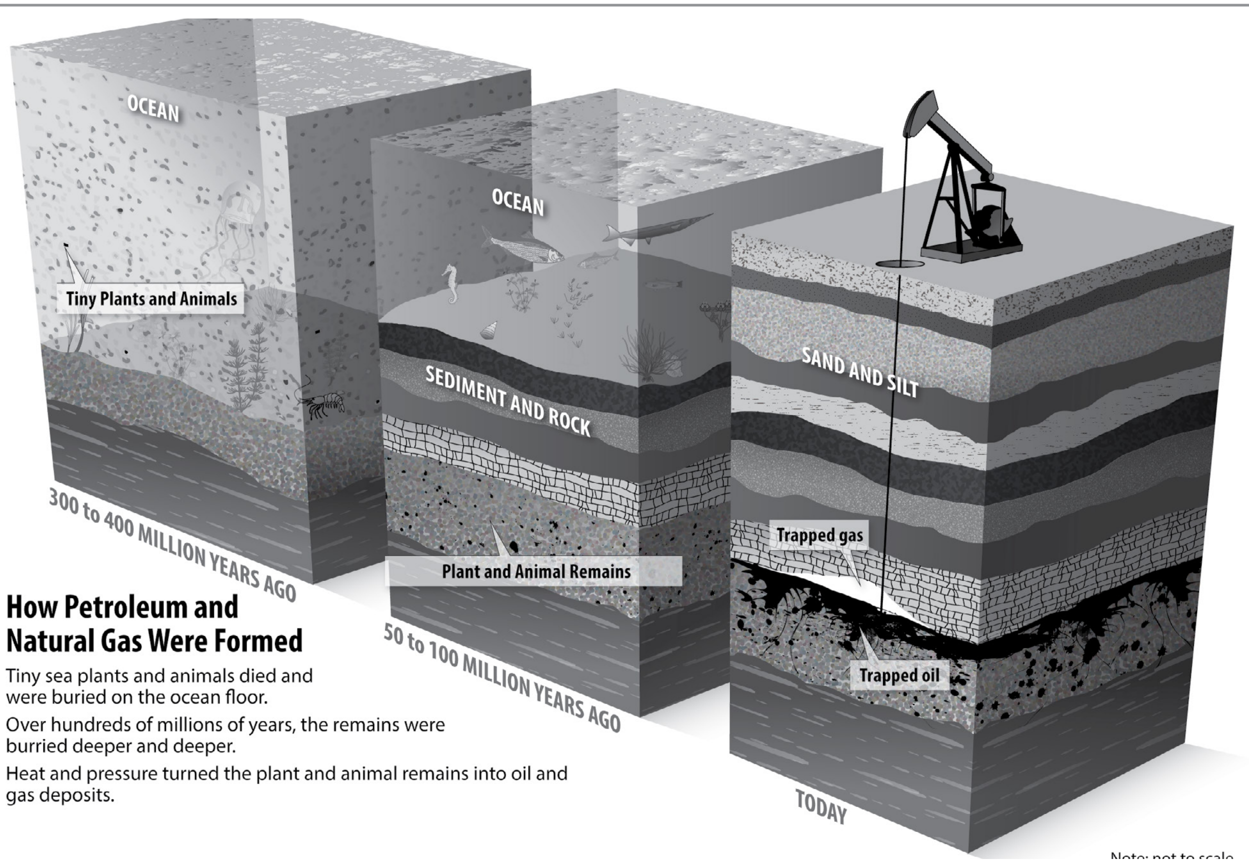
People have used naturally available **crude oil** for thousands of years. The ancient Chinese and Egyptians, for example, burned oil to produce light.

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.

Petroleum

Producing Oil

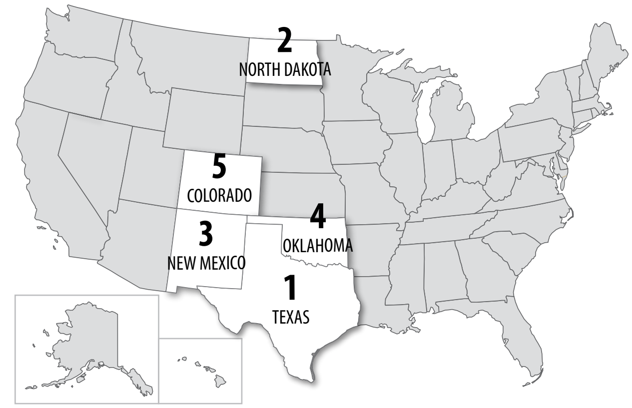
Although research has improved the odds since Edwin Drake's days, petroleum exploration today is still a risky business. Geologists study underground rock formations to find areas that might yield oil. Even with advanced methods, only between 60 and 75 percent of exploratory wells find oil, depending on the region. Developmental wells fare much better; over 90 percent can find 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 10-15 barrels of oil, a day, depending how the well is drilled. However, some new wells can yield over 1,000 barrels per 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.

