Secondary Energy Infobook

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



Grade Level:

Sec Secondary

Subject Areas:

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

NEED
National Energy Education Development Project

NEED Mission Statement

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

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NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at **www.eia.gov**.

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Standards Correlation Information

www.NEED.org/educators/curriculum-correlations

Next Generation Science Standards

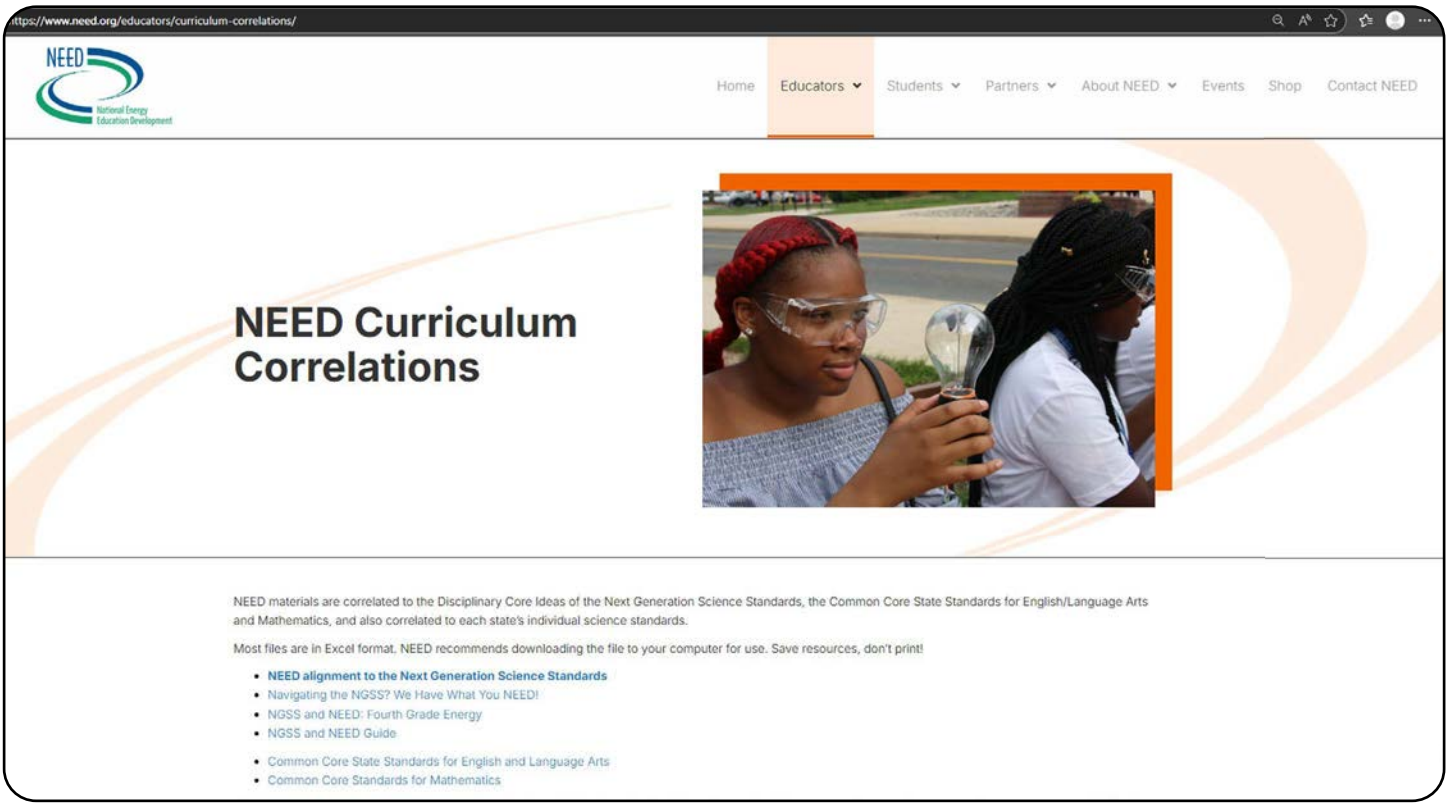
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts within your required curriculum. For more details on these correlations, please visit NEED's 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 **www.NEED.org/shop** to fit with our eight-step, comprehensive energy unit.

NEED also has careers content and units specifically designed for the CTE classroom. For a listing of NEED's energy-focused career and workforce content, head to **www.need.org/product-category/career-and-workforce-development**.

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 Marine Hydrokinetics Exploring Nuclear Energy Exploring Ocean Energy and Resources Exploring Offshore Wind Exploring Oil and Natural Gas Exploring Photovoltaics Exploring Wind Energy Floating Offshore Wind 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	Baseload Balance Current Energy Affair Energy Expos Energy Games and Icebreakers Mission Possible Reliably Smart Secondary Energy Infobook Activities Sidekick Circuits The Science of Electricity

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	Building Science Carbon Capture, Utilization, and Storage Chemistry and Energy Efficiency Energy Career Enigma Energy Conservation Contract Energy Expos Energy Games and Icebreakers Energy House Exploring Climate Science Managing Home Energy Use Museum of Solid Waste and Energy School Energy Managers School Energy Survey
STEP SIX: Synthesis and Reinforcement	Energy Analysis Energy and Our Rivers Energy Around the World Energy Careers Excursion 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 one of 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, balloons, 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, 2024

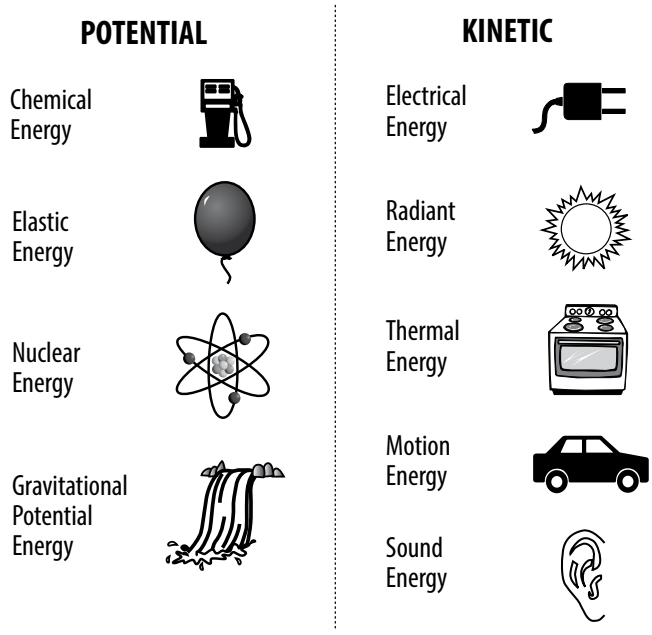
	2023	2024
World Population	8,061,900,000	8,200,000,000
U.S. Population	334,914,895	341,000,000
World Energy Production	592.299 Q	605.91 Q
U.S. Energy Production	102.782 Q	103.548 Q
• Renewables	8.437 Q	8.787 Q
• Nonrenewables	94.344 Q	94.519 Q
World Energy Consumption	590.865 Q	606.037 Q
U.S. Energy Consumption	93.691 Q	94.556 Q
• Renewables	8.256 Q	8.58 Q
• Nonrenewables	86.833 Q	85.613 Q

Q = Quad (10^{15} Btu), see Measuring Energy on page 8.
Data: Energy Information Administration

*2024 is the most recent available global data for comparison. 2025 data is available for the U.S. throughout this guide.

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

Forms of Energy



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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.

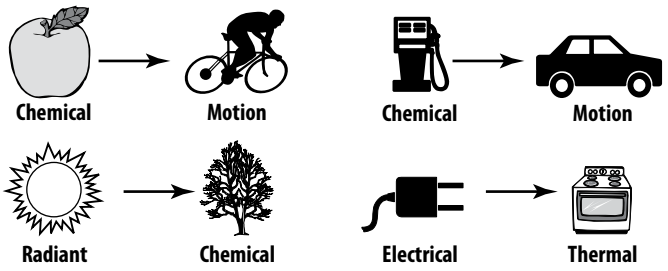
Conservation of Energy

Your parents may tell you to conserve energy. "Turn off the lights," they probably 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

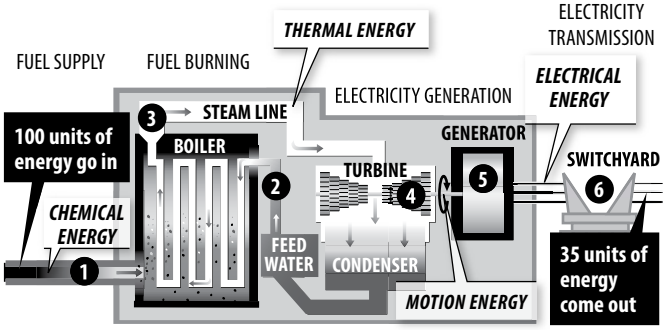
Energy efficiency is the amount of useful energy you can get out of a system. In theory, a 100 percent energy-efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of thermal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

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.



Fuel Sources



How a Thermal Power Plant Works

1. Fuel is fed into a boiler, in which it is burned to release thermal energy. Nuclear plants are thermal plants, however the fuel is not burned; it 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, allowing it to travel through the electric grid.

Introduction to Energy

Sources of Energy

People have always used energy to do work for them. Thousands of years ago, early humans burned wood to provide light, heat their living spaces, and cook their food. Later, people used the wind to move their boats from place to place. Over a century 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. These sources are used to generate electricity, to heat our homes, to move our cars, and to manufacture a wide range of 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 fossilized remains of ancient sea life, so it cannot be made quickly. We could run out of economically recoverable nonrenewable resources some day.

Measuring Energy

"You can't compare apples and oranges," the old saying goes. This is also 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.

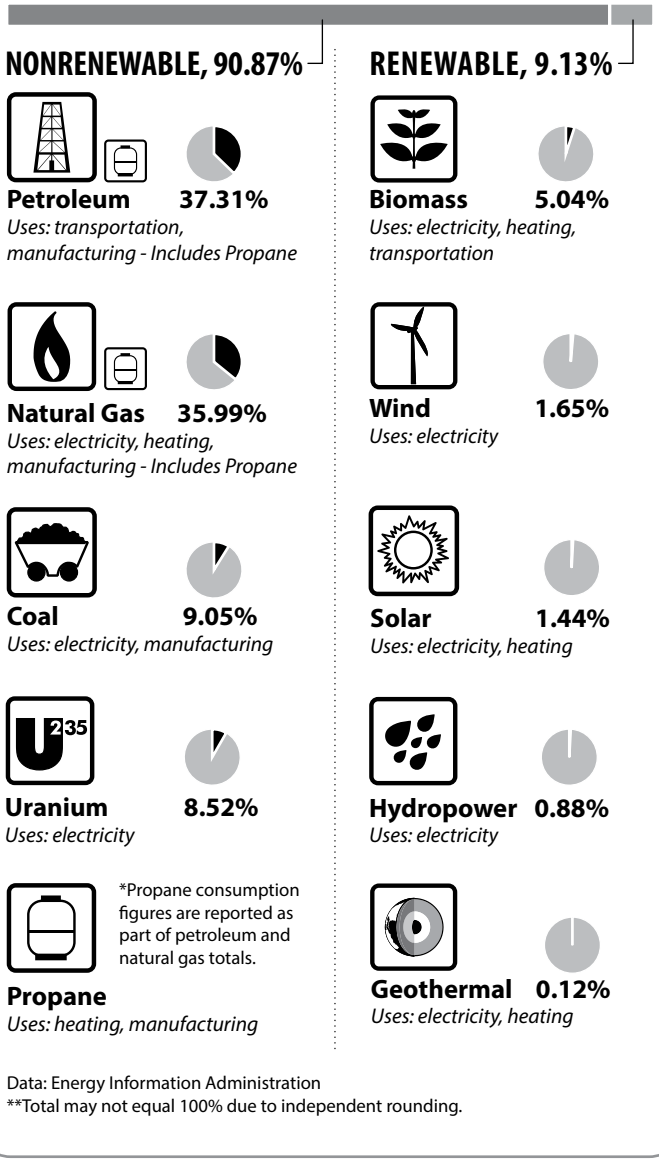
One Btu is the amount of thermal energy needed to raise the temperature of one pound of water one degree Fahrenheit. A single Btu is quite small. A wooden kitchen match, if allowed to burn completely, would give off about one Btu of energy. One ounce of gasoline contains almost 1,000 Btu of energy.

Every day the average American uses about 769,171 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 3.79 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high. In 2018, consumption was holding at 100.961 quads, but a drastic change occurred in 2020 with the Covid-19 pandemic; energy consumption fell to 92.943 quads. In 2021, consumption rose again quickly to 97.331 quads, and in 2025, consumption was 96.222 quads.

Renewable energy sources include biomass, geothermal, hydropower, solar, and wind. These energy sources are called renewable 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.

U.S. Energy Consumption by Source, 2025



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

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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 six gallons of gasoline. That's every person, every day. Over the course of one year, the sum of this energy is equal to nearly 2,400 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 and 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.

Together, residential and commercial sectors of the economy consumed 11.94 percent of the primary energy supply in 2025, with a total of 11.498 quads. The residential sector consumed 6.663 quads and the commercial sector consumed 4.835 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 23.040 quads of energy in 2025, which accounted for 23.94 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 34.84 percent of the total energy supply in 2025, more than any of the other sectors, with a total of 33.526 quads.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, pipelines, and airplanes. In 2025, the U.S. consumed 28.148 quads of energy for transportation, which accounted for 29.25 percent of total consumption. 89.05 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.

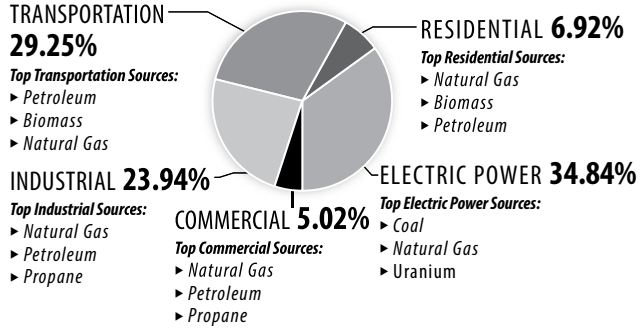
We don't want to simplify energy demand too much, as the price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances. In 2020, we saw that global issues, like a pandemic, can shape demand and pricing of energy. In 2022, we observed how global politics can shift prices on energy, with the Ukraine-Russia conflict.

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 2025, the United States used 27 percent more energy than it did in 1973. That might sound like a lot, but the population has increased by over 60 percent, and the nation's **gross domestic product** was 4.85 times that of 1973.

You may wonder why the 1970s are important, when they were so long ago. However, the energy crisis during that 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 today 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. Energy efficiency technologies and conservation behaviors will need to continue to be utilized in order to prepare us for the energy demands of the future and to enable the use of resilient energy sources and infrastructure.

U.S. Energy Consumption by Sector, 2025



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

Biomass

What Is Biomass?

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

Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called **photosynthesis**, sunlight gives plants the energy they need to convert water and **carbon dioxide** into oxygen and sugars. These sugars, called **carbohydrates**, supply plants and plant-eating animals 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

Nearly any organic matter can be used as an energy source. Most biomass used today is domestically produced. We use several types of biomass, including wood, agricultural products and wastes, solid waste, landfill gas and biogas, and biofuels.

▪ Wood

Waste wood products—logs, chips, bark, and sawdust—account for almost 40 percent of biomass energy. Wood and wood waste are used as a heat source and to generate electricity. A very small percentage of homes use wood as its heating fuel. Most waste wood products are used by industries making the waste to generate electricity. This electrical power is not distributed by utilities but is used in a process called cogeneration. Paper mills and saw mills use much of their wood waste products to generate steam and electricity for their use. However, since they use so much energy, they still 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 can 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 wood biomass for energy 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; roughly 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 often remains unused.

▪ Landfill Gas and Biogas

Biomass at a Glance, 2025

Classification:
- renewable

Major Uses:
- industry, transportation fuel, electricity

U.S. Energy Consumption:
- 4.853 Q
- 5.04%

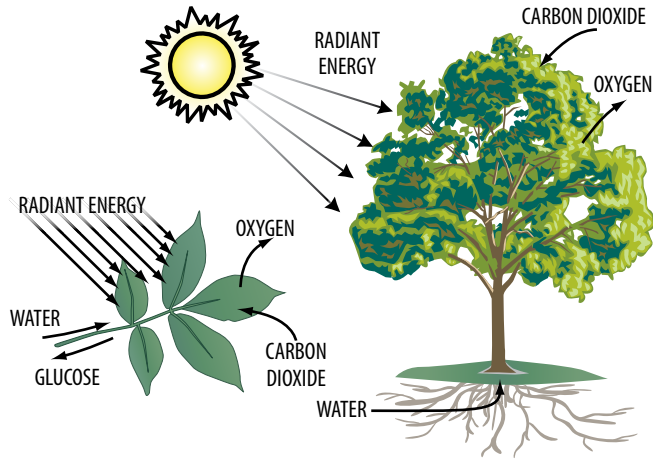
U.S. Energy Production:
- 5.247 Q
- 4.91%

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

Data: Energy Information Administration

Photosynthesis

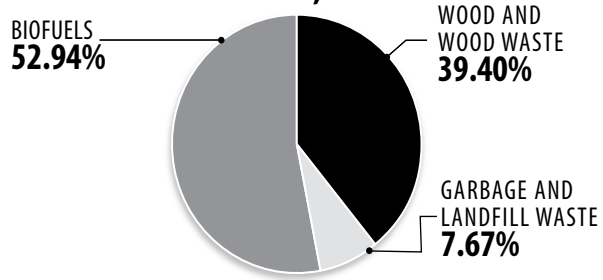
In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



water + carbon dioxide + sunlight ⟶ glucose + oxygen

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

U.S. Sources of Biomass, 2025



Data: Energy Information Administration
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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 can be dangerous. The gas can cause fires or explosions if it seeps into nearby homes and is ignited. Landfills can either burn the gas (flare it) onsite or 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. Many 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. Over 500 facilities across the country use their landfill gas for electricity, with potential for more.

However, still only a relatively small portion of landfill gas is used to provide energy today. 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, a more potent greenhouse gas than carbon dioxide, is an estimated 28 times better at trapping heat in the atmosphere. It is better for the environment to burn landfill methane and change it into carbon dioxide through combustion than to release it directly 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 relatively safe and clean-burning gas, producing little carbon monoxide and no smoke in comparison to other cooking fuels.

Biogas digesters are inexpensive to build and maintain. They can be built as family-sized or community-sized units on farms, at water treatment facilities, and at landfills. 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 overused fields, and produce clean, safe energy for communities.

Use of Biomass

Until the mid-1800s, wood gave Americans 90 percent of the energy used in the country. In 2025, biomass provided 5.04 percent of the total energy we consumed in the U.S. Biomass has largely been replaced by natural gas and petroleum.

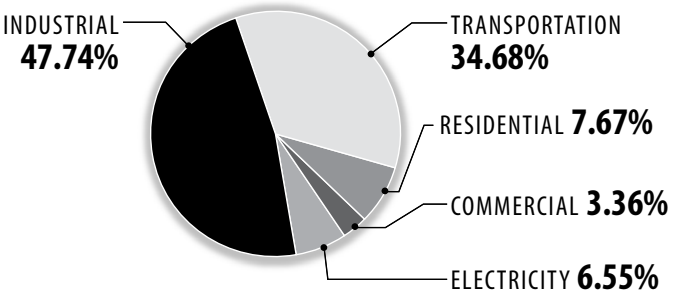
Thirty-nine percent of the biomass used today comes from burning wood and wood scraps such as sawdust. About 53 percent is from **biofuels**, principally ethanol, that are used as a gasoline additive or alternative.

Industry is the biggest user of biomass. Nearly 48 percent of biomass is used by industry. Electric utilities use about seven percent of biomass for power generation. In turn, biomass produces 1.04 percent of the electricity we use.

Transportation is the next biggest user of biomass; about 35 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 eight percent of the biomass supply. The most recently reported data showed less than two 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, 2025



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

Using Biomass Energy

Usually we burn wood and use its energy for heating. 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. Combustion, however, is not the only way to convert biomass energy into a usable energy source. There are three other 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.

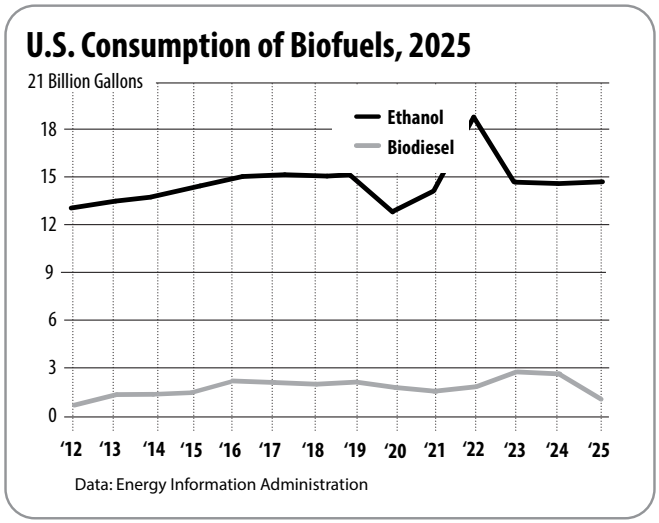
Bacterial Decay: Bacteria feed on dead plants and animals, producing methane. Methane is produced whenever organic material decays. Methane is the main ingredient in natural gas, the gas sold by natural gas utilities. Landfills can recover and use the methane gas produced by the garbage.

Conversion: Biomass can be converted into gas or liquid fuels by using chemicals or heat. Cow manure can be 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 (CO_2), but growing plants for use as biomass fuels can also help keep CO_2 levels balanced. Plants remove CO_2—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. Vehicles that can burn E85 and gasoline have been designated as flexible-fuel vehicles (FFVs), or simply flex-fuel. When FFVs were introduced, they were sold as a more environmentally friendly option as compared to conventional gasoline-powered vehicles because of their use of high amounts of ethanol. As many as 21 million FFVs were on the road at one point. However, FFVs have been declining in popularity due in part to the reduced fuel efficiency when burning E85 and also to the shift toward electric vehicles. In 2025, just under 20 million flex-fuel vehicles were in use, but it is estimated that many do not regularly use E85.

Characteristics of Ethanol

With one of the highest octane ratings of any transportation fuel, ethanol increases the energy efficiency of an engine. It is widely used in automobile racing blends for this reason. 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, fuel efficiency, or distance traveled on one gallon of fuel, is 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 2025, ethanol plants in the U.S. produced more than 18 billion gallons of ethanol. There are 191 plants operating nationwide, located mostly in the Midwest. There are currently nearly 5,000 E85 fueling stations in 44 states. Ethanol fuels for heavy-duty applications are available only through bulk suppliers.

Economics of Ethanol

The Federal Government established a renewable fuels standards through the EPA that sets annual volume requirements for renewable fuels. For 2025, the target was set for 22.3 billion gallons. The U.S. exceeded this mark, producing 18.5 billion gallons of ethanol alone in 2025. For comparison, however, the U.S. consumed a little less than 137 billion gallons of gasoline in 2025. Today, it costs more money to produce ethanol than gasoline.

Since it is the second largest use of corn, ethanol production can add 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 are predicted to increase.

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 (CO) 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 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 CO_2 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 (non-food, plant-based material) 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, the 2008 experience has caused concern that greatly increasing the use of corn ethanol could affect food prices more significantly.

A study by the U.S. 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 cannot sustainably meet all of our transportation fuel needs with ethanol, increased ethanol use in the future can 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.

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 EPA requires that sulfur levels in diesel fuel be at 15 parts per million or less 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 safer. 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 petroleum-based 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. Even though the number of biodiesel fueling stations is still relatively low compared to those offering petroleum-based diesel, the availability of biodiesel is growing. Currently, there are roughly 2,000 biodiesel fueling stations across 29 states.

Economics of Biodiesel

Today, B99-B100 costs about $4.30 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.

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).

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

BIODIESEL-POWERED GARBAGE TRUCK



Image courtesy of NREL

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

BIODIESEL FUELING STATION



Image courtesy of Analogue Kid via wikimedia commons

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. However, biodiesel increases emission of nitrogen oxides 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 because an increased demand for biodiesel may lead to converting forests and grasslands to crop land for fuel and food. This conversion releases CO_2 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 compared to petroleum diesel could reduce CO_2 emissions by over 80 percent.

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 U.S. 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. Expanding the 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



Image courtesy of Joe Mabel via wikimedia commons

SOYBEANS



Image courtesy of branex/Adobe Stock

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Coal

Coal at a Glance, 2025

Classification:
- nonrenewable

Major Uses:
- electricity, industry

U.S. Energy Consumption:
- 8.710 Q
- 9.05%

U.S. Energy Production:
- 10.876 Q
- 10.17%

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 or more 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 swampy land 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.

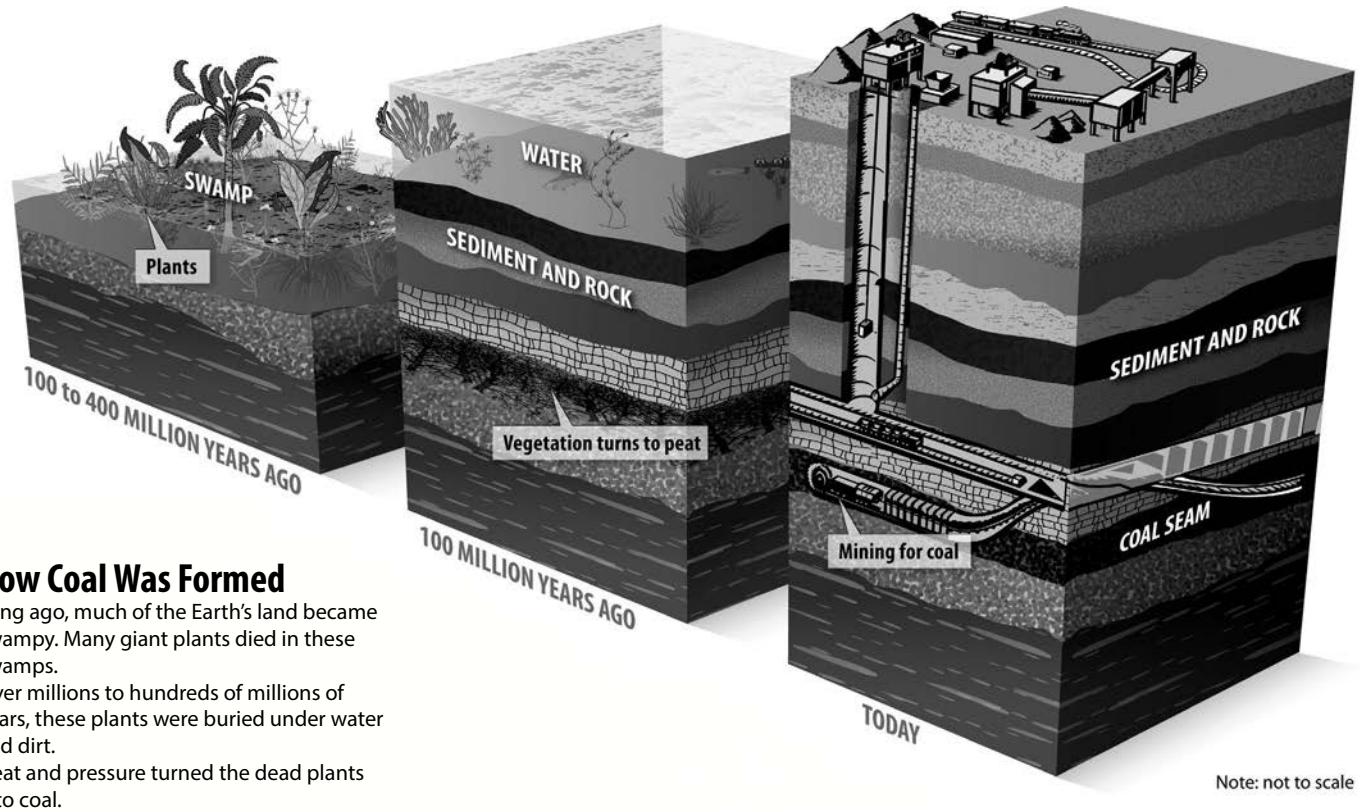
Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

History of Coal in America

Indigenous Americans used coal long before the first settlers arrived in the New World. The Hopi Tribe, 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 during which coal production was up by as much as 48 percent. Today, coal supplies only about nine percent of the nation's total energy needs, mostly for electricity production. The increased use of natural gas and renewable energy sources for electricity has led to a sharp decline in the amount of coal consumed for electricity generation.

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 sites for commercial development.

About 60 percent of the nation's coal is obtained through surface mining. Surface mining is typically much less expensive than underground mining. New technologies increased surface mining productivity as much as 100 percent after 1970. Today, however, new technology gains are attributable to a 12 percent increase in productivity, because productivity overall, has decreased.

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 be 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

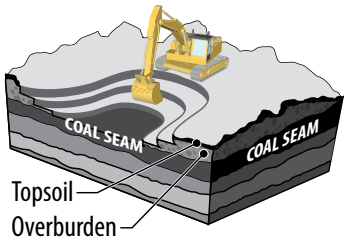
After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other impurities, increasing the heating value of the coal.

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.

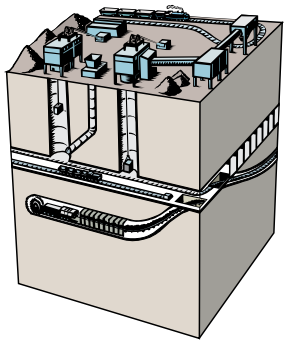
Underground pipelines can easily move petroleum and natural gas to market, but not coal. Huge trains and barges transport most of U.S. coal for some or all of its journey to market.

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 2024 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. In 2024, 43 percent of the coal mined 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. In 2024, 48 percent of the coal mined 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 2024 in the U.S. was anthracite.

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Coal Reserves

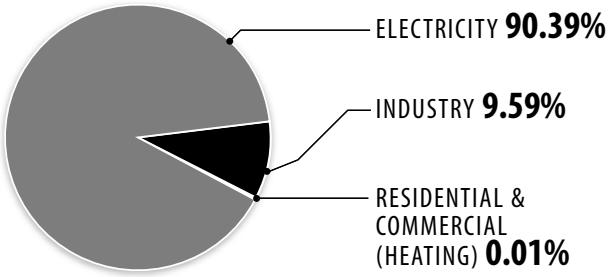
When scientists estimate how much coal, petroleum, natural gas, or other energy sources there are in the United States, they use the term **reserves**. Reserves are deposits that can be harvested using today's methods and technology.

Experts estimate that the United States has over ten million short tons (1 short ton = 2,000 lbs.) 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 400 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 20 states. Wyoming has the most coal—about 3.6 billion mineable tons. Coal is also found in large quantities in West Virginia, Illinois, Pennsylvania, Texas, North Dakota, Kentucky, and Montana. Western coal generally contains less sulfur than eastern coal.

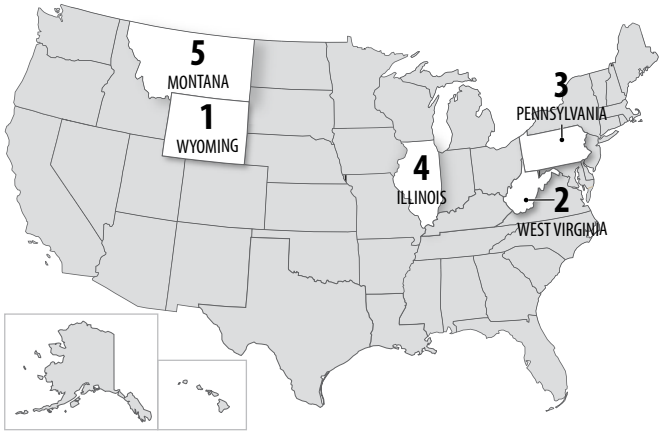
The Federal Government is by far the largest owner of the nation's coalbeds. The Bureau of Land Management leases over 570 million acres of coal bed mineral estates to landowners. Most of these leases are found in Western states.

U.S. Coal Consumption by Sector, 2025



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

Top Coal-Producing States, 2024



Data: Energy Information Administration
2024 is the most current reporting available at the time of publication.

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 21 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 2024, the West provided 55 percent of total production, and states east of the Mississippi River provided 45 percent.

Total U.S. coal production was 513 million tons in 2024. The leading coal states are Wyoming, West Virginia, Pennsylvania, Illinois, and Montana. 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 2024, foreign countries bought 21.14 percent of all the coal produced in the U.S. The biggest foreign markets for U.S. coal are India, the Netherlands, Brazil, Japan, Morocco, Canada, and South Korea.

How Coal Is Used

The main use of coal in the United States is to generate electricity. In 2025, 90 percent of all the coal in the United States was used for electricity production. Coal generates 16.64 percent of the electricity used in the U.S. Other energy sources used to generate electricity include natural gas, uranium (nuclear power), wind, solar, and hydropower.

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 MINE



Image courtesy of Wikimedia Commons

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 must continually work to tackle 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 the passing of the Clean Air Act and Clean Water Act, 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 byproduct) 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. 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. However, the use of combustible fuels like coal plays a major role in the changes in greenhouse gas levels in the Earth's atmosphere that are responsible for a change in the Earth's climate.

The scientific community agrees that the Earth is already experiencing a warming trend due to increased greenhouse gas concentrations. Long-term studies by scientists in many countries are being conducted to determine the effect of increased CO_2 and methane gas levels in the atmosphere and how these atmospheric concentrations affect the oceans, ice sheets, and ecosystems. Scientists are continually 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 Combustion: One technique that cleans coal as it burns is a fluidized bed combustion. In a 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 at which 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 continuing around the U.S. and the world to capture CO_2 from power plants and use it or store it deep underground in geologic formations. Researchers are investigating the best ways to capture CO_2, either before or after coal is combusted. The CO_2 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 CO_2: 1) deep saline formations, 2) oil and gas reservoirs that are near depletion or have been depleted, and 3) unmineable coal seams. Fifteen carbon capture and storage projects are currently operating in the U.S.

Geothermal

Geothermal at a Glance, 2025

Classification:
- renewable

Major Uses:
- electricity, heating

U.S. Energy Consumption:
- 0.117 Q
- 0.12%

U.S. Energy Production:
- 0.117 Q
- 0.11%

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 alloy of nickel and iron surrounding a solid-like iron center. Estimates of the temperature of the core range from 7,000 to 11,000 degrees Fahrenheit (°F).

Surrounding the Earth's core is the **mantle**, made mostly of solid silicate rocks and **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 brittle pieces called plates.

These slabs of continental and oceanic crust 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.

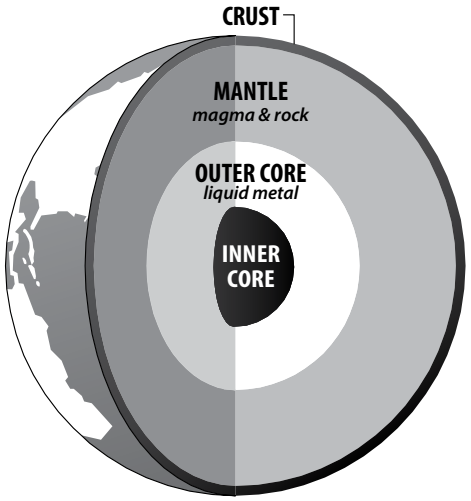
Geothermal energy is called a **renewable** energy source because the water is replenished by rainfall, and the heat is continuously produced within the Earth by the slow radioactive decay of particles that naturally occur in all rocks.

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 food products and lumber, and for mineral baths.

The Earth's Interior

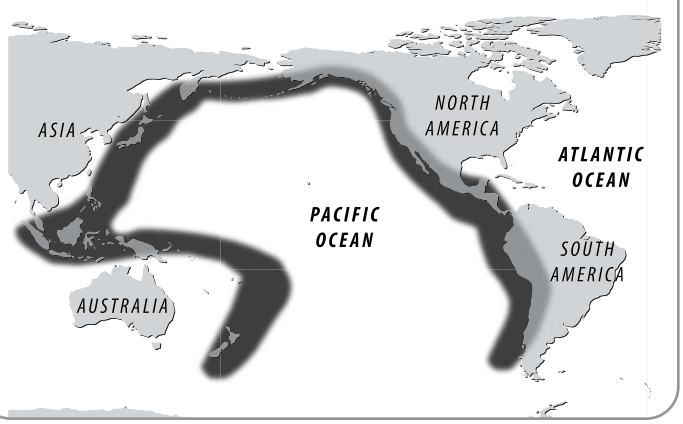


Where Is Geothermal Energy Found?

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 below), which rims the Pacific Ocean and is bounded by Indonesia, the Philippines, Japan, the Aleutian Islands, North America, Central America, and South America.

Ring of Fire



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 250°F to 700°F (150-370°C)—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.

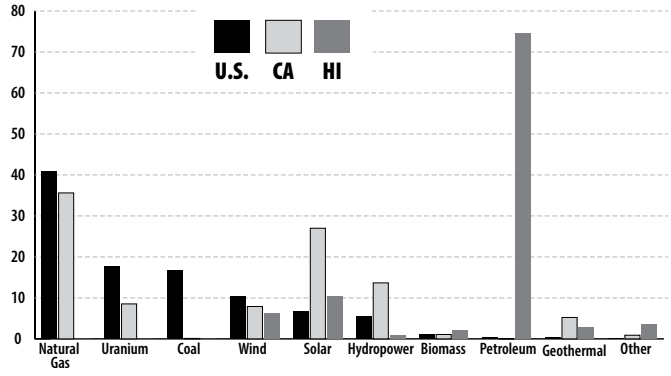
▪ Dry Steam Plants

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 facility, "Valle Secolo," is still producing electricity today and is the largest of its kind in Europe.

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 still produces enough electricity to supply 715,000 California homes. The average monthly consumption in California is 503 kWh, while the US average is 863 kWh. The reservoir is also replenished by local wastewater to ensure steam pressure is sustainable for power generation.

Electricity Generation by Source, 2025



The graph above shows U.S. electricity generation by source compared to Hawaii and California, two major contributors to geothermal electricity generation in the U.S.

▪ 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, 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 has the capacity to produce 38 megawatts of power. The Kilauea volcanic eruption in 2018 forced PGV to cap the wells and cease production but was reopened in 2021. The ongoing active nature of the volcano can cause disruptions in productivity at PGV. When fully operational, the facility can provide 15 percent of the power consumed on the Hawaii island (the Big Island). PGV is in the process of a modernization project that will increase generation to 46 megawatts, while decreasing its footprint and utility costs for residents.

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. Many homes, metro stations, the Orly airport and even the 2024 Olympic village are heated and cooled by geothermal systems.

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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 85 percent of residents use geothermal energy for heat and hot water. In Reykjavik, Iceland, district heating systems provide 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.

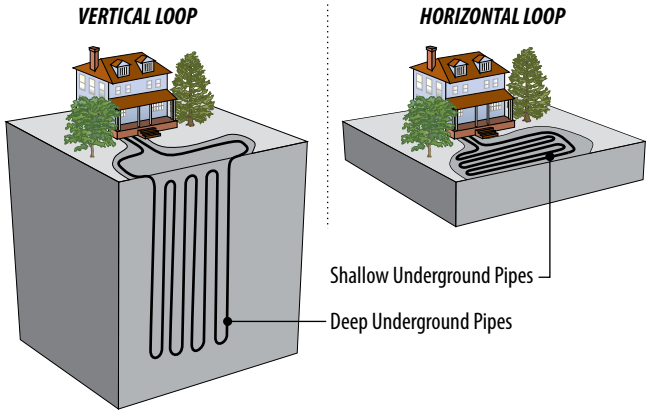
A geothermal exchange system doesn't look like a traditional furnace or air conditioner. For one thing, most of the equipment is underground. A liquid—usually a mixture of water and antifreeze—circulates through a long loop of pipe buried in the ground. This liquid absorbs heat from the ground and carries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

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.

Residential Geoexchange Units

HEATING AND COOLING FROM LOW TEMPERATURES



If a large lake or pond is nearby, the pipes can be buried underwater. 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.

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.

Geothermal systems are low maintenance and should last twice as long as conventional systems. The pumps can 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.

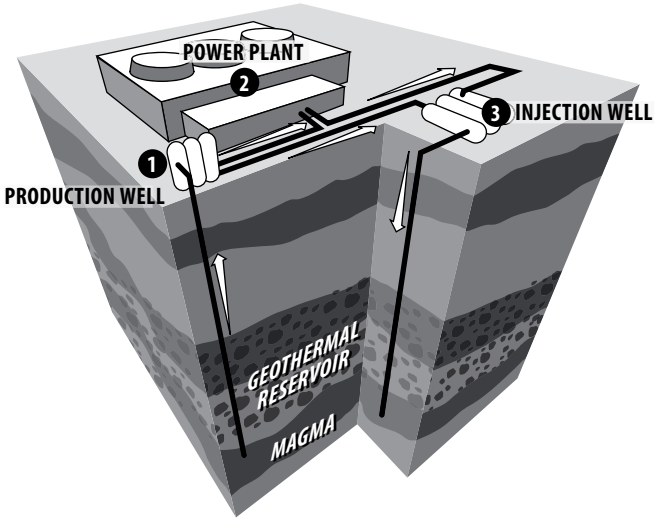
Today, roughly two million homes and buildings in the United States use geothermal heat exchange systems. They are an efficient, economical alternative to conventional heating and cooling systems. The U.S. Environmental Protection Agency has rated geothermal heat pump systems among the most efficient heating and cooling technologies.

Geothermal Electricity Generation in the U.S.

Geothermal energy is put to work in many places around the world. The best-known geothermal energy sources for electricity generation in the United States are located in western states and Hawaii.

Geothermal Power Plant

GENERATES ELECTRICITY FROM HIGH TEMPERATURES



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. This shaft is attached to the generator. The generator spins magnets inside a large coil of wire to generate electricity.
3. **Injection Well:** Used geothermal fluids are returned to the reservoir.

Geothermal

Geothermal power plants operate in California, Nevada, Hawaii, Idaho, Oregon, New Mexico, and Utah. Today, the total installed capacity of geothermal power plants in the United States is around 4,000 megawatts (MW) with 167 generators.

In 2025, geothermal energy produced about 15.669 billion kilowatt-hours (kWh) of electricity, or 0.35 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.

Geothermal Economics

Geothermal power plants can produce electricity for lower cost than to many conventional power plants, due to increasing demand for and cost of other fuels. 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.

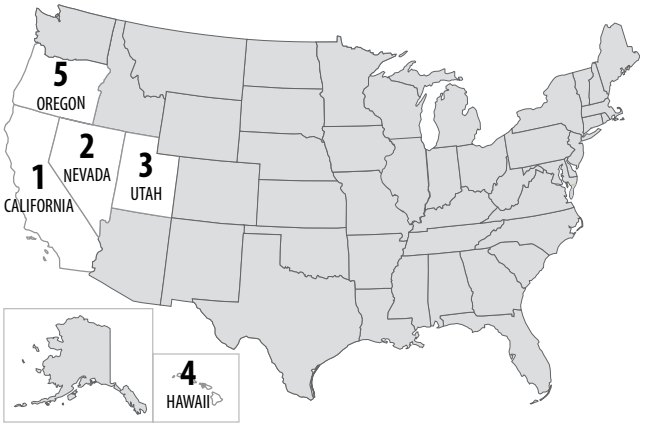
Geothermal power plants are compatible with many environments. They have been built in deserts, in the middle of crops, and in mountain forests. Development is often allowed on federal lands because it does not significantly harm the environment. Geothermal features in national parks, such as geysers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

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 worldwide geothermal resources—hot dry rock and magma, for example—are awaiting further technology development.

In 2023, there were geothermal power plants in 27 countries, generating more than 90 billion kilowatt-hours of electricity. Direct uses of geothermal reservoirs provide thermal energy in even more countries.

Top Geothermal-Producing States, 2024



Data: Energy Information Administration
*2024 is the most current data available at the time of publication.

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 *hydro,* 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, built on the Fox River in Appleton, WI in 1882, powered multiple homes and businesses. 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 these fossil fuel plants 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. According to the Army Corps of Engineers, there are more than 92,000 dams in the United States, but most were not built specifically for electricity generation. Most dams were built for recreation, flood control, fire protection, and irrigation, and fewer than 3,000 are federally owned.

Hydropower at a Glance, 2025

Classification:
- renewable

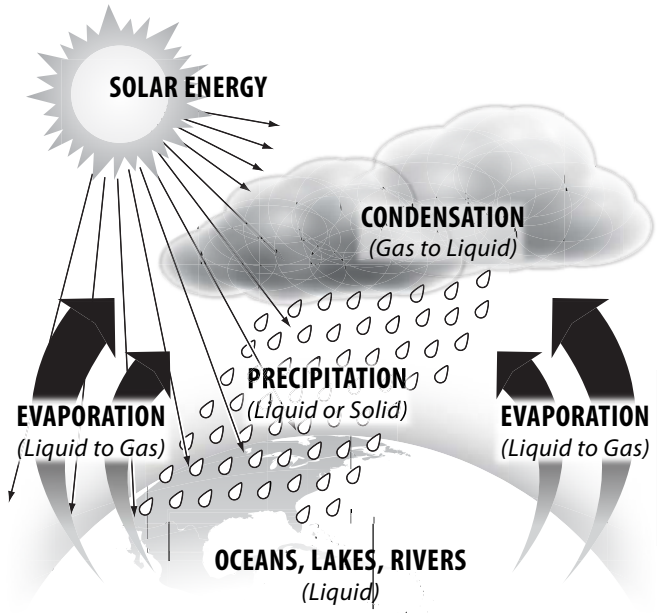
Major Uses:
- electricity

U.S. Energy Consumption:
- 0.843 Q
- 0.88%

U.S. Energy Production:
- 0.843 Q
- 0.79%

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, as they 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.