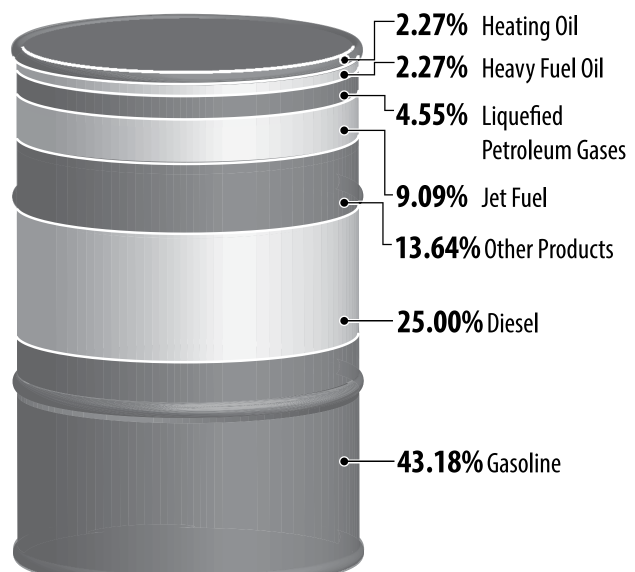
Texas produces more oil than any other state. The other top producing states are North Dakota, New Mexico, Oklahoma and Colorado. These five states account for 67 percent of all U.S. crude oil production. In all, 32 states produce petroleum.

Top Petroleum Producing States, 2018



Data: Energy Information Administration

Products Produced From a Barrel of Oil, 2018



Data: Energy Information Administration

From Well to Market

We cannot use crude oil exactly as 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. Chemical processes in refineries can take 42 gallons in a barrel and actually create the equivalent of 45 gallons of products.

Refineries use many different methods to make these products. One method is a heating process called **distillation**. Since oil products have different boiling points, molecule sizes, and densities, 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. A small percentage 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 190,000 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 to three 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.

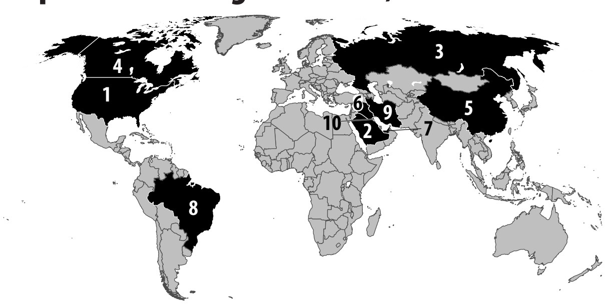
Demand for Oil

Since World War II, petroleum has replaced coal as the leading source of energy consumed in the United States. Petroleum supplies about 37 percent of total U.S. energy demand. Natural gas supplies about 31 percent, and coal supplies about 13 percent of our total energy needs.

America uses about 20.5 million barrels of oil (about 920 million gallons) every day of the year. And experts say we will continue to use oil at these rates, especially for transportation, in the coming years.

Even now, we use about 59 percent more oil than we did in 1973, simply for transportation. 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 when the first oil crisis hit the U.S. Today, about 71 percent of U.S. oil consumption is used for transportation.

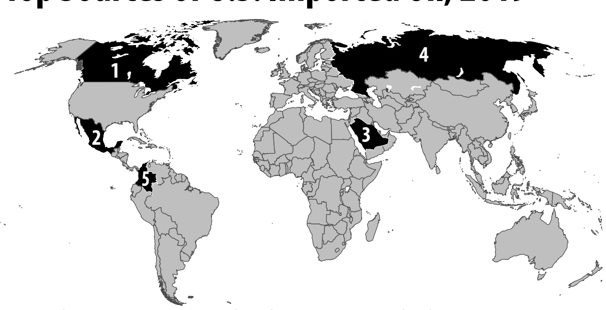
Top Oil Producing Countries, 2019



1. United States
2. Saudi Arabia
3. Russia
4. Canada
5. China
6. Iraq
7. United Arab Emirates
8. Brazil
9. Iran
10. Kuwait

Data: Energy Information Administration

Top Sources of U.S. Imported Oil, 2019



1. Canada, non-OPEC
2. Mexico, non-OPEC
3. Saudi Arabia, OPEC
4. Russia, non-OPEC
5. Colombia, non-OPEC

Percentage of Total Imports from Non-OPEC Nations: 81.99%
Percentage of Total Imports from OPEC Nations: 18.01%

Data: Energy Information Administration

Imported Oil

The United States uses more petroleum than it produces. In 2019, we imported 44 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 **oil 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. OPEC member nations include Saudi Arabia, Venezuela, United Arab Emirates, Iran, Iraq, Kuwait, and several others mostly in the Middle East and Africa. 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, and again after events like the September 11, 2001 terrorism attacks, and Hurricane Katrina in the Gulf of Mexico in 2005.

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 tapped in 1991, during the first Persian Gulf War, and has since been tapped following events like Hurricanes Rita and Katrina in 2005, and the Libyan civil conflict in 2011.

The United States imports oil from both non-OPEC and OPEC countries. Today, we import more oil from Canada than any other country (39.96 percent), followed by Saudia Arabia (9.41 percent). The United States is a major consumer in the 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 thousands of drilling platforms, servicing thousands of wells. OCS production supplies approximately 3.92 percent of the nation's natural gas production and 15.5 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 Bureau of Ocean Energy Management (BOEM), part of the U.S. Department of the Interior (DOI), grants permission to use offshore lands through lease sales. After companies pay for a lease, they apply for BOEM permits to develop energy resources from the lease. A lease is generally 9 square miles. Offshore petroleum exploration and production have been ongoing in the central and western portions of the Gulf of Mexico. Until recently, the Pacific Coast, the eastern portion of the Gulf of Mexico, and parts of Alaska were restricted from new lease sales. However, those restrictions have been lifted, and lease sales will begin in phases, starting in 2020 and continuing through 2024. A few areas off the Gulf coast of Alabama and the northwest shore of Alaska will still be excluded from lease sales.

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.

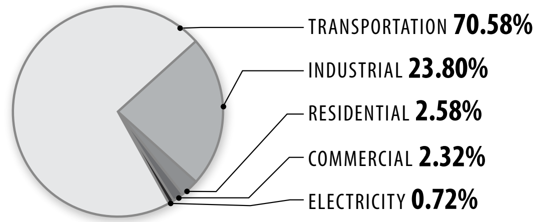
In 2010, the Macondo (Deepwater Horizon) well accident released oil into the Gulf of Mexico for several months. The companies involved in developing Macondo, the Coast Guard, and the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) quickly began work to determine the cause of the 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 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. The average price at the end of 2019 was just about $57 a barrel.

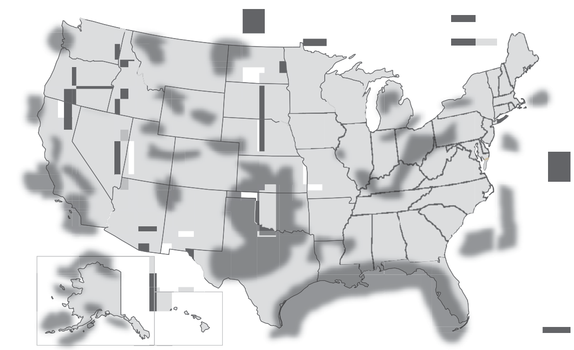
In early 2020, the coronavirus pandemic set up the perfect storm for plummeting oil prices. By mid-April, a combination of decreased demand from the pandemic and excess oil from unadjusted production led to a glut on the market. Producers were running out of places to store oil. The price of one barrel of West Texas Intermediate (WTI) oil was negative, meaning producers were paying buyers to take oil. Russia, Saudi Arabia, and other OPEC countries agreed to reduce the amount of oil produced in May, but prices dropped below $20 per barrel.

U.S. Petroleum Consumption by Sector, 2018



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

U.S. Oil and Gas Basins


Data: Energy Information Administration

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.

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 found mixed in natural gas and petroleum deposits. To obtain propane, it must be separated from natural gas and crude oil when they are processed for their final uses. 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, similar to the way a wet sponge holds water.