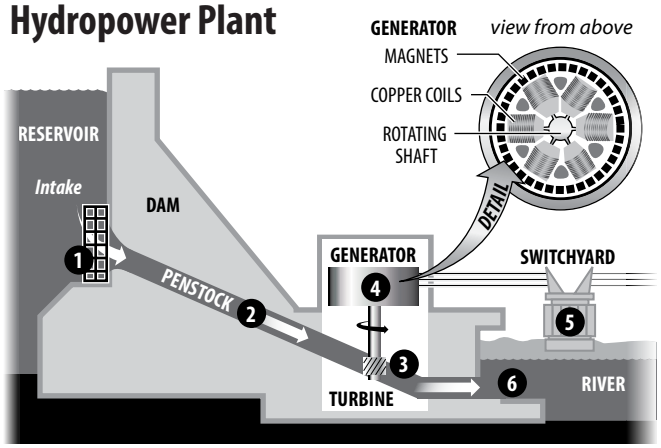
Pumped Storage Systems

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 storage hydro is the most reliable energy storage system used by American electric utilities. Most power plants have no energy storage systems. They must turn to gas- and oil-fired generators or renewables when people demand lots of electricity. Many 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 decreased relative to other renewable sources. Hydropower provides as much as half of the electricity in some states in the Northwest—Washington, Oregon, and Idaho. The top five states for hydropower generation are Washington, Oregon, California, New York, and Montana. These five states provide 61 percent of the electricity generated from hydropower in the U.S.

Today, there is approximately 80,000 megawatts of conventional hydro generating capacity in the United States and more than 102,000 megawatts when including pumped storage. That's enough to power 25 million homes. In 2025, hydropower accounted for 5.46 percent 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 imports some hydropower-generated electricity from Canada. Some New England utilities buy this 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 additional 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 can cost as little as about two cents per kilowatt-hour (kWh) to produce electricity at a typical existing hydropower plant. In comparison, it often costs coal plants about four cents per kWh and nuclear plants about three cents per kWh to generate electricity.

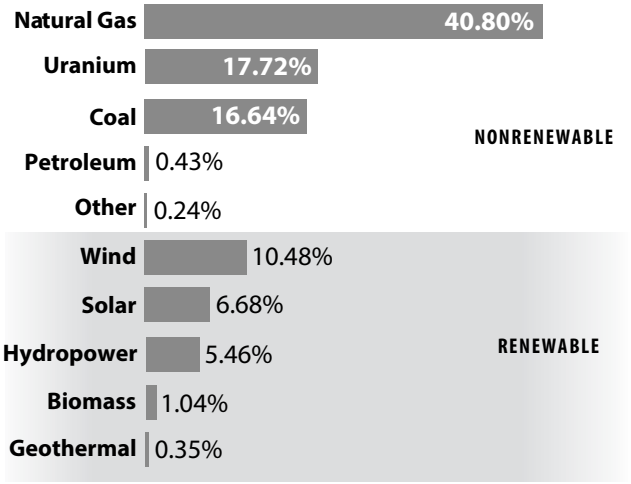
One reason producing electricity from hydropower is cheap is that once a dam has been built and equipped, the energy source—flowing water—is free. Hydropower plants also produce power cheaply due to their study structures, simple equipment, and high efficiency. Nearly all of the energy in the flowing water is transformed into electricity—between 85 and 95 percent. For comparison, thermal power plants, like natural gas and uranium, are about 35 percent efficient. Hydropower plants are dependable, extremely efficient, long-lived, and have low maintenance costs compared to coal or nuclear plants. All of these factor into the low cost of using hydropower to generate electricity.

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 often requires up to seven years to get a license to build a hydroelectric dam or to relicense it for continued operations.

Hydropower and the Environment

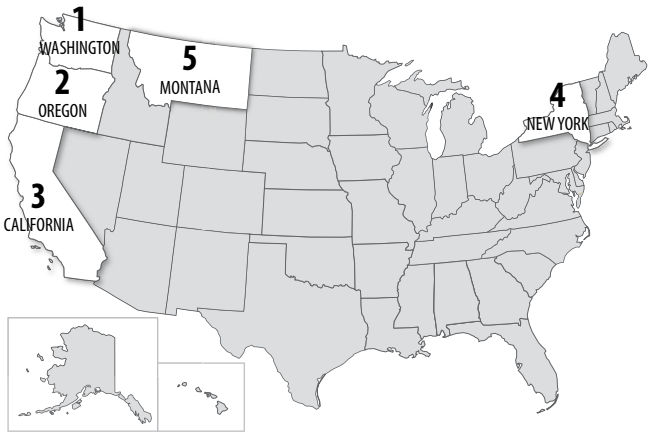
Hydropower dams can cause several environmental problems, even though they burn no fuel. Damming rivers permanently alters river systems and wildlife habitats. For example, fish may no longer be able to swim upstream. Blocking water flow through a river system also prevents important nutrients and minerals from moving downstream. Silt, sediment, and debris build up behind the dam, and native species may not be able to thrive in the river.

U.S. Electricity Net Generation, 2025



*Total may not equal 100% due to independent rounding.
Data: Energy Information Administration
Other: purchased steam, fossil fuel gases, tire-derived fuels, non-biogenic waste, batteries, chemicals, etc.

Top Hydropower-Producing States, 2025



Data: Energy Information Administration

Hydropower plant operations may also affect water quality by churning up dissolved metals that may have been deposited by industry long ago. In addition, they may also change water temperatures and change the levels of dissolved oxygen. Water quality and the ecosystems around a dam are closely monitored. 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.

Hydropower: Marine 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, since there's no one there to use it. We can use only the energy near shore, where people need it.

Tidal energy is a 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 in the U.S. 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.

Some 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. Other options for tidal energy can be less costly. Tidal turbines work very much like wind turbines underwater, capturing the kinetic energy of the moving water with spinning blades. There are many designs for tidal turbines. 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. However, 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 was located in the Cobscook Bay and had the capacity to power up to 2,000 homes while it was grid-connected. More testing is underway in the same area. Alaska is exploring the possibility of incorporating tidal power into the Railbelt grid. The keys to a successful tidal energy project are to lower construction costs, increase output, and protect the environment.

Wave Energy

Research and development of wave energy is happening all over the globe. Worldwide, many conceptual designs of wave energy conversion devices have been developed, but only a few have been built as full-scale prototypes and tested under real world conditions. So far, no particular technology is considered an ultimate solution. Off the coast of Oregon, PacWave, the first utility-scale, grid-connected wave energy test site in the U.S. allows developers and researchers to test their prototypes.

OSCILLATING WAVE SURGE FLAP DEVICE



Image courtesy of IKM 3D UK

Wave energy devices use the energy of the waves to move and generate electricity. Devices can be anchored to the seafloor, like this surge flap, or floating on the surface like buoys.

Wave energy devices turn motion or mechanical energy into electric current. Wave energy technology can be grouped into a few major categories, each with a different method for harnessing energy from waves: attenuators, point absorbers, overtopping devices, pressure differential, oscillating water columns, and oscillating wave surge converters. Attenuators float on the surface and generate electricity as waves move segments of the device up and down. Point absorbers are devices like buoys that bob vertically to generate electricity. Overtopping devices capitalize on waves flowing over a barrier. Oscillating devices and pressure differential devices are situated underwater and generate electricity as waves move the devices. Wave energy technologies must survive the harsh ocean environment, efficiently extract energy from waves while being able to be connected to the electric grid, and must ensure the local environment is not harmed during operation.

OTEC

Oceans cover about 70 percent of the Earth's surface. Radiant energy from the sun is absorbed by the ocean's surface and some of it is transformed into heat. Deep ocean water does not receive any sunlight and stays at a cool, constant temperature year round. The difference in temperature between these ocean layers can be used to generate electricity in an Ocean Thermal Energy Conversion (**OTEC**) plant. An Ocean Thermal Energy Conversion power plant uses a heat engine to capture energy as heat flows naturally from hot to cold.

OTEC systems are presently not very efficient, and pumping water is a giant engineering challenge. OTEC systems work best when conditions allow for a 20˚C temperature gradient, which limits its use to tropical regions where surface waters are very warm and the water is very deep. Hawaii, with its tropical climate, has experimented with OTEC since the 1970s. A small grid-connected facility was built in Hawaii in 2015 and has the capacity to power a neighborhood or small military installation.

Natural Gas

What Is Natural Gas?

Most **natural gas** is a **nonrenewable** fossil fuel. Some sources of methane, the main ingredient in natural gas, are renewable and are discussed elsewhere in this section. Natural gas is predominately called a **fossil fuel** because it was formed from the fossilized 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

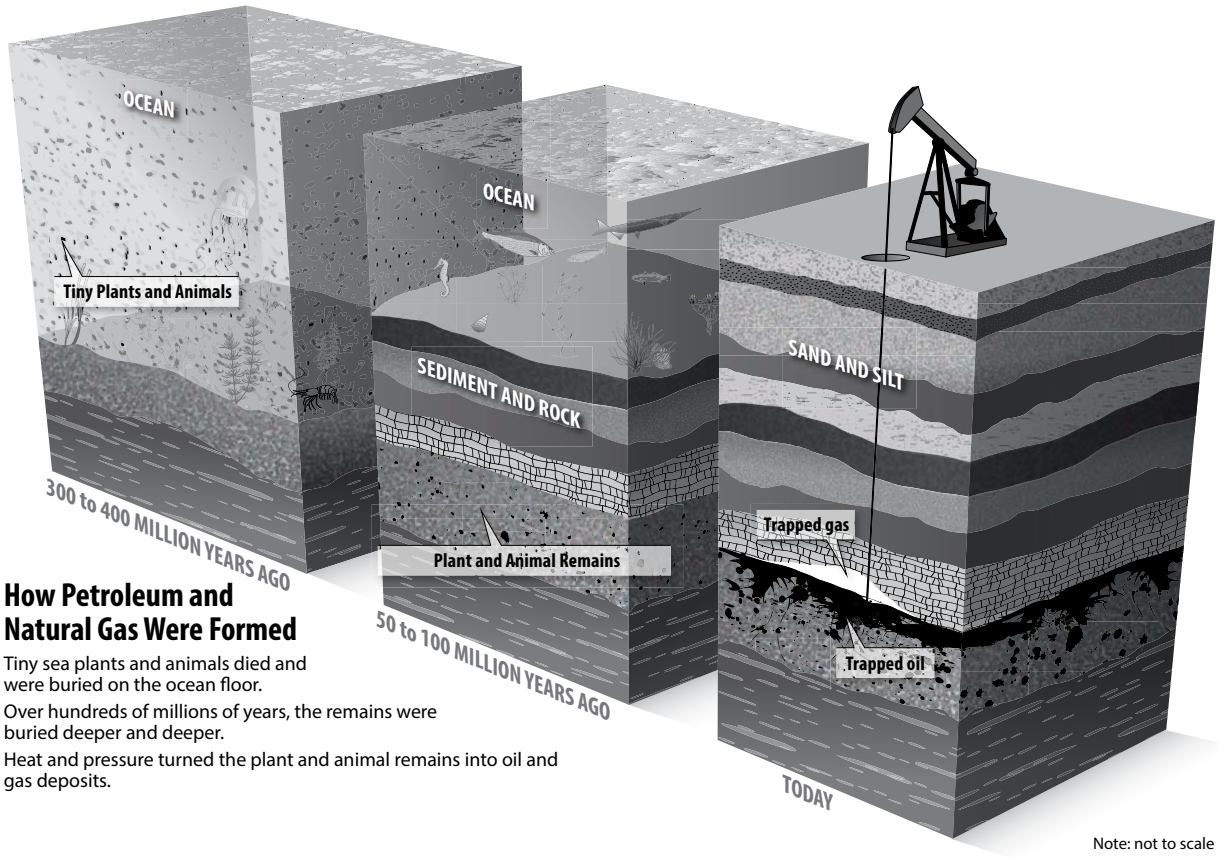
The ancient peoples of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeping from cracks in the ground was ignited by lightning. They sometimes built temples around these eternal flames so they could worship 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 35 percent of the energy we use.



Natural Gas

Natural Gas at a Glance, 2025

Classification:
- nonrenewable

Major Uses:
- heating, industry, electricity

U.S. Energy Consumption:
- 34.632 Q
- 35.99%

U.S. Energy Production:
- 40.708 Q
- 38.08%

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 production industry, about half of the **exploratory wells** yield natural gas, with the other half coming up empty. The odds are better for **developmental wells**—wells drilled on known gas fields. Over 90 percent of the developmental wells drilled in the recent past yielded natural gas. Natural gas can be found in pockets by itself or in petroleum deposits.

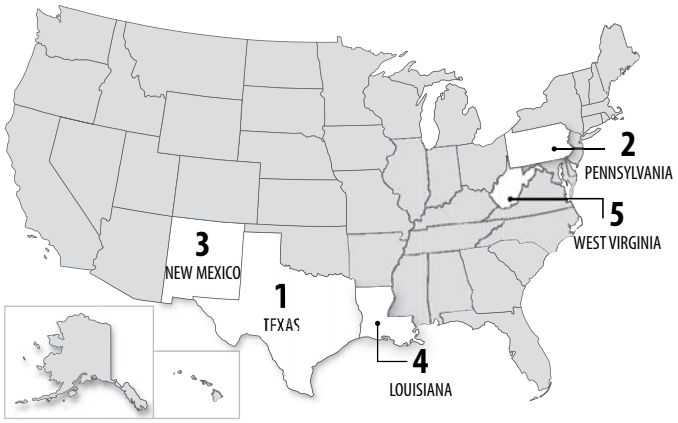
After natural gas comes out of the ground, it goes to a processing plant where it is cleaned of impurities and separated into its various components. Approximately 90 percent of natural gas is composed of methane, but it also contains other gases such as propane and butane.

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 or by water treatment facilities. This natural gas is considered a renewable source of methane since it comes from decaying waste. **Biogas** recovered from landfills and wastewater facilities may be burned onsite to generate electricity for the facility itself.

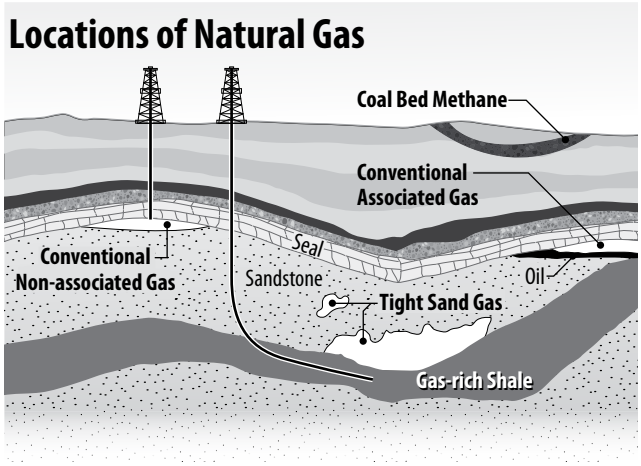
Today, natural gas is produced in 33 states, but the top five states—Texas, Pennsylvania, New Mexico, Louisiana, and West Virginia—produce 74 percent of the U.S. total. Natural gas is also produced offshore. A little more than three percent of U.S. natural gas comes from offshore wells. Altogether, the U.S. produces about one-fourth of the world's natural gas each year.

Top Natural Gas-Producing States, 2025

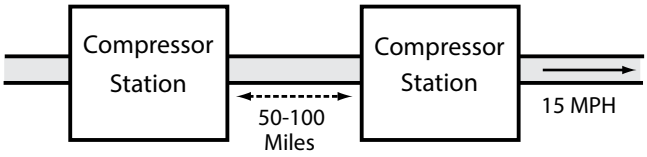


Data: Energy Information Administration

Locations of Natural Gas



Natural Gas Distribution System



Transporting and Storing Natural Gas

How does natural gas get to you? Usually by pipeline. Over three million miles of **pipelines**, both above ground and underground, 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.

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Some gas moved along this 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.

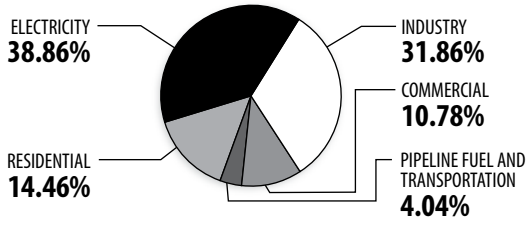
Natural Gas Use

Just about everyone in the United States uses natural gas. Natural gas ranks second in energy consumption, after petroleum, with 35.99 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 could not be made without the chemicals derived from natural gas.

Homes and businesses—the residential and commercial sectors of the economy—consume about one quarter of the natural gas in the country, as roughly half of homes use natural gas for heating and cooking. Many homes also use natural gas water heaters and clothes dryers. 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, 2025



Data: Energy Information Administration
*Total may 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, or 100 cf as used for more simple conversions by the U.S. EIA.

About 39 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 so. Natural gas power plants are cleaner than coal plants and can be brought online very quickly. Natural gas plants generate 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 almost 41 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 23 million vehicles run on natural gas across the globe, including many buses and fleet vehicles in the U.S.

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,** or proven 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 sizeable reserves of natural gas. Most reserves are in the Gulf of Mexico and in the following states: Texas, Alaska, Pennsylvania, West Virginia, New Mexico, Oklahoma, Ohio, and Louisiana. Starting in the late 1990s, proven reserves increased steadily almost every year due to improvements in shale gas exploration and production technologies. The U.S. natural gas reserves increased in 2022 to its highest level ever, 691 trillion cubic feet (Tcf). Since then, reserves have been decreasing because of the increasing demand for natural gas to generate electricity. If this continues, the United States will continue to diminish its reserves.

Natural Gas Prices

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

How much does it cost to heat your home with natural gas? Compared to other energy sources, natural gas is often the most economical choice, though the price varies regionally. For most Americans, it is cheaper than heating oil or electricity, both of which are common ways 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 burns more cleanly than other fossil fuels. 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 (CO_2), a greenhouse gas. The majority of scientists believe that increasing levels of CO_2 in the atmosphere, caused in large part by fossil fuel use, have long-term effects on the global climate. Methane released into the atmosphere before it is burned also contributes to climate change.

Natural Gas

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 that is formed by the compaction of silt and clay-size mineral particles. Shale formations, also called shale gas plays, are found all over the world. Currently, shale gas accounts for around 80 percent of all U.S. natural gas production.

SHALE GAS PRODUCTION

Horizontal Drilling: A vertical well is drilled thousands of feet down 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 (detergents), 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

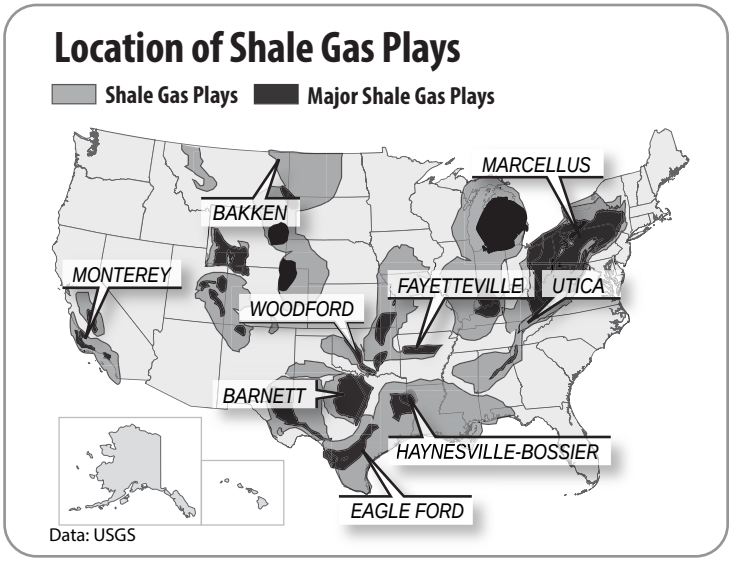
There are benefits to natural gas development. When burned, it is cleaner than coal or oil, and releases fewer emissions. Advancements in drilling and fracturing techniques have made the extraction of shale gas possible to meet increasing demand for natural gas.

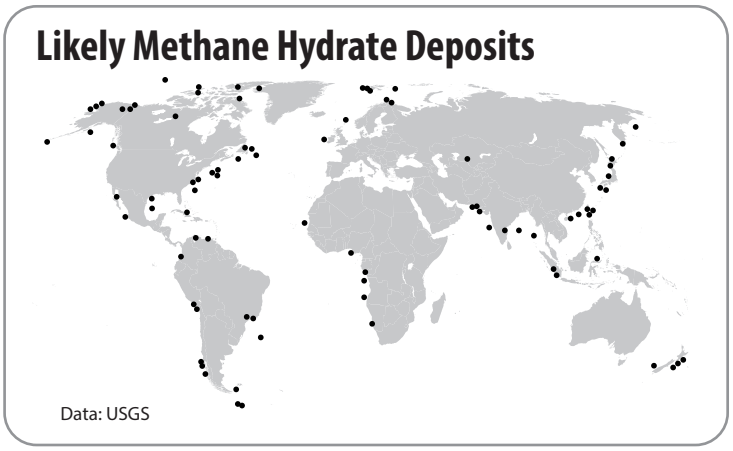
Development of natural gas from shale plays using hydraulic fracturing presents some challenges, including the need for access to water for use in the process and the need to protect local drinking water and other natural resources. In some areas, development of shale gas brings drilling operations closer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

▪ Methane Hydrates

Within sediments on the deep ocean floor, 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, the methane is captured by cage-like crystals of water molecules. Known as **methane hydrate**, this ice surrounds the methane molecules, keeping them trapped in layers that 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.





▪ Biogases and Renewable Natural Gas

Depending on how the gas is obtained and used, methane from biogases can be classified as renewable natural gas (RNG). Biogases are fuel sources derived from plant and animal waste (see *Biomass*, page 10). Biogas can be treated and dried to have the same chemical properties and quality as natural gas in pipelines. We call this renewable natural gas or RNG.

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 2023, landfill gas generated 8 billion kilowatt-hours of electricity, 0.2 percent of all U.S. utility-scale electricity generation. Industrial wastewater and sewage treatment facilities can also collect and use biogas produced by anaerobic digesters. They sell the biogas to generate electricity or treat it to be used as RNG.

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. In 2024, the U.S. exported 11.9 billion cubic feet per day of LNG.

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Petroleum

What Is Petroleum?

Petroleum, often known as **oil**, is a **fossil fuel**. It is called a fossil fuel because it was formed from the fossilized 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.

Not all organic material buried underground turns 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), called a caprock, 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 transparent and pale in color 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.