Propane is one member of the family of **hydrocarbon gas liquids** (HGL). These **hydrocarbons** are mixtures of molecules of hydrogen and carbon that can occur as gases, or can be easily pressurized to become liquids. HGLs are found in both natural gas and crude oil because both are mixtures of hydrogen and carbon. Once natural gas and petroleum

Propane at a Glance, 2018

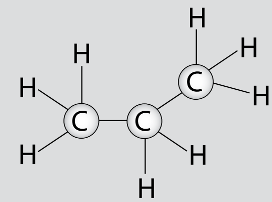
Classification:
- nonrenewable

Major Uses:
- industry, heating, transportation

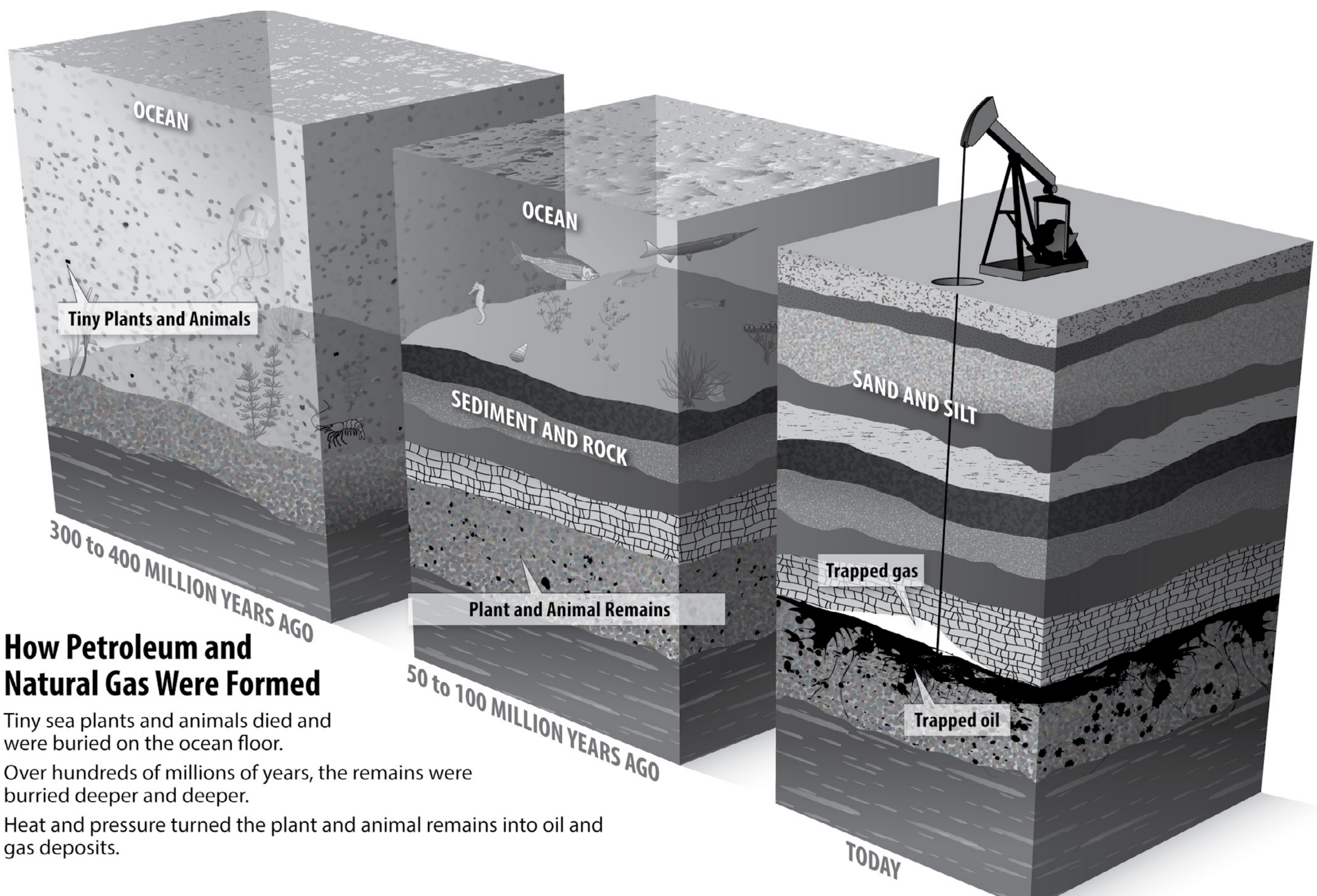
Alternative Names:
- Hydrocarbon Gas Liquid (HGL)
- Liquefied Petroleum Gas (LPG)

Consumption and Production
- produced from refined petroleum and natural gas
- almost 900 thousand barrels consumed per day

PROPANE = C_3H_8



Data: Energy Information Administration



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.

are processed, the HGLs can be extracted. These materials straddle the line between gas and liquids, and this makes them very versatile for making products and use for energy consumption. Propane is a special type of HGL called **liquefied petroleum gas** (LPG), that is extracted from refining crude oil and natural gas. Propane (C_3H_8) is the most common LPG, but the fuels isobutane and butane are also classified as LPGs. Butane is often used in lighters, while isobutane is used as a fuel and as a propellant for aerosols. HGLs account for a small percentage of U.S. petroleum consumption because of their many uses in creating products, and as fuels for transportation, heating, cooking, and drying. Propane, or LPG, is the most used gas liquid in the U.S.

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 tank you see attached to a gas barbecue grill, for example.

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

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

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

History of Propane

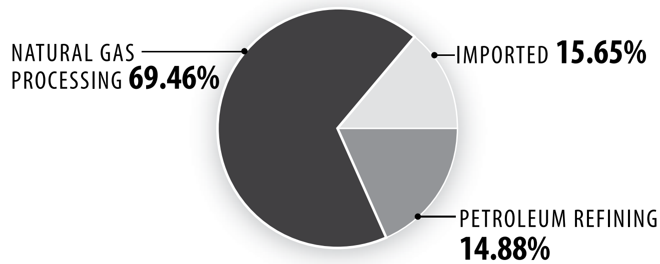
Propane does not have a long history. It wasn't discovered until 1912 when people were trying to find a way to store gasoline. The problem with gasoline was that it evaporated when stored under normal conditions.

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

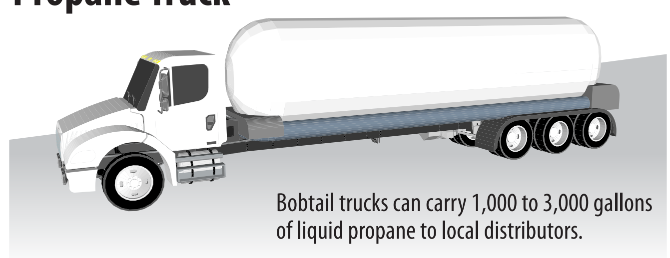
Propane comes from natural gas and petroleum wells. About 69 percent of the propane used in the United States is extracted from raw natural gas. Raw natural gas contains about 90 percent methane, five percent propane, and five percent other gases. The propane is separated from the raw natural gas and the other gases at a natural gas processing facility.

Sources of U.S. Propane, 2018



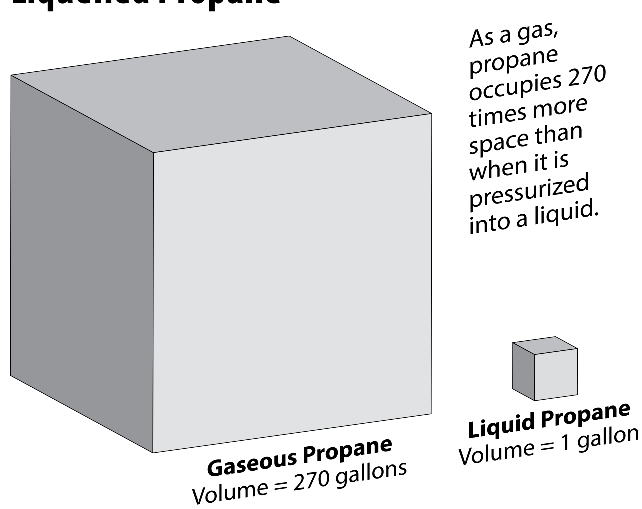
Data: Energy Information Administration

Propane Truck



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

Liquefied Propane



About 15 percent of propane is extracted from crude petroleum. Petroleum is separated into its various products at a processing plant called a **refinery**. Almost 16 percent of the propane we use in the U.S. is imported from other countries, mostly from Canada by rail car.

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.

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 over 100,000 propane dealers, such as hardware stores and gas stations, in the U.S. today.

How Propane Is Used

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

▪ Homes

Homes and businesses are a major consumer of propane 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. Millions of homes use propane to meet some of their energy needs. Over seven million households use propane as their main heating source. Many 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. Recreational vehicles (RVs) usually have propane-fueled appliances, giving them a portable source of energy for cooking, hot water, and refrigeration.

▪ Farms

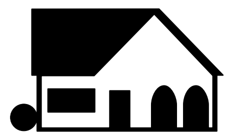
Many of America's farms use propane to help meet their energy needs. Farmers use propane to dry crops such as corn, soybeans, grains, tobacco, apples, peanuts, and onions. Propane is also used to ripen fruit, heat water, and refrigerate foods.