Petroleum at a Glance, 2025

Classification:
- nonrenewable

Major Uses:
- transportation, industry

U.S. Energy Consumption:
- 35.899 Q
- 37.31%

U.S. Energy Production:
- 28.211 Q
- 26.39%

Data: Energy Information Administration

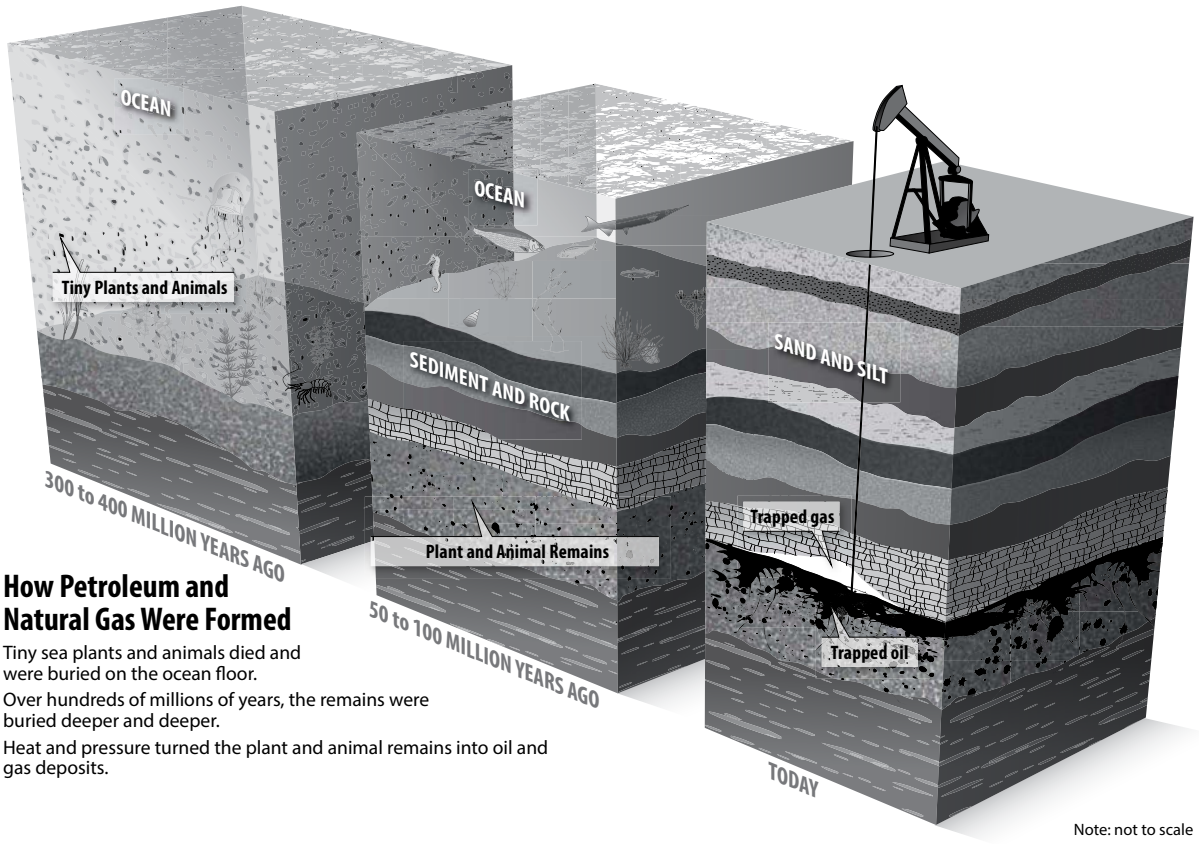
History of Oil

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 adoption 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.



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 buried deeper and deeper.

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

Note: not to scale

Petroleum

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

Producing Oil

Although research has improved the odds since Edwin Drake's days, petroleum exploration today is still a risky business. Geologists study underground rock formations to find areas that might yield oil. Even with advanced methods, only 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 might produce anywhere from 10-100 barrels of oil per day, depending how the well is drilled. However, some new wells can yield thousands of 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 petroleum than any other state. The other top-producing states are New Mexico, North Dakota, Colorado, and Alaska. These five states account for 73.88 percent of all U.S. crude oil production. In all, 32 states produce petroleum.

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?

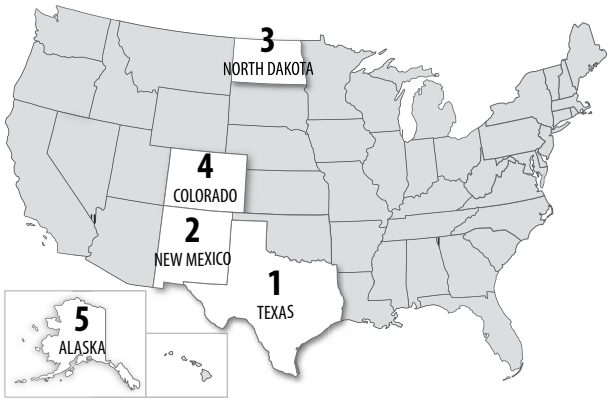
Oil's first stop after being pumped from a well is an oil refinery. A **refinery** is a plant where crude oil is processed. Sometimes, refineries are located near oil wells, but usually the crude oil has to be delivered to the refinery by ship, barge, pipeline, truck, or train.

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 byproducts. 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 about 45 gallons of products.

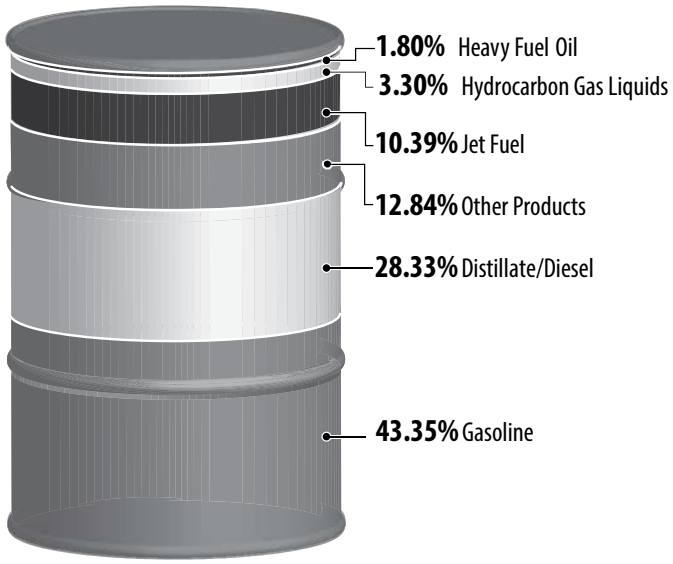
Refineries use many different methods to make these products. One method is a heating process called **distillation**. Since oil products have different boiling points, molecule sizes, and densities, the end products can be distilled, or separated. For example, asphalts have a higher boiling point than gasoline, allowing the two to be separated.

Top Petroleum-Producing States, 2025



Data: Energy Information Administration

Products Produced From a Barrel of Oil, 2025



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

Refineries have another job: they remove contaminants from the oil. A refinery removes sulfur from gasoline, for example, to increase its efficiency and 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 ship or tanker.

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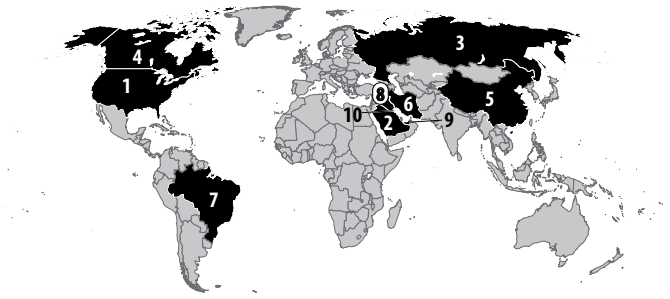
Top Oil-Producing Countries, 2025



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

Data: Energy Information Administration

Top Sources of U.S. Imported Oil, 2025



1. Canada, non-OPEC
2. Mexico, non-OPEC
3. Saudi Arabia, OPEC
4. Iraq, OPEC
5. Brazil, non-OPEC

Percentage of Total Imports from Non-OPEC Nations: 85.76%
Percentage of Total Imports from OPEC Nations: 14.24%

Data: Energy Information Administration

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.

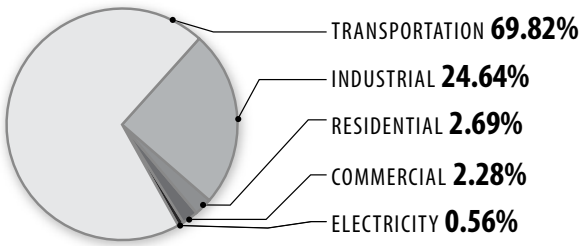
Demand for Oil

Since World War II, petroleum has been the leading source of energy consumed in the United States. Petroleum supplies almost 38 percent of total U.S. energy demand.

America uses over 20 million barrels of oil (about 925 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 57 percent more oil than we did during the oil embargo and energy challenges of the 1970s and 1980s. Most of our oil is and was simply for transportation. This is true even though today's vehicles get almost twice as many **miles per gallon (mpg)** 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 70 percent of U.S. oil consumption is used for transportation.

U.S. Petroleum Consumption by Sector, 2025



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

Imported Oil

Even though the United States produces more oil than any other country, not all domestic oil is compatible with U.S. refineries. Some of the petroleum we use must be imported. In 2025, we imported 39 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. Other major price increases resulted from the Persian Gulf War in 1990–1991, the September 11, 2001 terrorism attacks, Hurricane Katrina in the Gulf of Mexico in 2005, the Ukraine-Russia conflict that began in 2022, and the 2026 conflict between the U.S. and Iran.

As many countries in the Middle East, North Africa, and Europe experience political change and other countries respond, 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 United States stores emergency supplies of crude oil in the Strategic Petroleum Reserve (SPR), which was established in 1975 after the oil supply crisis. The SPR is the largest government-owned emergency oil supply in the world and is used during major disruptions, such as wars, natural disasters, or global conflicts. It helps protect the U.S. economy by providing a backup supply of oil if normal sources are interrupted. In recent years, oil has been released from the SPR in response to global supply disruptions and to help stabilize fuel prices.

The United States imports oil from both non-OPEC and OPEC countries. In 2025, most imported oil came from Canada (56.76 percent) and Mexico (6.37 percent), neither of which is an OPEC country. 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 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, which might include areas like the Arctic National Wildlife Refuge (ANWR) in northern Alaska and offshore. Others say we should increase our use of other transportation options like electricity. Many people agree that the United States must increase production from domestic sources, increase efficiency, and continue development of non-petroleum transportation fuels.

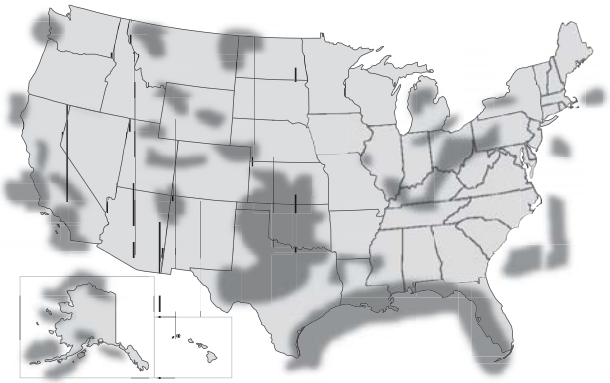
Offshore Oil Reserves

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 (Gulf of America). 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 percent of the nation's natural gas production and about 14 percent of its oil production. Most of the active wells are in the central and western Gulf of Mexico (Gulf of America), with additional wells off the coasts of California and Alaska.

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.

U.S. Oil and Gas Basins



Data: Energy Information Administration

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. For a brief time, the Pacific Coast, the eastern portion of the Gulf of Mexico, and parts of Alaska were restricted from new lease sales. However, those restrictions were lifted, and a few lease sales took place in 2020. In January of 2021, all new lease sales were paused in an effort to address climate concerns in the U.S., however, a new lease program is in place for 2024-2029.

OFFSHORE OIL RIG



Image courtesy of Wikimedia Commons

Crew transport on the Green Canyon Oil Rig, Gulf of Mexico (Gulf of America).

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. By 2024, prices averaged much higher at $76 per barrel, and it continues to yo-yo with changes to global politics and with major Earth events.

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. Air quality suffers, and more greenhouse gases are emitted, impacting the climate.

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. However, petroleum production, distribution, and consumption can 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. Refineries must curb emissions and monitor water quality. Fuels have been reformulated to burn cleaner, reducing the levels of lead, nitrogen oxide, carbon monoxide, and hydrocarbons released into the air.

Despite regulations and advances, using petroleum-based fuels and creating products from petroleum still emit greenhouse gases that impact the environment. Continued dependence on petroleum presents an ongoing challenge. The future must balance the demand for petroleum products with protection of the global environment.

THE PRICE OF OIL



Image courtesy of Adobe Stock

Oil tankers wait to offload product at a time of high demand.

HABITAT CLEANUP



Image courtesy of Wikimedia Commons

RISK TO WILDLIFE



Image courtesy of NOAA

Turtle Rescue and Rehabilitation. Dr. Brian Stacy, NOAA veterinarian, prepares to clean an oiled Kemp's Ridley turtle after the BP Gulf of Mexico (Gulf of America) oil spill.

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 fossilized 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.

Propane at a Glance, 2025

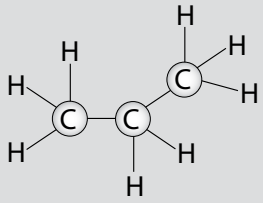
Classification:
- nonrenewable

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
- over 830 thousand barrels consumed per day

PROPANE = C_3H_8



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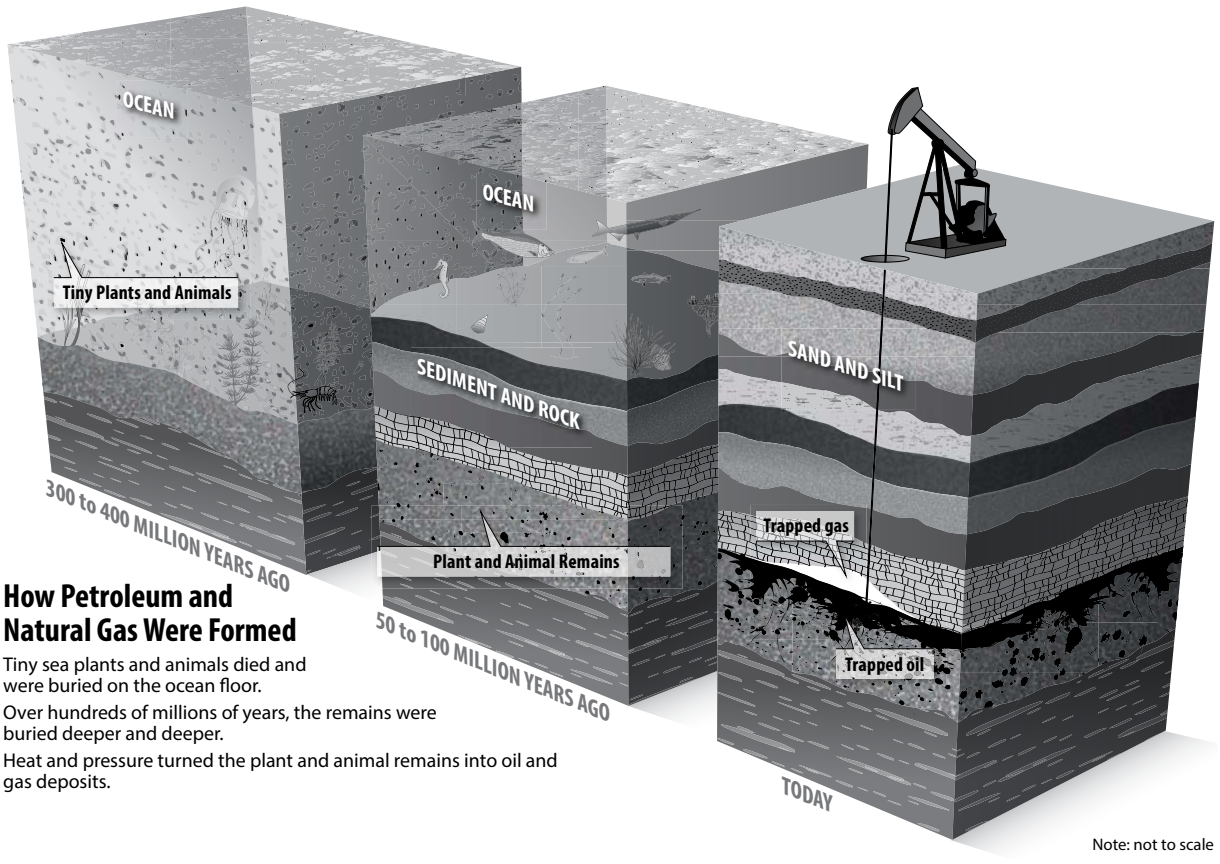

How Petroleum and Natural Gas Were Formed

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

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

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

Note: not to scale

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Propane

Once natural gas and petroleum 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 being used 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 some 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

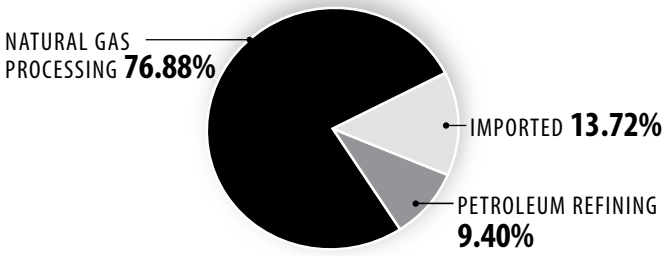
Propane does not have a long history. It wasn't discovered until 1912 when people were trying to find a way to store gasoline, which evaporated when stored under normal conditions.

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

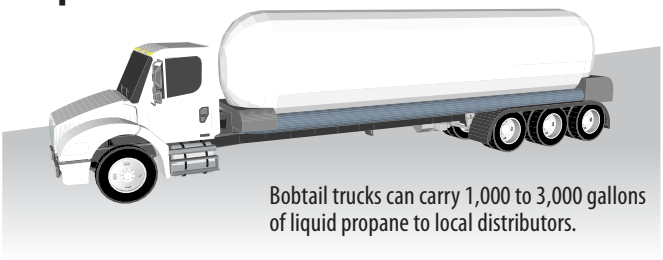
Propane comes from natural gas and petroleum wells. About 77 percent of the propane used in the United States is extracted from raw natural gas. Raw natural gas contains about 90 percent methane, five percent propane, and five percent other gases. The propane is separated from the raw natural gas and the other gases at a natural gas processing facility.

Sources of U.S. Propane, 2025



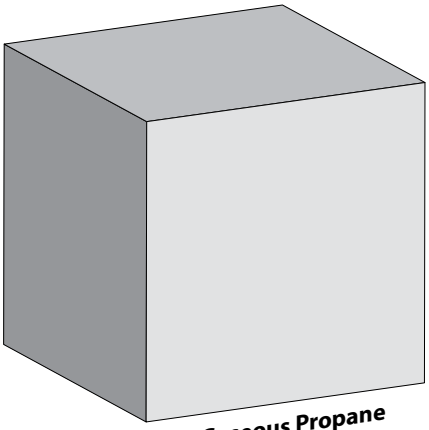
Data: Energy Information Administration
*Total may not equal 100% due to independent rounding.

Propane Truck



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

Liquefied Propane



Gaseous Propane
Volume = 270 gallons

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



Liquid Propane
Volume = 1 gallon

About 9 percent of propane is extracted from crude petroleum. Petroleum is separated into its various products at a processing plant called a **refinery**. About 14 percent of the propane we use in the U.S. is imported from other countries, mostly by railcar from Canada.

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 or exchanged. There are tens of thousands of 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 the largest consumers 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. It is estimated that over 50 million homes use propane to meet some of their energy needs. About 5.2 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

Roughly 800,000 American 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 system pumps, standby generators, and seedling planters.

RESIDENTIAL TANK

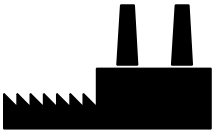


Image courtesy of Adobe Stock/ Muchtar

How Propane Is Used



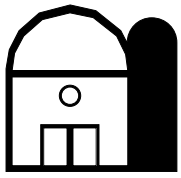
To heat homes



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

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Propane

- **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.

- **Industry**

Industry uses about 41 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 86 percent of the propane used in this country is produced in the United States from petroleum and natural gas but, since we import 39 percent of the petroleum we use, about 14 percent of the propane we produce here is made from imported fuel.

Propane and the Environment

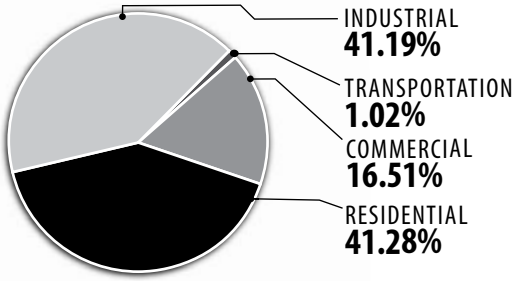
Propane is a very clean-burning fossil fuel, which explains its use in indoor settings. It was approved as an alternative fuel under the Clean Air Act, as well as the National Energy Policy Act of 1992.

PROPANE-POWERED FORKLIFT



Image courtesy of Adobe Stock/ Henry Saint John

U.S. Propane Consumption by Sector, 2025



Propane is used very little for electricity generation. If used for electric power, often it is in off-grid applications.
Data: Energy Information Administration
*Total may not equal 100% due to independent rounding.

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.

Image courtesy of the U.S. Department of Energy

Propane-fueled engines produce less air pollution than gasoline engines. Carbon monoxide emissions from engines using propane are 20 to 90 percent lower than emissions from gasoline-fueled engines. Total hydrocarbon emissions are 40 to 80 percent lower.

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

Solar

What Is Solar Energy?

Solar energy is radiant energy that is produced by the sun. Every day the sun radiates, or sends out, an enormous amount of energy. The sun radiates more energy in one day than the world uses in one year. Solar energy is continuously supplied by the sun. 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 (3.0×10^8 meters per second).

Only a small portion of the energy radiated by the sun into space strikes the Earth, one part in two billion. Yet this amount of energy is enormous. Each hour the sun provides enough energy to supply our nation's energy needs for one year.

Where does all this energy go? About 30 percent of the sun's energy that hits the Earth is reflected back into space. Another 25 percent is used to evaporate water, which, lifted into the atmosphere, produces rainfall. Solar energy is also absorbed by plants, the land, and the oceans. The rest could be used to supply our energy needs. Currently, solar energy accounts for just under 2 percent (1.44%) of our total energy consumed.

Solar at a Glance, 2025

Classification:
- renewable

Major Uses:
- light*, heat*, electricity

U.S. Energy Consumption:
- 1.388 Q
- 1.44%

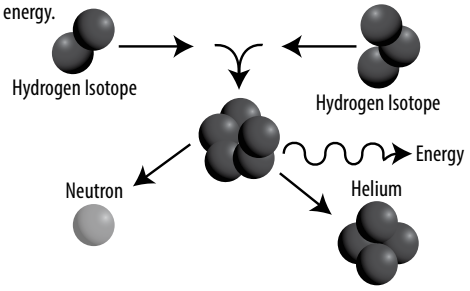
U.S. Energy Production:
- 1.388 Q
- 1.30%

*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

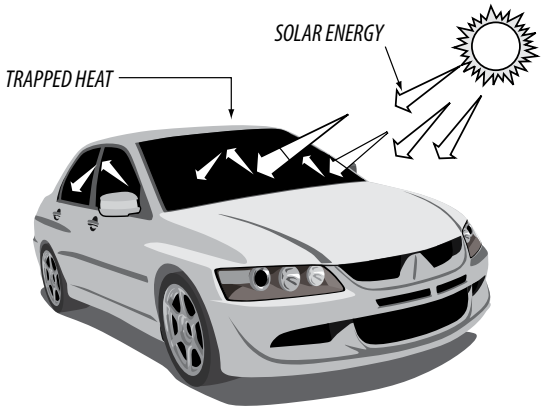
Fusion

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.



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. About 72 percent of the solar energy used by the U.S. goes to electricity generation. Much of the rest (26%) is used by homes and businesses for heating, and a very small amount is used by industry.

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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, including the time of day, season of the year, latitude of the area, and cloudiness of the sky.

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

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

- allows sunlight in through the glass (or plastic);
- absorbs the sunlight and changes it into heat; and
- traps most of the heat inside.

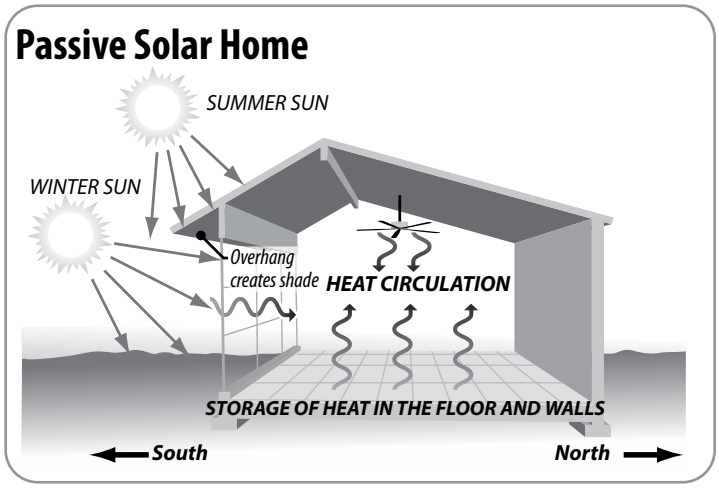
Solar Space Heating

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

▪ Passive Solar Homes

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

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



Heating a house by warming the walls or floors is more comfortable than heating the air inside a house. It is not so drafty. Passive buildings are quiet, peaceful places to live. A passive solar home can get 30 to 80 percent of the heat it needs from the sun. Many homeowners install equipment (such as fans to help circulate air) to get more out of their passive solar homes. When special equipment is added to a passive solar home, the result is called a hybrid solar system.

▪ Active Solar Homes

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

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 Thermal Energy

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

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

In active solar homes, thermal energy 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 supplemental heating 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-largest home energy expense. Heating water can cost the average family around $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 by 50 to 80 percent. A well-maintained system can last 20 years, longer than a conventional water heater.

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

The heated fluid then goes to a storage tank where it heats water. The hot water may then be piped to a faucet or showerhead. Most solar water heaters that operate in winter use a heat transfer fluid, similar to antifreeze, that will not freeze when the weather turns cold.

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

Photovoltaic Cells

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

There are four major steps involved in generating electricity from the silicon in PV cells (see page 43). Current PV cell technology is not as efficient as it could be. Today's PV cells convert about 20–50 percent of the radiant energy into electrical energy, depending on the type of cell. Most are only roughly 20-25 percent efficient. Thermal power plants, on the other hand, convert about 35 percent of their fuel's energy into electrical energy.

The cost per kilowatt-hour to produce electricity from PV cells has historically been as much as three times higher than conventional sources, but today solar PV is nearly the same cost as more conventional generation sources. PV cells make sense for many uses today, such as providing power in remote areas or other areas where electricity is difficult to provide and in areas where large amounts of power are needed. Scientists are continually working on ways to improve PV cell technology.

SOLAR HOUSE



Image courtesy of Adobe Stock

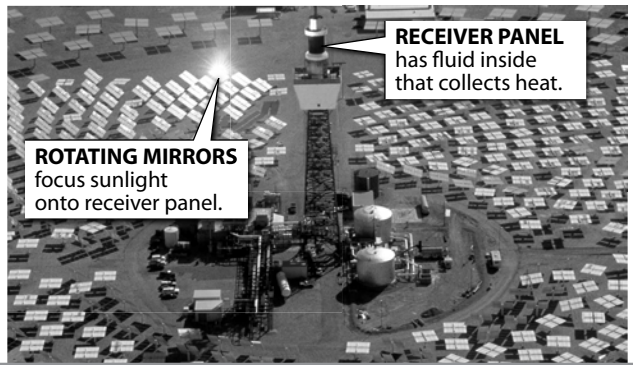
Concentrated Solar Power

Like solar cells, solar thermal systems use solar energy to make electricity. **Concentrated solar power (CSP)** technologies focus heat in one area to produce the high temperatures required to make electricity. Since the solar radiation that reaches the Earth is so spread out and diluted, it must be concentrated to produce the high temperatures required to generate electricity. There are several types of technologies that use mirrors or other reflecting surfaces to concentrate the sun's energy up to 2,000 times its normal intensity.

Parabolic troughs use long reflecting troughs that focus the sunlight onto a pipe located at the focal line. A fluid circulating inside the pipe collects the energy and transfers it to a heat exchanger, which produces steam to drive a turbine. The U.S. has several large parabolic trough systems located in California and Arizona. However, the world's largest, a 600-megawatt trough system, is located in Dubai. The solar park that houses the trough also includes a power tower system that will be the tallest in the world.

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, but this facility's future is uncertain as it is embroiled in closure litigation.

Solar Power Tower



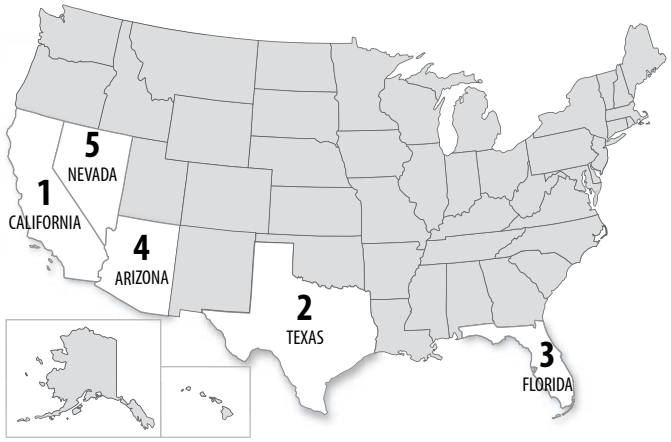
Dish/engine systems are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators are small mobile units that can be operated individually or in clusters, in urban and remote locations.

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. Today, solar provides the U.S. with 6.68 percent of its electricity and is expected to continue to increase.

Top Solar States (Net Generation), 2025



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

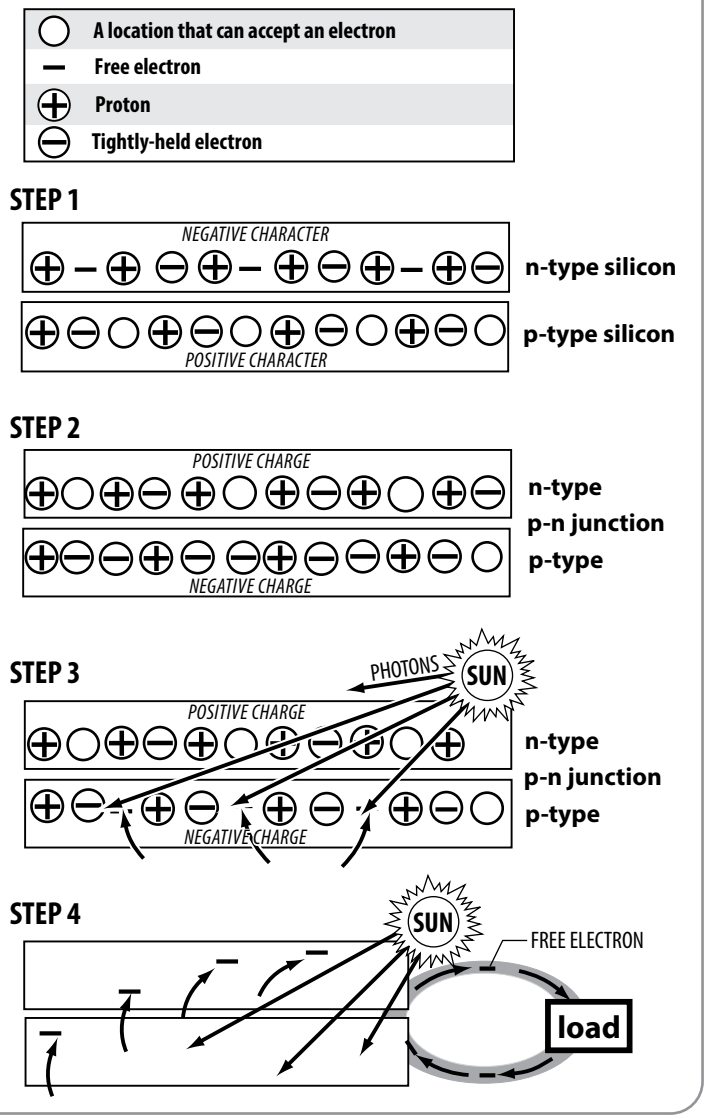
If the PV cell is placed in the sun, **photons** of light strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-type silicon and repelled by the negative charge in the p-type silicon. Most photon-electron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



PV ARRAY



Image courtesy of Adobe Stock/ bilanol

Uranium (Nuclear)

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 in the United States.

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, pitchblende, or uraninite. 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 40).

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

History of Nuclear Energy

Compared to other energy sources, nuclear energy is a very new way to produce energy. It wasn't until the early 1930s that scientists discovered that the nucleus of an atom is made up of protons and neutrons. Then in 1938, two German scientists split the nucleus of the atom apart by bombarding it with a neutron—a process called fission. Soon after, a Hungarian scientist discovered the chain reaction and its ability to produce enormous amounts of energy.

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

The first nuclear power plant came online in Shippingport, PA in 1957. Since then, the industry has experienced dramatic shifts in fortune. Through the mid 1960s, government and industry experimented with demonstration and small commercial plants. A period of rapid expansion followed between 1965 and 1975.

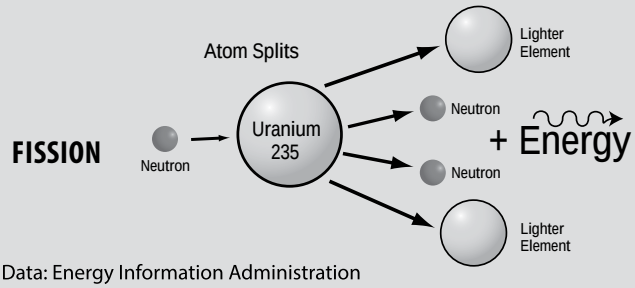
Uranium at a Glance, 2025

Classification:
- nonrenewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 8.195 Q
- 8.52%

U.S. Energy Production:
- 8.195 Q
- 7.67%



Data: Energy Information Administration

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, with new reactors recently coming online and decommissioned reactors being renewed for use.

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**, in situ recovery, 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, six in situ leach plants are operating in the United States, mostly in Wyoming, with others licensed, decommissioned, or on standby, which could be used in the future.

▪ 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.

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Uranium

▪ 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, 1 ton of coal, or 17,000 cubic feet of natural gas. 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

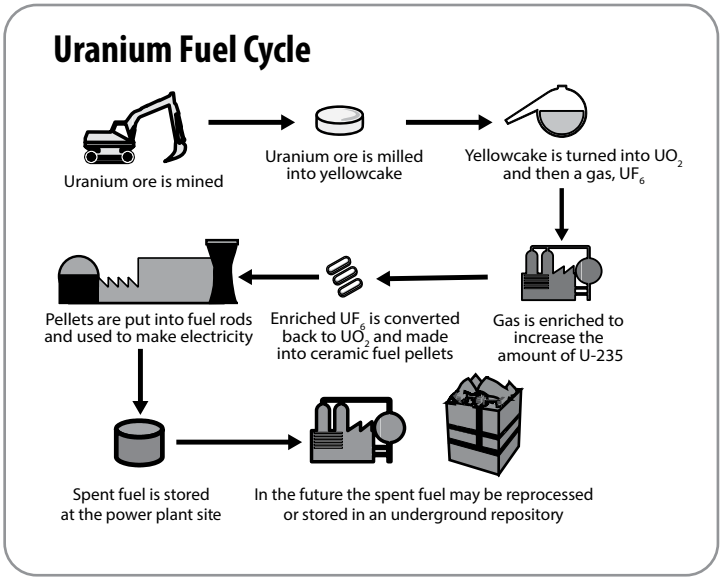
The uranium fuel is now ready for use in a nuclear **reactor**. The reactor is the center of the nuclear power plant. Fissioning takes place in the reactor core. Surrounding the core of the reactor is a shell called the reactor pressure vessel. To prevent heat or radiation leaks, the reactor core and 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 that of 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 to one-half 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; and in 10 years, 90 percent. The spent fuel pool is a temporary method for storing used nuclear fuel. However, there is no permanent storage solution for spent fuel, and space in fuel pools can run out quickly.

The nuclear industry utilizes dry cask storage as another storage solution. Currently, the spent fuel stays in the pool for five to seven years. Then, it is moved elsewhere on the nuclear power plant site to be stored in vaults or dry casks. Each of these methods for managing spent nuclear fuel puts the fuel into airtight steel and concrete structures. The U.S. Nuclear Regulatory Commission has stated that it is safe to store spent fuel on site for at least 120 years. Eventually, the spent fuel will be reprocessed and/or transported to a permanent federal disposal site, although no permanent facilities exist at this time.

▪ Reprocessing

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

Currently, American nuclear power plants store the spent fuel in spent fuel and then dry casks—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

Many scientists believe the safest place 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.

What Is Radiation?

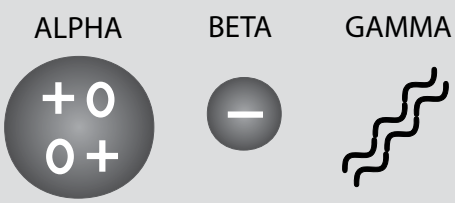
Radiation is energy released by atoms. It is very powerful and moves very fast. Not all atoms are radioactive. Some atoms—the radioactive ones—have more neutrons than protons, making them unstable. In a natural process called **radioactive decay**, these atoms give up their energy and nuclear particles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

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

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

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

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



The Department of Energy (DOE) originally looked at Yucca Mountain, NV, to be the site of a national spent nuclear fuel repository. In 2010, the DOE withdrew its Yucca Mountain application with the intention of pursuing new long-term storage solutions.

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

Nuclear Energy Use

Nuclear energy is an important source of electricity, ranking second after natural gas and providing 17.72 percent of electricity in the U.S. in 2025. There are 94 total reactors at 54 plants operating in 28 states. Two formerly decommissioned plants—one in Michigan and one in Pennsylvania—will be brought back online by 2028.

Nuclear energy now provides about 9 percent of the world's electricity. China, United States, India, Russia, Japan, Canada, South Korea, Ukraine, Spain, and Sweden are world leaders. France generates over 60 percent of its electricity with nuclear power. Japan was a former leader in worldwide nuclear production. The Fukushima incident (see page 47) prompted Japanese authorities to temporarily halt nuclear power generation, and in 2014, Japan produced no electricity from uranium. New safety measures have led to the gradual reopening of Japan's nuclear power plants, restoring its status as a leader. Ukraine is a leader in nuclear generation; however, a 2022 conflict involving a Russian military invasion has slowed operation of some of its large facilities. The International Atomic Energy Agency and the Nuclear Energy Agency will continue to monitor the operation and safety of these facilities.

Licensing Nuclear Power Plants

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

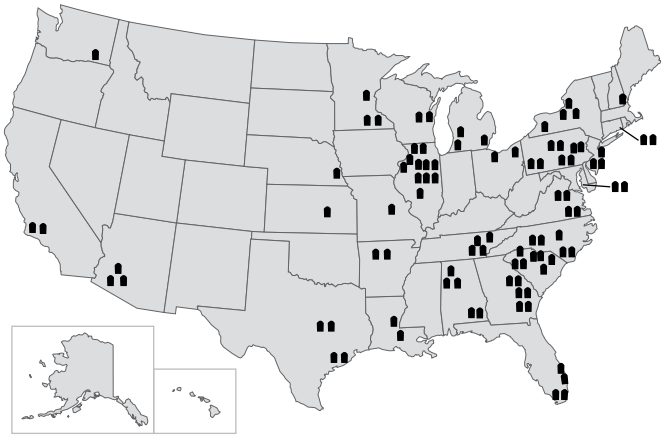
When the builders of a nuclear power plant apply for a license, local hearings are held so people can testify and air their concerns and opinions. After a plant is built, the Nuclear Regulatory Commission places inspectors at the site to assure the plant is operating properly.

Economics of Nuclear Energy

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

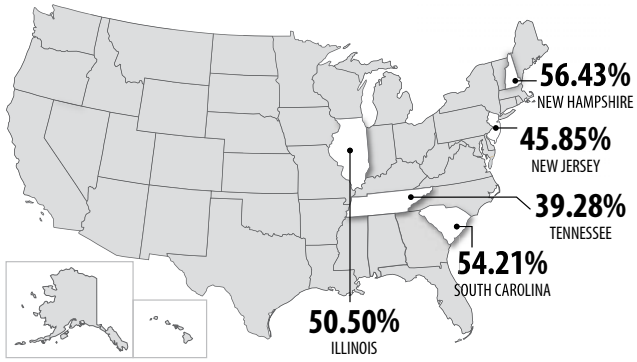
If you consider only the fuel costs and operating costs, nuclear electricity is about three cents per kilowatt-hour (kWh). In comparison, the cost of producing electric power from new coal plants is approximately four and a half cents per kWh.

U.S. Nuclear Power Reactors, 2025



Data: Energy Information Administration
*Some plants contain more than one reactor.

States with the Largest Percentage of Electricity Generated by Nuclear Energy, 2025



Data: Energy Information Administration

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

Nuclear Energy and the Environment

Nuclear power plants have very little impact on the environment. Generating electricity from nuclear power produces no air pollution because no fuel is burned. Most of the water used in the cooling process is recycled. Using nuclear energy may become an important way to reduce the amount of carbon dioxide produced by burning fossil fuels and biomass. Carbon dioxide is considered the major greenhouse gas.

People are using more and more electricity for computing and devices. Nuclear energy is beginning to be used to help meet increased demand for data centers and to produce the amount of electricity people need at a cost they can afford.

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

Nuclear Safety

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

In 1979, at the Three Mile Island facility in Pennsylvania, the top half of the uranium fuel rods melted in unit 2 when coolant to one reactor was cut off in error. A small amount of radioactive material escaped into the immediate area before the error was discovered. Due to the safety and containment features of the plant design, multiple barriers contained almost all of the radiation and no injuries or fatalities occurred as a result of the error. In response to the incident at Three Mile Island, the U.S. nuclear industry made upgrades to plant design and equipment requirements. Operator and staff training requirements were strengthened, and the U.S. Nuclear Regulatory Commission took on a greater role in emergency preparedness and routine inspections. Lessons learned from Three Mile Island were shared with the international nuclear industry. Three Mile Island Unit 1 was decommissioned in 2019 for economic reasons but is set to restart in 2027 as the Crane Clean Energy Center.

In 1986, in Ukraine (former Soviet Union) at the Chernobyl nuclear power plant, two steam explosions blew the top off of one of the units. A lack of containment structures and other design flaws caused the release of a large amount of radioactive material into the local community. More than 200,000 people were evacuated from their homes and about 200 workers were treated for radiation sickness and burns. Several people were killed immediately or died shortly thereafter, with others suffering longer-term medical ailments. This region has once again become a focus of concern due to military conflict in the areas surrounding Ukraine's power plants. Safe operating procedures have been followed to minimize risks where allowable.

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

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

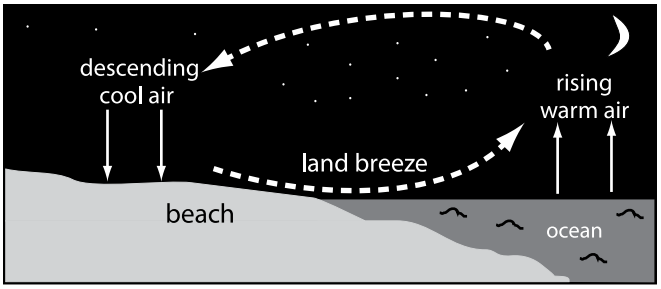
Wind

What Is Wind?

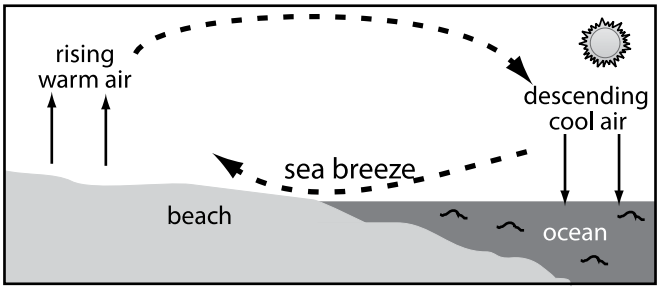
Wind is simply air in motion. It is produced by the uneven heating of the Earth's surface by energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's radiant energy at different rates. Much of this energy is converted into heat as it is absorbed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

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

Land Breeze



Sea Breeze



Windmill



Weather Vane



Anemometer



Wind at a Glance, 2025

Classification:
- renewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 1.585 Q
- 1.65%

U.S. Energy Production:
- 1.585 Q
- 1.48%

Data: Energy Information Administration

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

The History of Wind

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

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

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

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

Monitoring Wind Direction

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

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

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Wind

Wind Speed

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

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

Modern Wind Machines - Wind Turbines

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

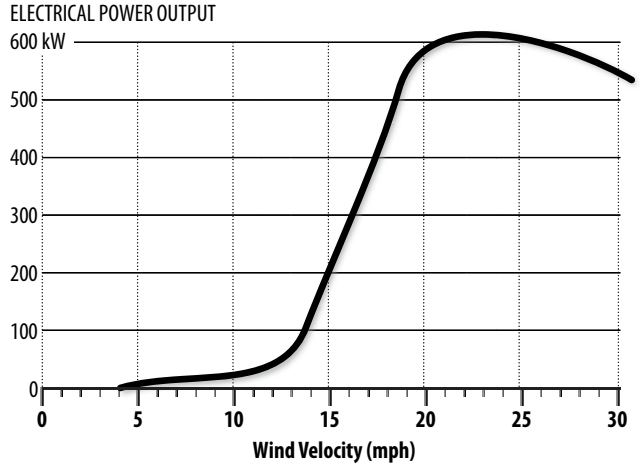
1. The moving air is caught by the blades and spins the rotor.
2. The rotor is connected to a low-speed shaft. When the rotor spins, the shaft turns.
3. The low-speed shaft is connected to a gear box. Inside the gear box, a large slow-moving gear turns a small gear quickly.
4. The small gear turns another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

Wind turbines are most efficient when they are built where winds blow consistently, at a minimum of 7-16 miles per hour (at least 3 meters per second). Faster winds generate more electricity, but if the wind speed is too fast, generation declines. High above-ground winds are stronger and steadier. Wind turbines today are typically placed on top of towers that are about 80 meters (260 feet) tall.