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

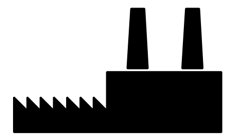
Propane is one fuel farmers use to operate a variety of farm equipment, including tractors, weeders, irrigation pumps, stand-by generators, and seedling planters.

RESIDENTIAL TANK

How Propane Is Used

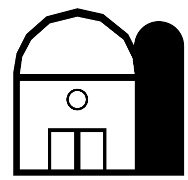


To heat homes



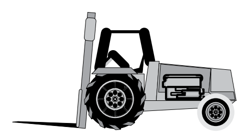
To make products and fuel industry

To fuel backyard grills



To heat barns and operate farm equipment

To fuel fleet vehicles



To fuel machinery that is used indoors

To fuel hot air balloons

To fuel appliances

▪ Business

Some businesses 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.

Propane

▪ Industry

Industry uses 45 percent 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.

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, rubber, pharmaceuticals, and other products.

Propane Today

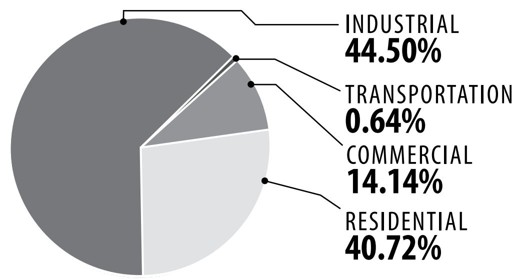
The United States ranks among the world's largest consumers of propane gas. About 84 percent of the propane used in this country is produced in the United States from petroleum and natural gas but, since we import 44 percent of the petroleum we use, about 7 percent of the propane we produce here is made 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.

PROPANE POWERED FORKLIFT

U.S. Propane Consumption by Sector, 2018



Propane is used very little for electricity generation. If used for electric power, often it is in off-grid applications.
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

Solar at a Glance, 2018

Classification:
- renewable

Major Uses:
- light*, heat*, electricity

U.S. Energy Consumption:
- 0.917 Q
- 0.91%

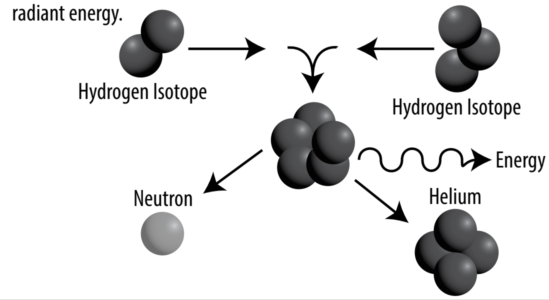
U.S. Energy Production:
- 0.917 Q
- 0.96%

*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.

Data: Energy Information Administration

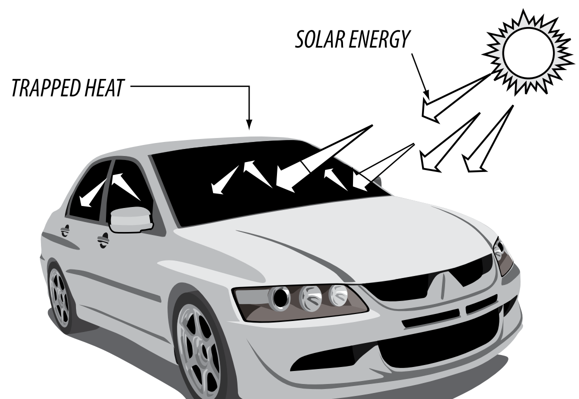
Fusion

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.



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. For this reason, we consider solar to be a **renewable** resource.

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** 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 hundreds of thousands of years for the energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes to travel the 93 million miles to Earth. The solar energy travels to the Earth at a speed of 186,000 miles per second, the speed of light ($3.0x10^8$ 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. Currently, solar energy accounts for just under 1% of our total energy consumed.

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.

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. Over 60 percent of the solar energy used by the U.S. goes to electricity generation. Much of the rest is used by homes and businesses for heating.

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 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.