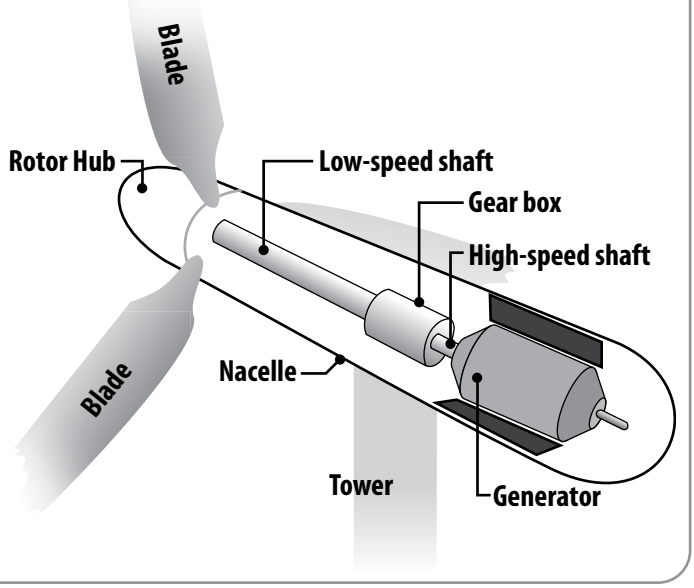
There are many different types of wind turbines with different tower and hub heights, as well as varying blade designs and lengths. Wind turbines can be designed to optimize output for specific ranges of wind speed. Turbines typically can generate electricity when winds are between 6 and 55 mph (3-25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

Wind turbines also come in different sizes, based on the amount of electric power they can generate. Small turbines may produce only enough electricity to power a few appliances in one home. Large turbines are often referred to as "utility-scale" because they generate enough power for utilities, or electric companies, to sell. The largest turbines on land in the U.S. produce 1.5 to 7.5 megawatts (MW), enough electricity to power 375 to 1,875 homes. Offshore turbines are even bigger—up to 15MW. Large turbines are grouped together into **wind farms**, which provide bulk power to the electrical grid.

Sample Power Curve of a Wind Turbine



Wind Turbine Diagram



Wind Farms

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

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

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

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

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

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

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

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

Wind farms are also constructed **offshore** in water where there is consistent wind speed much of the time. The wind blows stronger and steadier over water than land. There are no obstacles on the water to block the wind, and there is a lot of wind energy available offshore. Offshore wind farms are built in the shallow waters off the coast of major lakes and oceans using fixed-bottom designs, and using floating designs for deeper water. Offshore turbines are much larger and produce more electricity than turbines on land, generating up to 16 MW of electrical power per turbine. However, construction can be difficult and expensive. Large cables that carry the electricity must be laid on the bottom and will travel to shore.

The U.S. welcomed its first offshore wind farm in 2016. The Deepwater Wind Project, southeast of Block Island, RI, came online in August of 2016. This five-turbine, 30-megawatt farm can power 17,000 homes. Several more offshore turbines are under construction on the Atlantic coastline. Dominion Energy completed construction on a two-turbine pilot project in Federal waters off of the coast of Virginia Beach, Virginia. These two turbines can provide enough power for 3,000 homes. Dominion Energy is also building an additional 2.6 GW offshore wind project that began in 2024, and will finish in 2027. Additional wind farms are in progress along the Atlantic coast as well. Vineyard Wind 1 is the nations first utility-scale offshore wind project to generate electricity. Vineyard Wind 1 completed construction in early 2026 and is generating electricity. It aims to provide energy for over 400,000 homes in Massachusetts. The current federal administration has made attempts to block other projects from coming online.

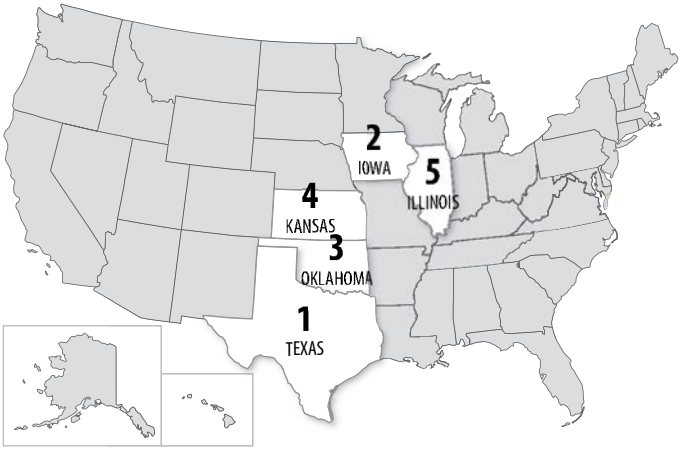
After a wind farm has been built, there are ongoing maintenance costs. In some states, these costs are offset by tax breaks given to power plants that use renewable energy sources.

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

Wind Resources

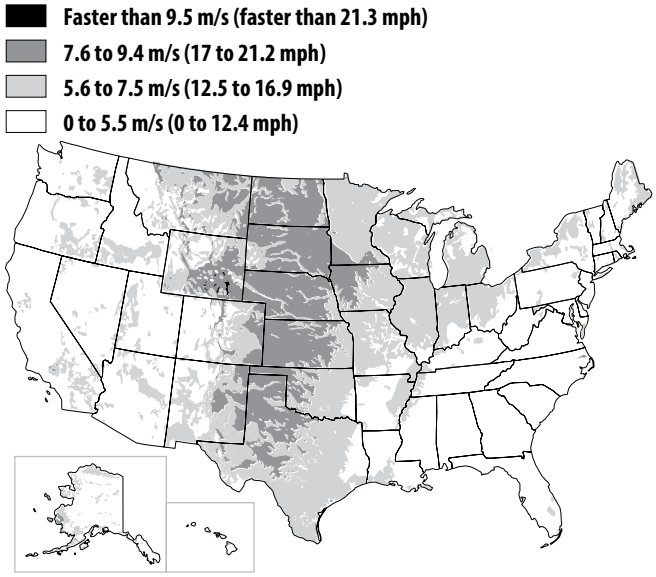
Where is the best place to build a wind plant? There are many good sites for wind farms in the United States including California, Alaska, Hawaii, the Great Plains, mountainous regions, and coastal areas. An average wind speed of 7-16 miles per hour (mph) is needed to convert wind energy into electricity economically. Currently, wind generates electricity in 43 states. Texas leads the nation, producing more than one-fourth of the wind-generated electricity in the country.

Top Wind States (Net Electricity Generation), 2025



Data: Energy Information Administration

Average Wind Speed at 80 Meters Altitude



Data: National Renewable Energy Laboratory

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Wind

Wind Production

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

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

How efficient are **wind turbines**? Wind turbines are just as efficient as most other plants, such as coal plants. Wind turbines convert 25 to 45 percent of the wind's kinetic energy into electricity. Any thermal power plant converts about 35 percent of the fuel's energy into usable electricity.

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

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

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

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

One 2.5-megawatt turbine can produce about 7.7 million kilowatt-hours (kWh) of electricity a year. That is enough electricity for nearly 750 homes per year. In this country, wind turbines produced 464 billion kWh of electricity in 2025. Wind energy provides 10.48 percent of the nation's electricity, which is enough electricity to serve nearly 45 million households.

Wind is one of the fastest-growing energy technologies in the world today. In the last four years, wind capacity worldwide has grown immensely and continues to rise. In 2024, China was the largest installer of new wind capacity. The U.S., Germany, India, and Brazil are also leaders in new installations. China, the U.S., Germany, India, and Spain are the top countries for total wind capacity installations to-date.

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

Small Wind Systems

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

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

Wind Economics

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

Second, the cost of producing electricity from the wind has dropped dramatically. Electricity generated by the wind cost 80 cents per kWh in 1980 but now can cost as little as two to five cents per kWh. Offshore wind is more expensive than onshore, but these costs will come down as the industry matures.

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

Wind Energy and the Environment

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

The most serious environmental drawbacks to wind turbines may be their negative effect on wild bat populations on land and whale populations offshore, as well as the visual impact on the landscape. To some, the glistening blades of turbines on the horizon are an eyesore; to others, they're a beautiful alternative to conventional power plants. Wind developers must carefully consider all stakeholders and species in the construction of a wind farm.

OFFSHORE WIND FARM



Image courtesy of Adobe Stock/Fokke Baarssen

Climate Change

Earth's Atmosphere

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

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

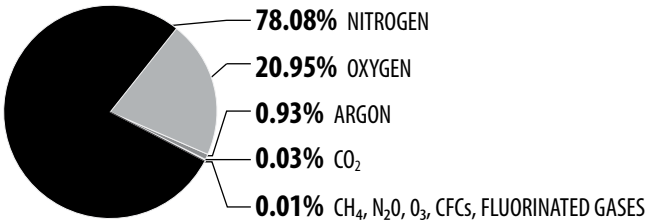
- Water vapor (H_2O) is produced naturally through evaporation. It is the most abundant and important GHG. Human activities have little influence on the concentration of water vapor in the atmosphere. However, a warmer climate increases evaporation and allows the atmosphere to hold higher concentrations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

GREENHOUSE



Image courtesy of Adobe Stock/ karegg

Major Gases in the Atmosphere (Dry)



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

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

Sunlight and the Atmosphere

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

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

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

The Greenhouse Effect

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

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

According to studies conducted by the National Aeronautics and Space Administration (NASA) and many other researchers around the world, the concentration of CO_2 has increased by more than 54 percent since the Industrial Revolution in the late 18th century. Climate change experts have concluded that this increase is due primarily to the expanding use of fossil fuels.

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Climate Change

In addition to the increase in the level of CO_2, there has also been a substantial rise in the amount of methane in the atmosphere. While there is much less methane in the atmosphere than CO_2, it is 21 times more effective than CO_2 at trapping heat. However, it does not remain intact as long in the atmosphere, only about 12 years.

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

Global Climate Change

Increased levels of greenhouse gases are trapping more heat in the atmosphere. This phenomenon is called global **climate change** or **global warming**. According to NASA, the average temperature of the Earth has risen by a little over 1.3°C (2.4°F) since 1880, with the majority of warming occurring after 1975. This increase in average temperature has been the major cause of a 21-24 centimeter rise in sea level over that time period, as well as an increase in extreme precipitation events. Sea levels are rising because sea water expands as it warms and land-based ice is melting in the Arctic, Antarctic, and in glaciers. Regions such as the Gulf Coast of the United States and several Pacific islands have already experienced losses of their coastlines. Rising global temperatures are also linked to increases in heavy precipitation events and to greater intensity in hurricanes and typhoons.

Climate scientists use sophisticated computer models to make predictions about the future effects of climate change. Because of the increased level of CO_2 and other GHGs already in the atmosphere, the Intergovernmental Panel on Climate Change (IPCC) forecasts an additional global temperature of 2.7 to more than 7 degrees Fahrenheit by 2100, depending on future greenhouse gas emissions. The climate models predict more floods in some places and droughts in others, along with more extreme weather, such as powerful storms and hurricanes. They predict an additional rise in sea level of up to two feet in some areas, which would lead to the loss of low-lying coastal areas.

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

International Awareness

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

The Greenhouse Effect

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

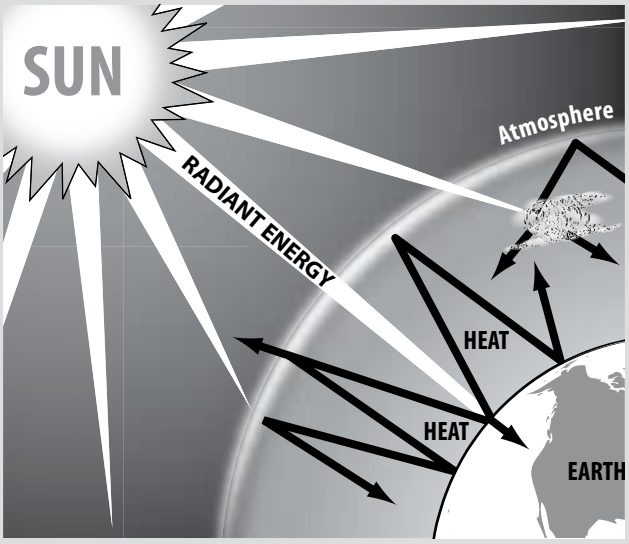
Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into thermal energy.

The Earth absorbs some of this thermal energy.

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

Very little of the thermal energy escapes back into space.

The trapped thermal energy flows back toward the Earth.



This agreement expired in 2012, and in an attempt to continue international efforts, world leaders continue to meet periodically. One of the main roadblocks is regulating GHG emissions from developing countries. These nations argue that since current climate change was primarily caused by emissions from the developed, industrialized countries, those countries should bear the responsibility of lowering emissions. They see limits on GHGs as a limit to their development and their efforts to bring millions of their citizens out of poverty. While the developed nations accept that they need to curb their emissions, they feel that developing nations will have an unfair economic advantage if they are not regulated. An international conference in Copenhagen, Denmark in 2009 ended without a strong agreement on how to regulate emissions globally. In 2015, the UN and EU hosted climate talks in Paris. The Paris Agreement set out a global plan of action to limit warming to below 2°C. The agreement has been ratified by 179 of the 197 Parties to the Convention and is a legally-binding treaty. The U.S. rejoined this agreement in early 2021, but due to an administrative change in early 2025, the U.S. has withdrawn from the Paris Agreement.

Hydrogen

What Is Hydrogen?

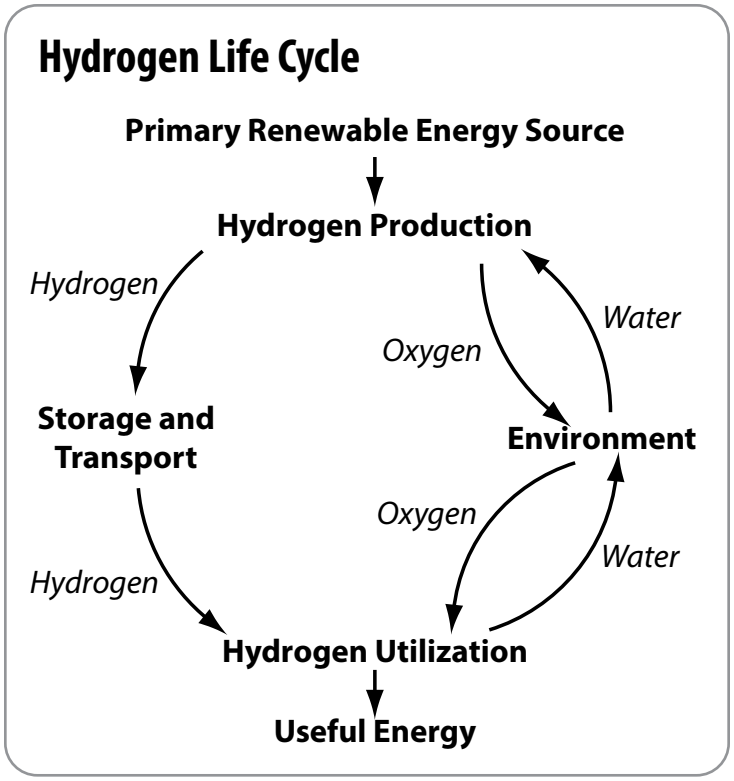
Hydrogen is the simplest element known to exist. An atom of hydrogen has one proton and one electron. Hydrogen has the highest energy content of any common fuel by weight but the lowest energy content by volume. It is the lightest element and a gas at normal temperature and pressure.

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

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

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

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



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

How Is Hydrogen Made?

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

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

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

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

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

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

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

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

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Hydrogen

Hydrogen Rainbow

Hydrogen may be assigned a color based on which renewable or nonrenewable source and process produces it. Green hydrogen is made from excess renewable sources (wind, solar, etc.) that power an electrolyzer. Blue hydrogen is produced from natural gas where CO_2 is captured and stored during steam reforming. Grey, black, and brown hydrogen are produced from natural gas steam reformation and coal gasification, where CO_2 is not captured and stored. Finally, pink, purple, or red hydrogen is generated through the use of nuclear energy to power electrolysis.

Hydrogen Uses

The U.S. hydrogen industry currently produces roughly 8.6 billion cubic feet of hydrogen every day. Most of this hydrogen is used for industrial applications such as refining, treating metals, and food processing. However, there is space for hydrogen to gain momentum for use in transportation, energy storage, and more.

Liquid hydrogen is the fuel that is used to propel rockets. Hydrogen fuel cells can also be used on transport vessels and space stations to power electrical systems.

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

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

A few hydrogen-powered vehicles are on the road today, but it will be some time before you can walk into your local car dealer and drive away in one. Today, just over 50 retail hydrogen fuel stations are operating, with most in California and one in Hawaii. There are an additional 20 stations in various stages of construction.

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

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

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

ARTEMIS I SPACE LAUNCH SYSTEM AND ORION SPACECRAFT

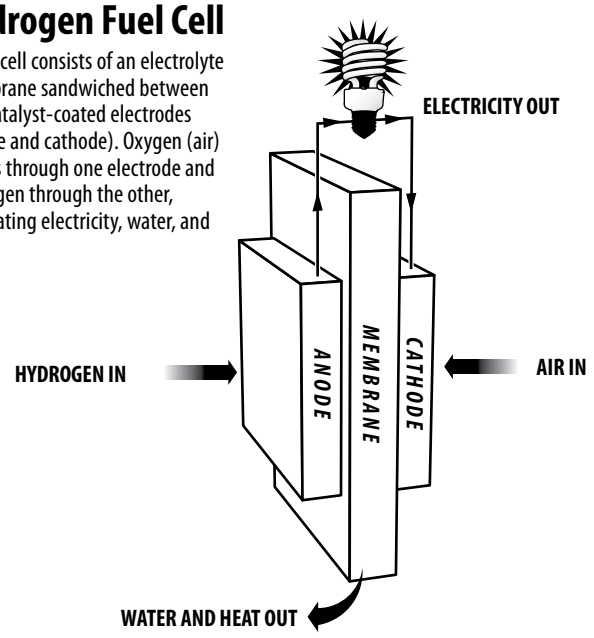


Hydrogen was used as the fuel for NASA space shuttles and rockets, beginning in the 1980s. While the U.S. shuttles have since been retired, hydrogen is still used internationally to launch satellites and as a space fuel. The NASA Artemis project will use hydrogen as a propellant. Hydrogen is a perfect fuel for space travel, as it has very high energy density while keeping weight down.

Image courtesy of NASA

Hydrogen Fuel Cell

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



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

Future of Hydrogen

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

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

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

Electricity

Electricity at a Glance, 2025

Secondary Source of Energy, Energy Carrier

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

U.S. Energy Consumption:
- 34.84%

Net U.S. Electricity Generation:
- 4,429.502 billion kWh

Major Uses of Electricity:
- manufacturing, heating, cooling, lighting, data/computing

Data: Energy Information Administration

The Nature of Electricity

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

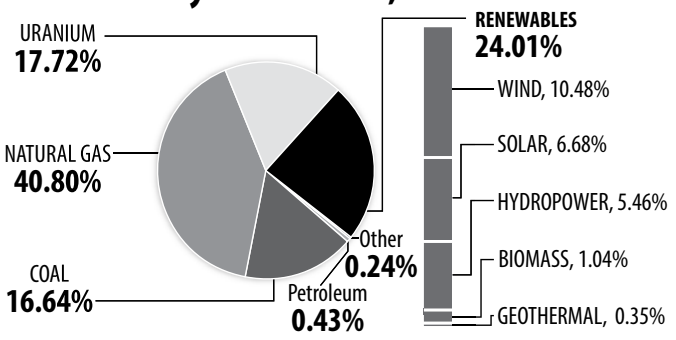
Making Electricity

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

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

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

U.S. Electricity Generation, 2025



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

Moving Electricity

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

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

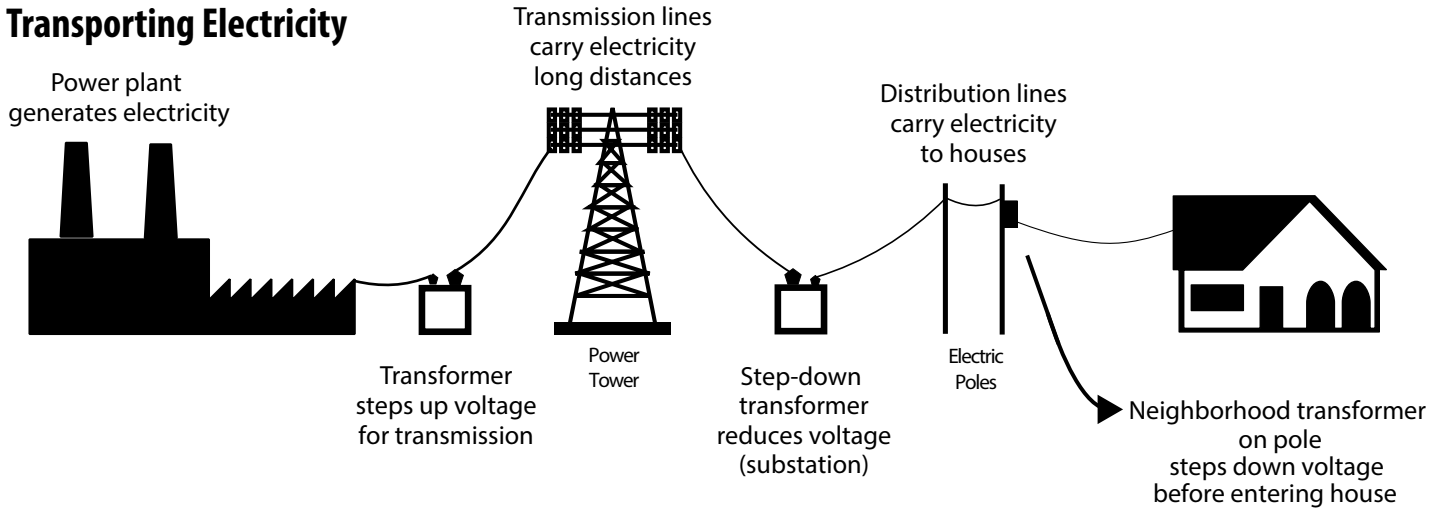
The electricity is then sent on a nationwide network of **transmission lines** made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway connected by tall power towers. The lines are interconnected, so should one line fail, another will take over the load.

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

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

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

Electricity



Power to the People

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

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

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

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

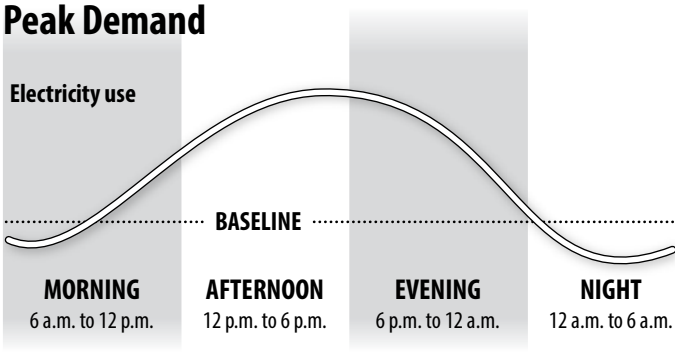
Baseload power is the electricity generated by utility companies around the clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower, and sometimes solar and wind. Baseload power stations usually run at full or near capacity.

When many people want electricity at the same time, there is a **peak demand**. Power companies must be ready for peak demands so there is enough power for everyone. During the day's peak, between 12:00 noon and 6:00 p.m., additional generators must be used to meet the demand. Peaking generators run on natural gas, diesel, or hydropower and can be put into operation in minutes because they require little start-up time. The more this equipment is used, the higher our utility bills. Stored energy can be accessed by using pumped hydropower, flywheels, compressed air, and even large battery systems. By managing the use of electricity during peak hours, we can help keep costs down.

The use of **power pools** is another way electric companies make their systems more reliable. Power pools, also known as Regional Transmission Operators (RTOs) or Independent System Operators (ISOs), link electric utilities together and manage the flow of power so they can share power as it is needed. A power failure in one system can be covered by a neighboring power company until the problem is corrected. There are seven regional power pool networks in North America. The key is to share power rather than lose it.

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

Peak Demand



Peak demand, also called peak load, is the maximum load during a specified period of time. This is a general curve that many regions experience; however, as states embrace and install different energy technologies, their curve may be shaped slightly differently.

Demand-Side Management

Demand-side management is all the things a utility company does to affect how much people use electricity and when. It is one way electric companies manage peak load periods. Through energy efficiency and load management, electric utilities can save over 1,000 billion killowatt-hours annually.

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

What's the difference between **energy conservation** and **energy efficiency**? Conservation of energy is turning off the hot water in the shower while you shampoo your hair. Energy efficiency is installing a better showerhead to decrease water flow. Both of these reduce energy use from pumping, treating, and heating the water.

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

America's Electric Grid

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

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

To get electricity to users, there are more than 640,000 miles of electric transmission lines across the U.S., with over 450,000 miles of high-voltage lines, and more than 2.5 million miles of feeder lines. They take the electricity produced at power plants to transformers that step up the voltage to reduce energy loss while it travels along the grid to where it is going to be used.

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

TRANSMISSION LINES



Image courtesy of Adobe Stock/ Volodymyr Shevchuk

Generating Electricity

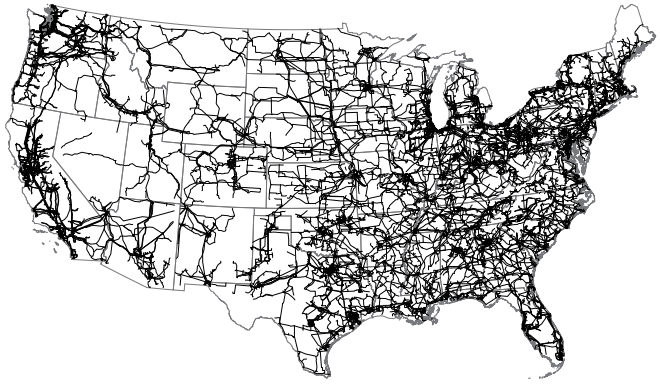
Three basic types of **power plants** generate most of the electricity in the United States—fossil fuel, nuclear, and wind. There are also hydropower, geothermal, waste-to-energy, and solar power plants, but together these four generate less than 15 percent of the electricity produced in the United States.

Fossil Fuel Power Plants: Fossil fuel plants burn coal, natural gas, or petroleum. These plants use the chemical energy in fossil fuels to superheat water into steam, which drives a **steam generator**. Fossil fuel plants are sometimes called thermal power plants because they use heat to generate electricity. Natural gas and coal are the fossil fuels of choice for most electric companies, producing 40.80 percent and 16.64 percent of total U.S. electricity, respectively. Petroleum produces 0.43 percent of the electricity in the U.S.

Nuclear Power Plants: Nuclear plants generate electricity much as fossil fuel plants do, except that the furnace is a **reactor** and the fuel is uranium. In a nuclear plant, a reactor splits uranium atoms into smaller elements, producing a great amount of heat in the process. The heat is used to superheat water into high-pressure steam, which drives a turbine generator. Like fossil fuel plants, nuclear power plants are thermal plants because they use heat to generate electricity. Nuclear energy produces 17.72 percent of the electricity in the U.S.

Wind Power Plants: Wind plants or wind farms use the kinetic energy in moving air to generate electricity. Wind turbines are installed in areas of unobstructed, consistent winds over five miles per hour. Turbine blades move in the wind and spin a generator to generate electricity. Wind farms are best sited for highest output on coastlines, in open plains, at higher elevations, and in deep water. Wind generates 10.48 percent of U.S. electricity.

The Continental U.S. Electric Grid



Data: Energy Information Administration

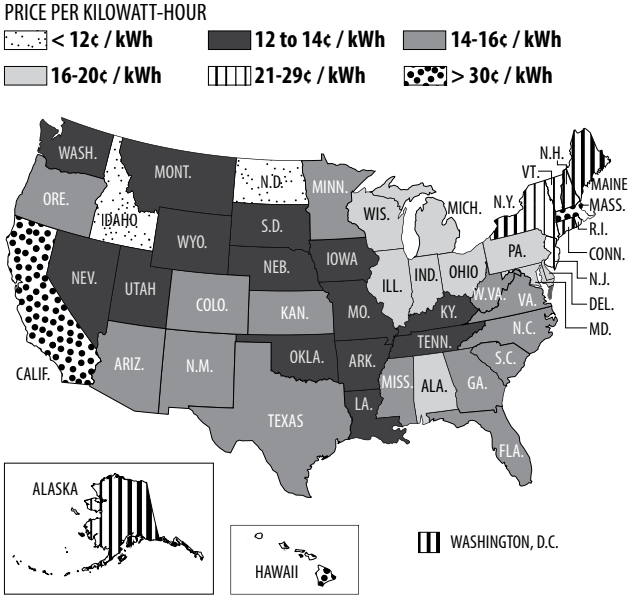
Electricity

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

While this basic system of electricity transmission has worked well since the late 1880s, the increase in electric use in recent years has put a strain on the country's electric grid. The grid we use today was designed and put into place in the 1950s and 1960s, with much of the equipment planned to handle far less electrical use. More than 70 years later, a great deal of the equipment is reaching the end of its lifespan. At the same time, our electricity use has increased tremendously, putting a huge load on the system. Just look around your home at the TVs, tablets, speakers, computers, gaming consoles, lamps, air conditioners, and all the other appliances found in the typical home today, and you'll see a tremendous demand for electricity far above the basic lights and products used in homes back when today's system was set up.

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

Average Residential Price for Electricity, 2025



Data: Energy Information Administration

In the past few years, many parts of the country have experienced brief "brownouts" or longer periods of power outages ("blackouts"), increasing public concern about the future of the system we use today. Think about this: right now, our electric grid is 98 percent reliable, meaning the power is usually there when we want it. But that very tiny percentage of time when the grid isn't working at its full capability can cost consumers billions to even hundreds of billions of dollars each year, depending on the type of outage. Outages can be due to weather, stoppages in automated equipment, computers that crash, and even the brief interruptions in the flow of energy and information in today's digital world that affect our work and our leisure activities. A more recent example of a major outage is the 2020 Texas outage due to winter weather.

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

Economics of Electricity

How much does electricity cost? The answer depends on the cost to generate the power (56 percent), the cost of transmission (14 percent), and local distribution (30 percent). The average cost of electricity is a little over 17 cents per kWh (17.30) for residential customers, about 13 cents (13.41) for commercial customers, and a little less than nine cents (8.62) for industrial customers. Electricity produced from natural gas, for example, costs more than electricity produced from uranium or hydropower. Location plays a part in electricity costs. Hawaii and California residents can pay as much as 40.59 cents and 32.54 cents per kWh, respectively, while residents of North Dakota may pay as little as 11.81 cents per kWh.

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

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

In 1900, most power plants were only four percent efficient. That means they wasted 96 percent of the fuel used to generate electricity. Today's thermal power plants are over eight times more efficient, with efficiency ratings around 35 percent. Still, this means 65 percent of the initial thermal energy used to make electricity is lost. You can see this waste heat in the clouds of steam pouring out of giant cooling towers on newer power plants. A modern coal plant burns about 4,500

tons of coal each day, and about two-thirds of the energy in this is lost when the chemical energy in coal is converted into thermal energy, then into electrical energy. A hydropower plant, on the other hand, is about 90 percent efficient at converting the kinetic energy of moving water into electricity.

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

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

Deregulation and Competition

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

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

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

Measuring Electricity

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

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

Just as we buy gasoline in gallons or wood in cords, we buy electricity in kilowatt-hours. Utility companies charge us for the kilowatt-hours we use during a month. If an average family of four uses 863 kilowatt-hours in one month, and the utility company charges 17 cents per kilowatt-hour, the family will receive a bill for $146.71 (863 x $0.17 = $146.71).

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

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

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

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

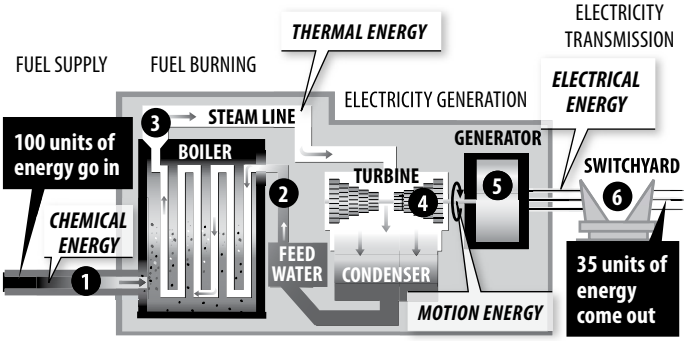
The **Federal Energy Regulatory Commission (FERC)** began changing rules to encourage competition at the wholesale level. Utilities and private producers could, for the first time, market electricity across state lines to other utilities.

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

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

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.



Fuel Sources

Petroleum | Coal | Natural Gas | Biomass | Uranium

How a Thermal Power Plant Works

1. Fuel is fed into a boiler, in which it is burned to release thermal energy. Nuclear plants are thermal plants, however the fuel is not burned; it 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, allowing it to travel through the electric grid.

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Electricity

In some states, individual consumers have the option of choosing their electricity generator or provider, much like people can choose their telephone carrier or internet service provider. Their local utility would distribute the power after it is generated to the consumer and maintain the infrastructure.

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

Future Demand

Home computers, microwave ovens, and video games have invaded our homes and are demanding electricity! Electronic devices are part of the reason why Americans use more electricity every year. Demand for electricity is projected to increase in the future despite technological energy-efficiency improvements in electric devices and appliances.

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

Conserving electricity and using it more efficiently will help, but everyone agrees we need more power plants now. That's where the challenge begins. Should we use natural gas, coal, or nuclear power to generate electricity? Can we produce more electricity from renewable energy sources such as wind or solar? And where should we build new power plants? No one wants a power plant in their backyard, but everyone wants the benefits of electricity.

Right now, most new power generation comes from natural gas, wind, and solar. Natural gas is a relatively clean fuel and is abundant in the United States. Natural gas combined-cycle turbines use the waste heat they generate to turn a second turbine. Using this waste heat increases efficiency to 50 or 60 percent, instead of the 35 percent efficiency of conventional power plants. In addition, old nuclear plants that were once decommisioned can be brought back online to help meet demand.

Smart Grids

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

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

Many areas benefit from this technology now, but further developing the smart grid would offer a variety of technologies that will help consumers lower their power usage during peak periods, allow power producers to expand their use of photovoltaics, wind, and other renewable energy technologies, provide system backup to eliminate power outages during peak times, and save money while reducing carbon dioxide emissions.

Independent Power Producers

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

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

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

For different reasons, some environmentalists also worry that IPPs may not be subject to the same pollution control laws as public utilities. In reality, the opposite is true. Because they are generally the newest plants, IPPs are subject to the most stringent environmental controls. In any case, most experts predict that IPPs will produce more and more electricity. Today, IPPs generate 42.73 percent of the nation's electricity.

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

Energy Storage

Scientists have been working hard to develop a wide range of energy storage methods and technologies that can allow electricity to be stored temporarily. Electric power producers use these energy storage technologies to quickly supply energy when it is needed and to consume energy when there is a surplus—helping to balance supply and demand instantaneously. Energy storage is continually at work, improving the way electricity is generated, delivered, and consumed in America, making our electricity grid more reliable and efficient.

Ultimately, energy storage helps power producers save money, which results in consumers saving money, too. Energy storage systems work with both nonrenewable and renewable sources of energy. Some examples of energy storage in use in small or large-scale applications include pumped storage, batteries, capacitors, flywheels, thermal storage, and compressed air. While some of these technologies have been used for many years, others are expanding more recently. Scientists continue to experiment and develop new storage methods that can help consumers on a smaller scale, and utilities on the largest of scales.

Monitoring Electricity Use

Homes and apartment buildings are equipped with meters so that utilities can determine how much electricity and natural gas each residence consumes. Most homes, apartment buildings, and commercial buildings in the U.S. have digital electric meters. However, some places may still have analog meters. Regardless of the type of meter, once a month the utility reads the meter and charges the customer for their electricity usage.

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

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

Smart meters allow customers to more closely monitor their energy usage and make changes to conserve energy. In 2024, more than 70 percent of all U.S. electric customers had smart meters.

Research and Development

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

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

Until just a few years ago, scientists thought that superconductivity was possible only at temperatures below -419°F. That temperature could be maintained only by using costly liquid helium. But new ceramic-like materials are superconducting at temperatures as high as -211°F. These new materials can maintain their superconducting state using liquid nitrogen. The economics of superconductivity is becoming practical. As helium reserves continue to diminish, costs of helium continue to rise. Its many high-tech uses will need to find substitutes. For superconductivity, liquid nitrogen may be a better bet than helium, as liquid nitrogen is far less expensive.

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

SMART METER



Image courtesy of PG&E

Smart meters communicate to the electric company daily so electricity use can be monitored by consumers more closely.

History of Electricity

Starting with Ben

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

Electricity is an action rather than a thing, so different forms of electricity had been known in nature for a long time. Lightning and static electricity were two forms.

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

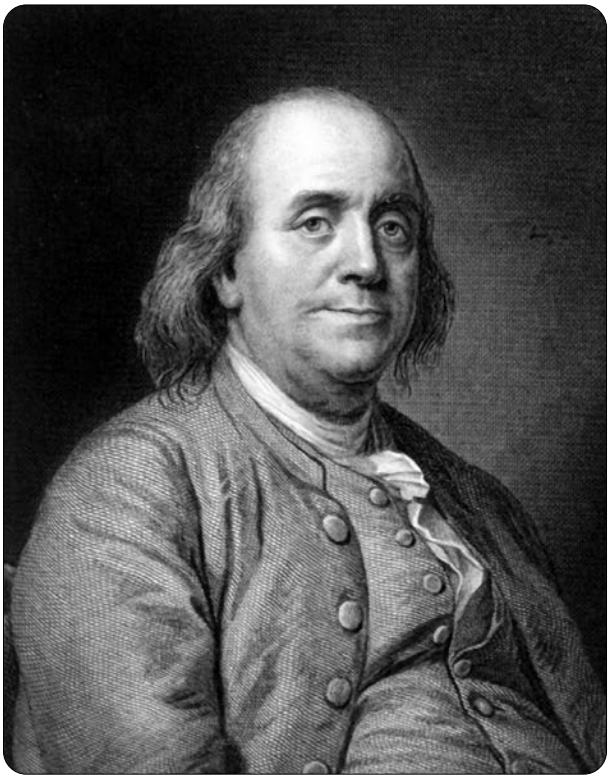


Image courtesy of NOAA Photo Library

Benjamin Franklin

A Different Kind of Power: The Battery

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

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

A Current Began

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

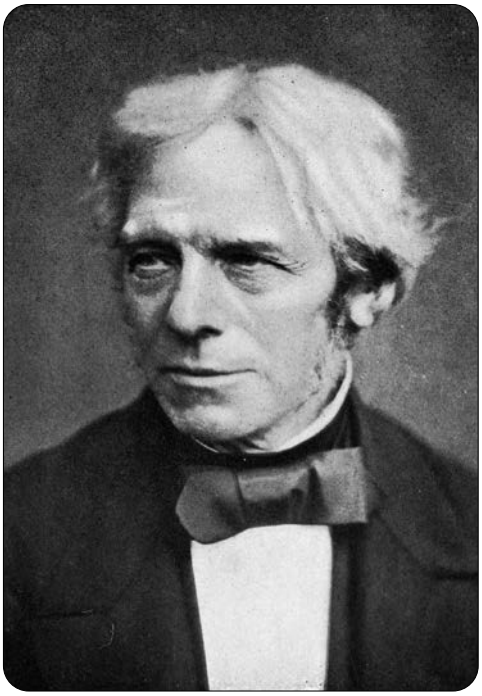


Image courtesy of Wikimedia Commons

Michael Faraday



Image courtesy of Teylers Museum

Alessandro Volta

History of Electricity

Mr. Edison and His Light

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

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

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

Edison's Pearl Street Power Station started up its generator on September 4, 1882, in New York City. About 85 customers in lower Manhattan received enough power to light 5,000 lamps. His customers paid a lot for their electricity. In today's dollars, the electricity cost $5 per kilowatt-hour! Today's electricity costs about 17 cents per kilowatt-hour.

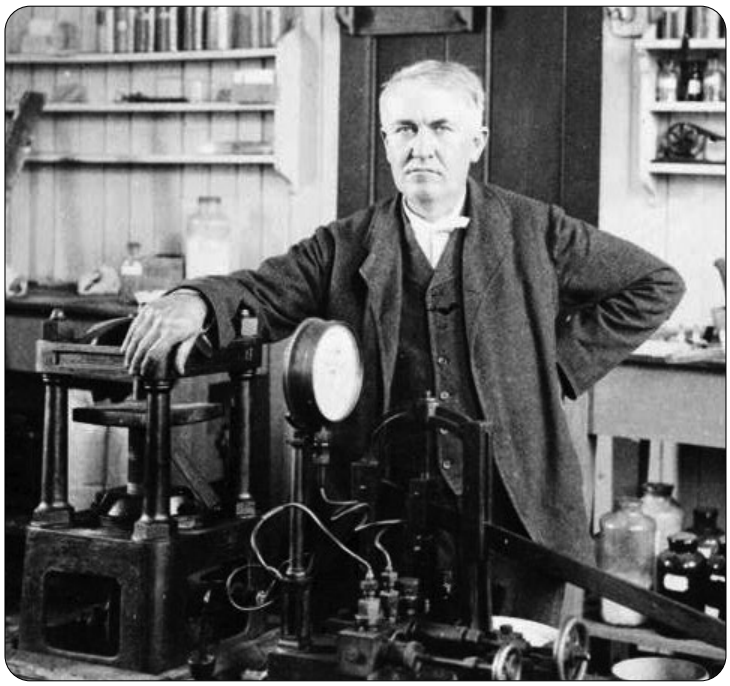


Image courtesy of U.S. Library of Congress

Thomas Edison in his lab in 1901.

The Question: AC or DC?

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

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

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

In 1920, about two percent of U.S. energy was used to make electricity. The heavy use of technology that requires more and more electricity, combined with the rapid development of artificial intelligence (AI) have propelled electric power generation into the top energy user out of all the economic sectors. In 2025, almost 35 percent of all energy consumed in the U.S. was used to generate electricity.

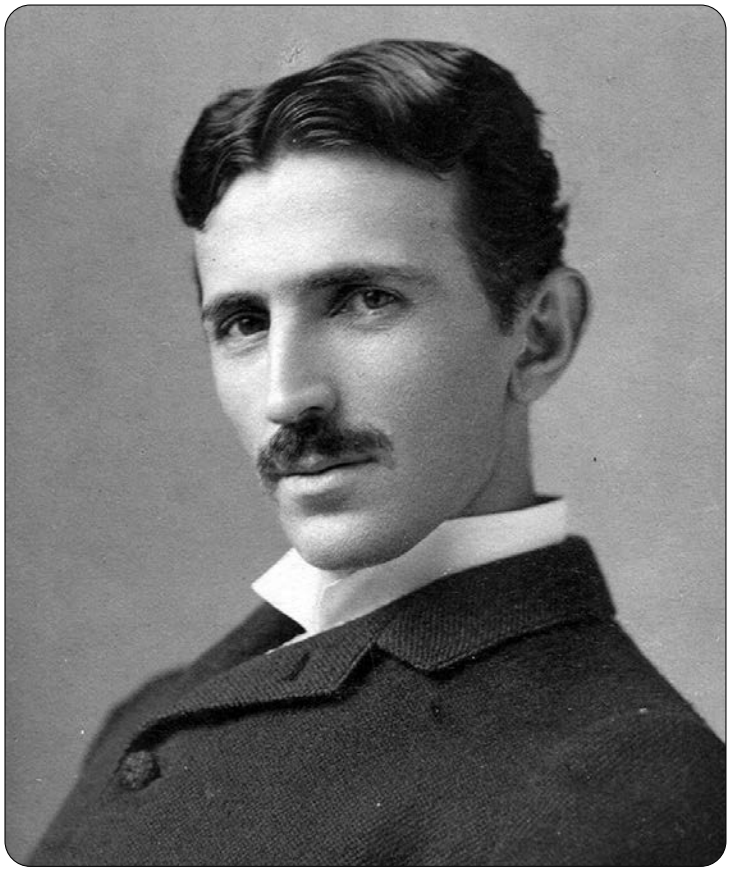


Image courtesy of Napoleon Sarony

Nikola Tesla

Measuring Electricity

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

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

Voltage

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

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

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

Current

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

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

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

Resistance

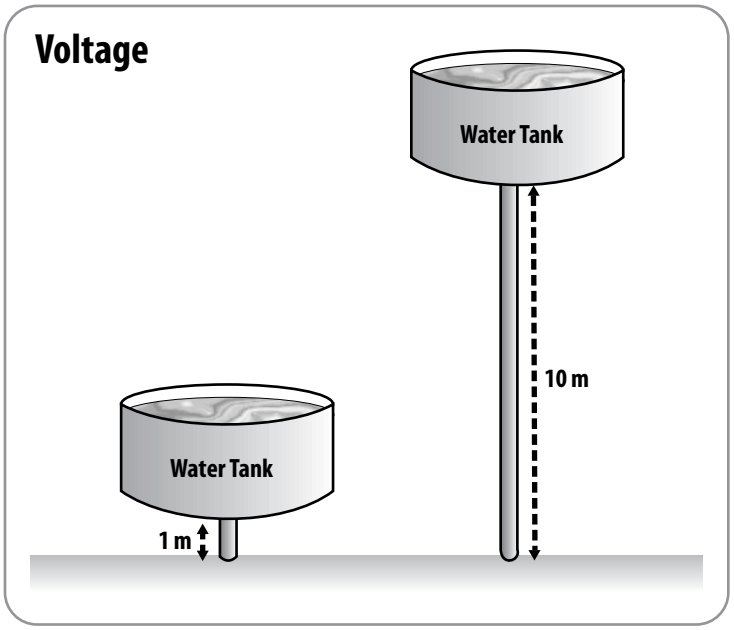
Resistance (R) is a property that slows the flow of electrons. Using the water analogy, resistance is anything that slows water flow, such as a smaller pipe or fins on the inside of a pipe.

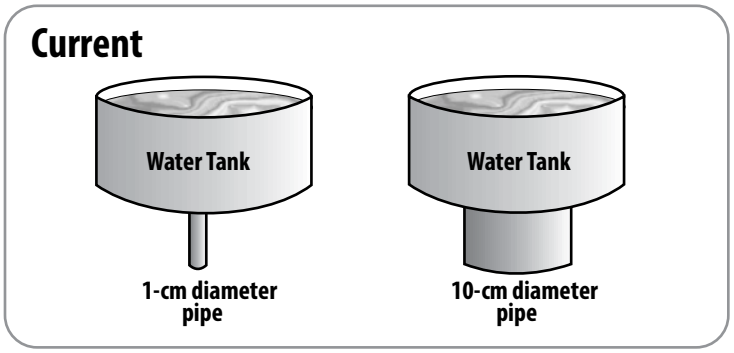
In electrical terms, the resistance of a conducting wire depends on the properties of the metal used to make the wire and the wire's diameter. Copper, aluminum, and silver—metals used in conducting wires—have different resistance.