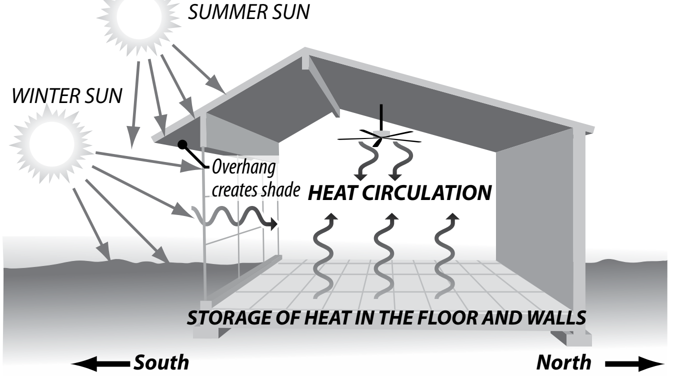
Passive Solar Homes

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.

Passive Solar Home



Active Solar Homes

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

Active solar systems use special solar collectors that look like boxes covered with glass. Dark-colored metal plates inside the boxes absorb the sunlight and change it into heat. (Black absorbs more sunlight than any other color.) Air or 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. Heating water can cost the average family almost $300 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.

SOLAR WATER HEATER

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.

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.

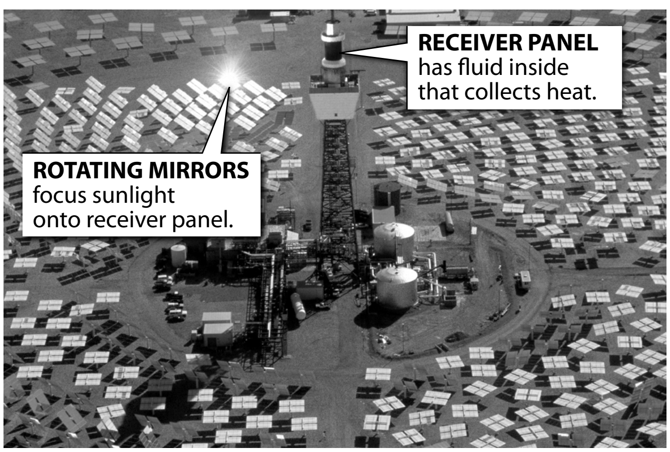
Photovoltaic Cells

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 42). Current PV cell technology is not very efficient. Today's PV cells convert only about 18–24 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 can sometimes be as much as 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, and costs per kilowatt-hour from PV cells are expected to continue to decrease.

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. One of the world's largest parabolic trough power plant is located in the Mojave Desert in California. This collection of plants 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. The world's largest solar thermal power tower system is also located in California. The Ivanpah Solar Electric Generation Station can generate enough electricity to power 140,000 homes per year.

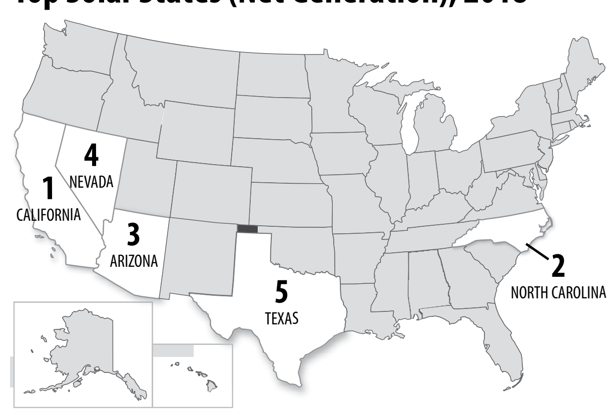
Dish/engine systems are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators are small mobile units that can be operated individually or in clusters, in urban and remote locations.

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 may look 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), 2018



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

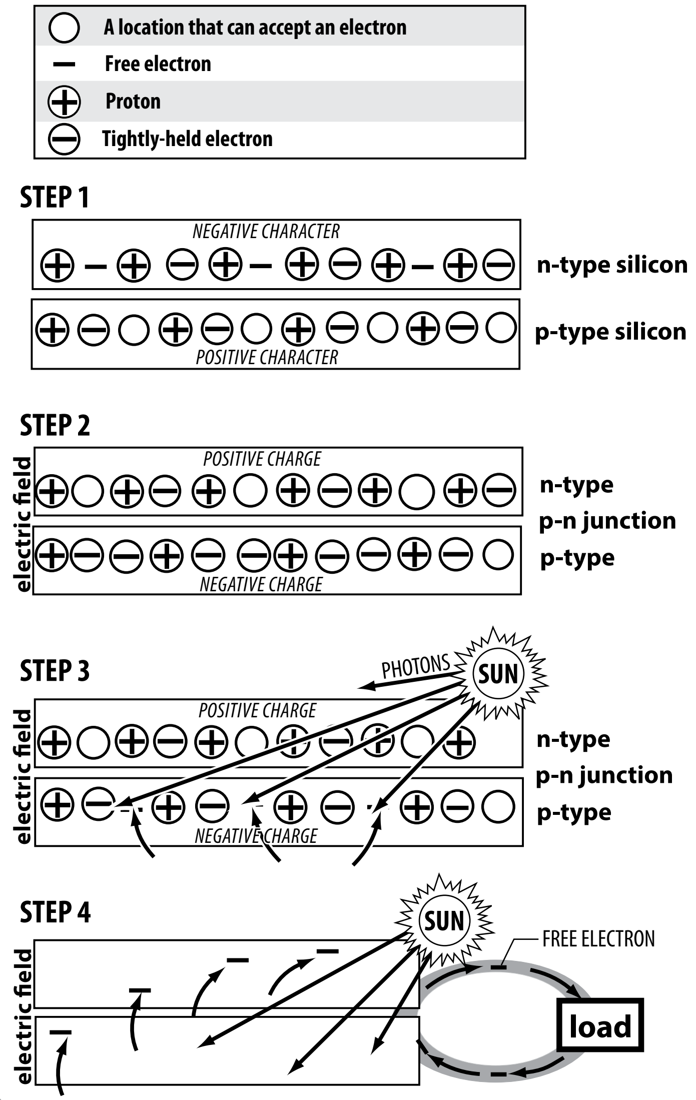
If the PV cell is placed in the sun, **photons** of light strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-type silicon and repelled by the negative charge in the p-type silicon. Most photon-electron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

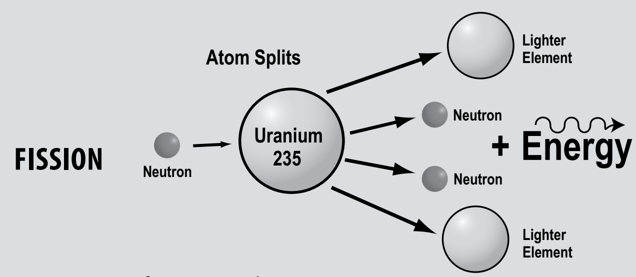
Uranium at a Glance, 2018

Classification:
- nonrenewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 8.438 Q
- 8.36%

U.S. Energy Production:
- 8.438 Q
- 8.82%



Data: Energy Information Administration

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 thermal and radiant energy, 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 39).

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 additional reactors 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, but these techniques are no longer used in the U.S. Uranium can also be mined using solution mining techniques. **In situ leaching**, or solution mining, 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. Presently, four in situ leach plants are operating in the United States.

▪ Milling

At the mill, conventionally mined ore is crushed and treated with an acid solution that separates the uranium ore from the rock. If in situ leaching was 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 solid 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 three to five percent, the percentage 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 150 gallons of oil. The pellets are sealed in 12-foot metal tubes called **fuel rods**. Finally, the fuel rods are bundled into groups called fuel assemblies.

▪ Nuclear Reactor

The uranium fuel is now ready for use in a nuclear **reactor**. 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 can house 200 or more 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**.

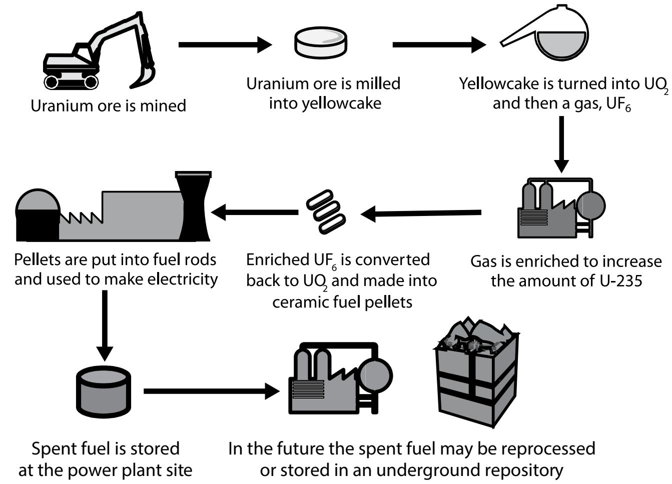
▪ Spent (Used) Fuel Storage

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 24 months to keep power plants in continuous operation.

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 fuel, and space in fuel pools can run out quickly.

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.

Uranium Fuel Cycle



▪ 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. The same law also established the Nuclear Waste Fund to pay for a permanent **repository**. People who used electricity from nuclear power plants would be charged 1/10 of one cent for each kilowatt-hour of electricity they used.