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

Ohm's Law

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





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

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

Electric Power

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

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

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

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

Electrical Energy

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

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

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

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

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

distance = 40 mph x 1 hour = 40 miles

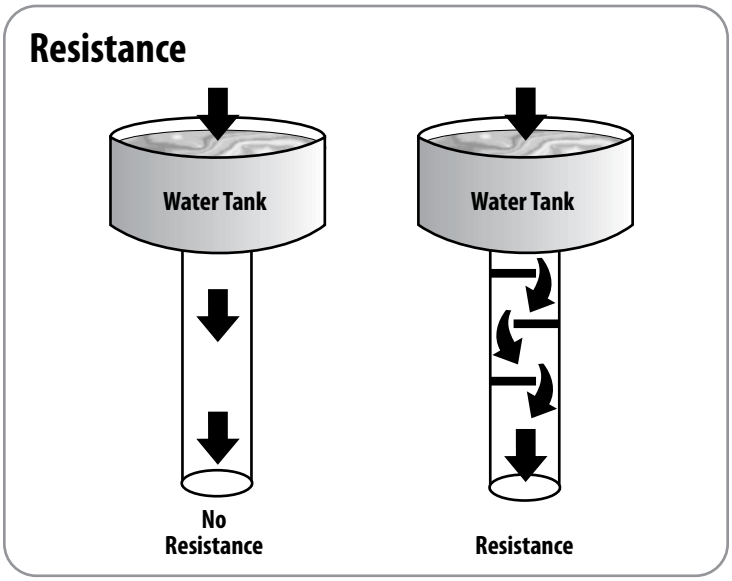
If a car travels for 3 hours at 40 miles per hour, it would travel 120 miles.

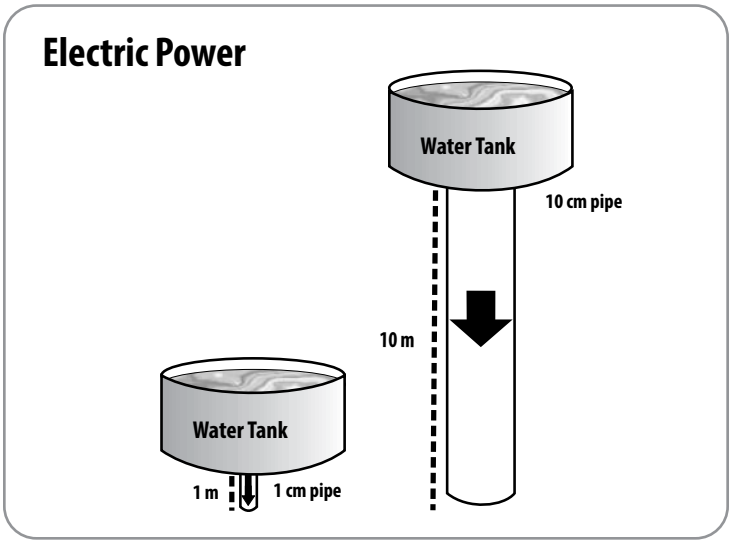
distance = 40 mph x 3 hours = 120 miles

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

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

The same applies with electric power. You would not say you used





100 watts of light energy to read your book, because a watt represents the rate at which you use energy, not the total energy used. The amount of energy used would be calculated by multiplying the rate by the amount of time you read.

If your TV uses 200 watts, and you watch TV for three hours, you would use the formula as follows:

energy = power x time (E = P x t)
energy = 200 W x 3 hour = 600 Wh

One watt-hour is a very small amount of electrical energy. Usually, we measure electric power in larger units called kilowatt-hours (kWh) or 1,000 watt-hours (kilo = thousand). A kilowatt-hour is the unit that utilities use when billing most customers. The average cost of a kilowatt-hour of electricity for residential customers is about $0.17.

To calculate the cost of watching TV for three hours, you would change the watt-hours into kilowatt-hours, then multiply the kilowatt-hours used by the cost per kilowatt-hour, as shown below:

$$600\ \text{Wh} \times \frac{1\ \text{kW}}{1000\ \text{W}} = 0.600\ \text{kWh}$$

$$0.600\ \text{kWh} \times \frac{\$0.17}{1\ \text{kWh}} = 0.102 \approx \$0.10$$

Therefore it would cost about a dime to watch TV for three hours.

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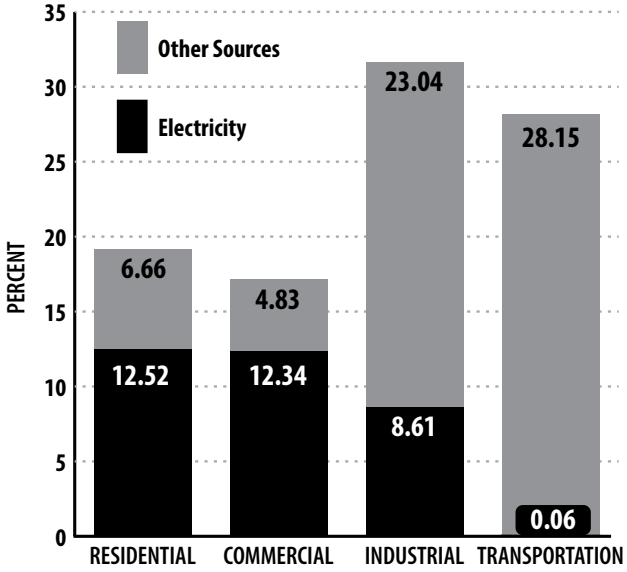
Energy Consumption

We use energy every day. We purchase food that was prepared and shipped to a store so we can cook, eat, and clean up after ourselves when finished. We wear clothes and shoes that were manufactured and shipped to us. We use artificial lighting throughout the day all year long. We ride in cars, trucks, buses, trains, and planes. We live in houses and work in businesses and schools made from a variety of building materials made at industrial facilities. We use energy to maintain a comfortable indoor temperature throughout the year, and we enjoy watching movies and TV shows and playing video games. The way humans have used energy over time has changed significantly, but one thing will always be true: people use a lot of energy.

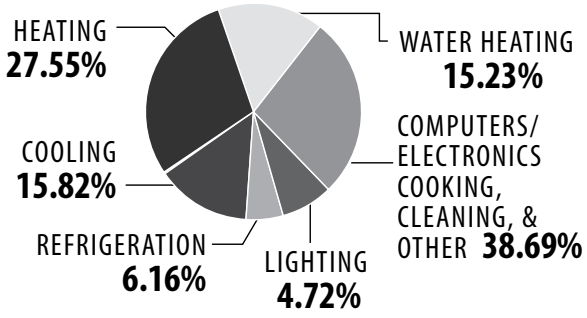
The U.S. Department of Energy divides the way we use energy into categories called sectors. All buildings or users within a sector share similar characteristics. The sectors of the economy are residential (homes); commercial (businesses, schools, hospitals, etc.); industrial (manufacturing complexes); transportation (vehicles); and electric power generation.

U.S. Energy Consumption by Sector, 2025



Data: EIA

Home Energy Expenditures



Data: EIA 2020 RECS
*Total may not equal 100% due to independent rounding

Residential and Commercial Sectors

The residential and commercial sectors are often grouped together because they both use energy similarly. Most of the energy these two sectors use is electricity, but residential and commercial buildings use energy from other sources, too. Homes and businesses use energy for heating, cooling, lighting, and operating appliances, technology, and office machines. In the last 50 years, Americans have significantly reduced the amount of energy used to perform these tasks, mostly through technological improvements in the systems themselves, as well as in the manufacturing processes to make those systems.

▪ Heating and Cooling

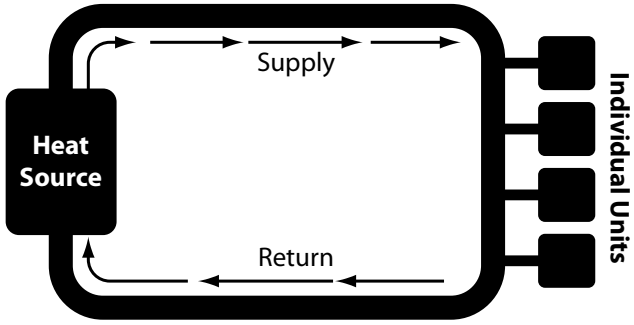
The biggest energy use in residential and commercial buildings is for keeping interiors comfortable. Heating and air conditioning use about 43 percent of all the energy used in homes, and about 51 percent in commercial buildings. The three fuels used most often for heating are natural gas, electricity, and propane. A little less than one-half of the nation's homes are heated by natural gas. Roughly 40 percent of homes use electricity for heating, and about five percent use propane.

Commercial buildings follow a similar pattern: 44 percent use natural gas for heating, 43 percent use electricity, and a little less than 13 percent use propane.

Heating can also be supplied by a district system. Good examples of district systems include college campuses or older cities with central steam systems. A building called a physical plant contains equipment that heats water that is pumped either as hot water or steam to the other buildings in the district. A heat exchanger, where air is circulated over specialized pipes containing the hot water, or a radiator, then heats the space. Cooling can also be provided in a similar manner, where enormous chillers cool water that is circulated.

Geoexchange systems are those that use the Earth as a source of thermal energy. Also known as geothermal systems, or ground-source heat pumps, these systems rely on the consistent temperature that is maintained a few feet underground. A fluid circulates through pipes in the ground and can absorb thermal energy for heating, or release it for cooling.

District Heating System

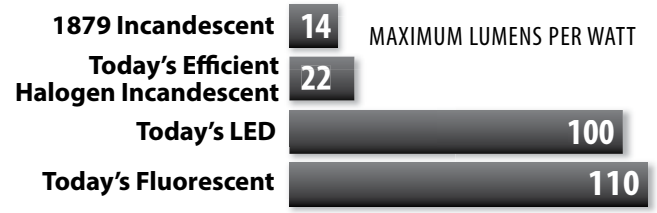


▪ Low-Temperature Lighting

The first lighting used in all buildings was incandescent lighting. This very inefficient style of bulb changes most of the electricity into heat rather than light. In the 1940s, commercial buildings were rapidly installing fluorescent lighting. These were very wide tube lights that had a flicker when they are turned on, and a continuous low-level hum. The **ballast** in early fluorescent lights was magnetic, and required a large surge of power to start. Electronic ballasts in commercial buildings and compact fluorescent lights in homes were much more efficient replacements.

Today, LED lighting is most common in homes and newly constructed or renovated commercial buildings. Residential customers spend about $89 annually just to operate lights. About 10 percent of all energy consumed in commercial buildings is for lighting, which equates to about 17 percent of the electricity used by schools. The actual dollar amount spent varies widely because some commercial buildings, like small coffee shops, are quite small, while others, like museums and hospitals, are huge.

Lighting Efficiency



Data: Madison Gas and Electric

▪ Appliances

Appliances have made our lives cleaner, easier, and safer. Water heaters use the most energy in this category—about five percent in commercial buildings and 15 percent in residential buildings. Generally speaking, the energy source used for heating in a home is also used for water heating. There are exceptions, of course, but most homes heat the interior space and water with the same fuel.

Refrigerators and freezers are the next-largest energy consumer. These appliances use a compressor and a chemical called a refrigerant to cool the interior. The refrigerant is put under pressure, condensed into a liquid, and then allowed to rapidly decompress and evaporate into a gas. The rapid evaporation makes the refrigerant get very, very cold. It can then absorb thermal energy and "carry" it outside the refrigerator or freezer compartment. Air conditioners work in a similar manner, but part of the cycle occurs indoors and part of it occurs outdoors.

Additional appliances used in homes and businesses include dishwashers, washing machines, dryers, humidifiers, dehumidifiers, ranges, cooktops, ovens, microwaves, and a plethora of small, plug-in devices like fans, coffee makers, and slow cookers. When electronics like TVs, cable boxes, and gaming systems are added, the amount of energy—primarily as electricity—we consume just to live our lives becomes overwhelming.

▪ Smart Things

There is no question that the Internet has dramatically changed modern life. The early Internet was used mainly by universities, government agencies, and researchers. It was not widely available to the public and required a land-based phone line and technical knowledge to use. As broadband Internet became more common in the late 1990s and early 2000s, manufacturers began developing products that could connect to home networks and be controlled remotely.

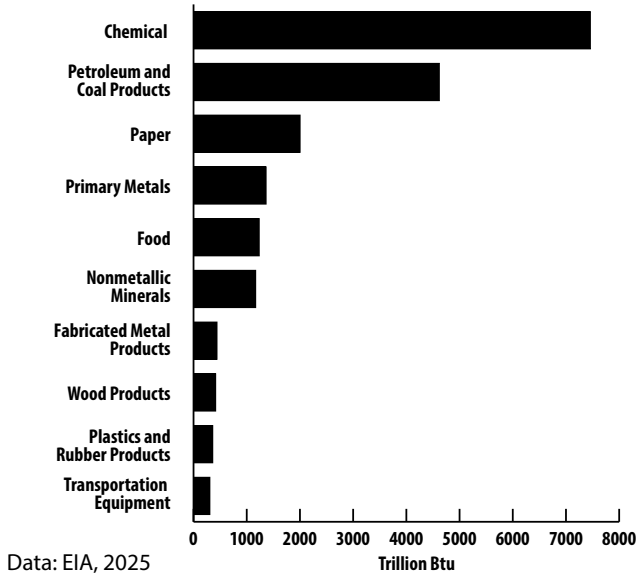
The modern smart-home era began when the Nest® smart thermostat was introduced. This Wi-Fi-connected control system allows the user to change settings with a smartphone. It also has the ability to recognize patterns in users' behavior and make adjustments, saving energy. Smart light bulbs from Philips were introduced about a year later, followed by smoke detectors, cameras, and door locks. In 2014, the Amazon Alexa burst onto the scene and rapidly grew in popularity. Today about half of all homes in the U.S. have at least one smart device, with the most popular items being smart TVs, voice assistants, and doorbell cameras.

The energy consumption of the "smart" part of Wi-Fi-enabled electronics and appliances is difficult to determine because surveys of home energy consumption do not typically separate smart devices from ordinary devices. However, smart things can be very useful when it comes to saving energy. Utilities frequently offer rebates for customers who allow the utility to adjust their smart thermostats during periods of high electricity demand. Energy managers of commercial buildings and campuses take advantage of remote control capabilities of smart devices, especially thermostats and lighting, as an energy-saving strategy. Smart devices are not only convenient, they can help us track and control energy consumption.

▪ Industrial Sector

Until the start of the 20th century, the United States was primarily **agrarian**—most people worked in agriculture. The Industrial Revolution started bringing people into cities to work in factories, and by the early 1900s, more people worked in manufacturing than on farms. The facilities that make both raw and finished products—factories, foundries, and refineries to name a few—make up the industrial sector. In 2025, 32.89 percent of U.S. energy consumption, including electricity, was used to make products and materials. American industry accounts for about 17 percent of the world's total manufacturing output. Every industry uses energy, but six are particularly energy intensive.

Top 10 U.S Industries for Total Energy Consumption



Data: EIA, 2025

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Energy Consumption

▪ Petroleum Refining

Crude oil is a mixture of many compounds. To be useful, it must be separated into its respective products, and this takes place at a refinery. The compounds in petroleum are separated by boiling point, and all that boiling requires a lot of thermal energy. Most of the energy used by the refinery comes from the petroleum itself, primarily as small-sized hydrocarbons like methane and ethane. Petroleum refining is the second-largest energy consumer in the industrial sector.

PETROLEUM REFINERY



Image courtesy of BP

▪ Steel Manufacturing

Steel is made from iron ore in a steel mill. Iron ore is an oxide of iron, such as hematite (Fe_2O_3) or magnetite (Fe_3O_4). Most iron ore mined in the United States comes from the Lake Superior region, especially northern Minnesota and Michigan's Upper Peninsula. The ore is often transported to steel mills by freight ships on the Great Lakes. At the mill, iron ore is heated in a blast furnace with coke, a fuel made from coal. The high temperature and chemical reactions remove oxygen from the iron ore, leaving molten iron. Elements such as carbon, manganese, and silicon are added to the iron to make steel, an alloy. Different types of steel contain different amounts and combinations of elements, giving them different properties.

The steel industry on its own is a major consumer of energy. However, when combined with the production of other metals such as aluminum, the energy consumption is even greater. The cost of energy is about 15 percent of the manufacturing cost of steel. Since 1990, the steel industry has reduced its energy consumption with improved technology, closing older plants, and the increased use of recycled steel. Recycling steel uses 75 percent less energy than making it from iron ore.

▪ Aluminum Manufacturing

Aluminum begins as **bauxite**, a mineral rich in aluminum, oxygen, and hydrogen, which must be mined. Bauxite is then heavily processed to produce aluminum. Manufacturing aluminum is very energy-intensive. Just one step alone requires 6-7 kWh of electricity for each pound of aluminum produced.

The aluminum industry has significantly reduced the amount of energy needed to produce aluminum. A large part of the reduction in energy use has come from increased recycling of aluminum. Recycling aluminum uses 95 percent less energy than extracting the same amount of aluminum from bauxite.

▪ Paper Manufacturing

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

The pulp and paper industry reduced its fossil fuel consumption per ton of paper by about 30 percent from 1990 to 2010, mostly through the use of better technology and cogeneration systems. Over 60 percent of the fuel the industry uses to power the cogeneration equipment comes from wood waste, a renewable energy source.

▪ Chemical Manufacturing

Modern daily life is heavily influenced by the chemical industry. Chemicals are more than just detergents, cleaners, and solvents. Chemical manufacturing includes medicines, cleaning products, fertilizers, food containers and wrappers, and the raw materials used to make plastics. The additives, dyes, and flavorings added to processed foods are also part of the chemical industry. Because it produces such a wide variety of products, chemical manufacturing is the largest energy consumer in the industrial sector.

Chemical manufacturing uses large amounts of energy to operate equipment and generate the thermal energy for industrial processes. Petroleum and natural gas are also used as feedstocks, or raw materials used to make products rather than provide energy. Feedstocks are used to manufacture plastics, synthetic fibers, medical supplies, packaging materials, and many other products. The chemical manufacturing industry accounts for the largest share of nonfuel energy use in the manufacturing sector.

▪ Cement Manufacturing

What is the largest concrete structure you have seen? A bridge? A power plant? Hoover Dam? Now imagine if modern concrete did not exist and all of those structures had to be built from stone. When cement is mixed with sand, gravel, and water, a fluid slurry called concrete is formed that can be molded into almost any shape. Like stone, concrete is strong and durable, but it can be formed into specific shapes much more easily and quickly.

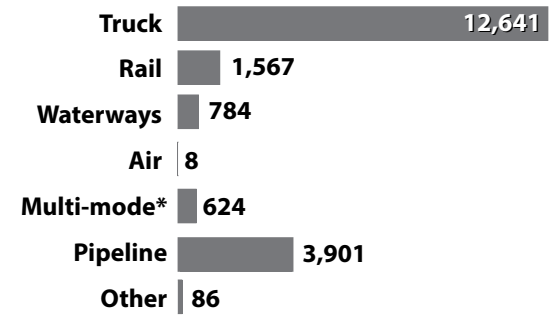
There are two major drawbacks to using concrete, and one feeds into the other. When cement is made from limestone, a byproduct is carbon dioxide—a lot of it. This does not include any CO_2 emitted from the energy used to make it. The second problem is the enormous amount of energy needed to manufacture, mix, and transport cement and concrete. In fact, manufacturing cement in the U.S. used more energy in 2024 than 134 countries! The United States manufactures an enormous amount of cement, and a large portion of it is shipped all over the world. New technologies in the last several decades have worked toward using less fossil fuels and reducing the amount of energy used to make cement, with the end goal of greatly reducing the carbon footprint of concrete.

Today, about 16 percent of the energy used to make cement comes from alternative energy sources, such as used tires. Pound-for-pound, used tires have about 25 percent more energy than coal. The American Cement Association is looking for ways to reduce the carbon emissions from cement manufacturing and concrete production. One possibility involves using fly ash, a waste product from coal-fired power plants, to replace some of the raw materials. Another solution proposes using renewable fuels in concrete production facilities. The cement industry has set an ambitious goal of decarbonizing cement manufacturing by 2050.

Transportation Sector

The United States is a nation on the move. We move ourselves from home to work, school, or on vacation. We visit friends and relatives. We attend sporting events and concerts. We go shopping and out to eat. We visit museums and places of worship. And sometimes, we just get out of the house for its own sake. Moving people and their goods is the business of the transportation sector and it requires a lot of energy. In 2025, about 29 percent of all of the energy consumed in the U.S. was used to move people, goods, and even energy.

U.S. Freight, by Mode of Transportation



*Multi-mode includes any combination of truck, rail, air, waterway, and mail.
Data: Bureau of Transportation Statistics, 2023 report

▪ The Automobile

Few technologies have influenced American life as much as the automobile. While large cities in Europe and Asia were developed before any mechanized transportation was contemplated, most of the large cities in the United States were developed and expanded around the idea that people would primarily use cars to get around. Consequently, the automobile is the primary transportation method people use, and the largest consumer of transportation energy today in the U.S.

Americans' relationship with the automobile changed dramatically during the twentieth century. Early drivers rarely traveled far from home, relying on trains for longer journeys. As automobiles improved and the nation's highway system expanded, long-distance driving became practical and the great American road trip became part of the culture. The oil embargoes of the 1970s brought a new concern: fuel economy. For the first time, many consumers began paying close attention to how much gasoline their vehicles used. Automakers responded by designing cars that were lighter, more aerodynamic, and propelled by engines with improved fuel efficiency. Today's cars drive almost twice as far on a gallon of gasoline than the vehicles of the 1970s. Furthermore, vehicle technology has improved to include alternative fuels, hybrid-electric vehicles, and fully electric vehicles, which reduce energy consumption in the transportation sector.

▪ Commercial Transportation

Passenger vehicles are typically owned and operated by individuals for their own needs. Commercial vehicles are owned by businesses, governments, and corporations to transport manufactured goods and provide services. Over land, trucks are used to move goods. In fact, almost every product is carried at some point in a truck. Most trucks, from large pickups to the biggest semi-tractor trailers, run on diesel fuel. Trains are also used to carry goods on land. Locomotives run on electricity from diesel-powered generators to pull freight on our nation's railroads. Many large industrial complexes have railroad tracks running through them to facilitate receiving raw materials and shipping finished products.

On water, ships and barges are used to carry items. Bulk products like coal are carried by barge and moved around by tug boats. A tug can move several barges at one time; the only limitation is the number of barges that will fit in a lock on a river. On the Great Lakes and across oceans, ships are used. They might have large holds below deck to carry bulk items like grain or iron ore, or they might have wide, flat decks upon which steel containers with finished goods are stacked. Most ships run on a specially formulated diesel fuel.

If you need transportation in a hurry, you will probably ship your package by air. Jet planes have gone through many design changes over the last 50 years. Today's jets are faster and more efficient and can move dozens of passengers or tons of freight several hundred miles in a matter of hours. That speed comes at a price—air freight is about 10 times more expensive than shipping by truck, and even more expensive compared to rail.

▪ Public Transportation

Moving people in large groups by bus and train is the job of public transportation. This category is different from commercial transportation because the buses and trains are typically owned and operated by a municipal or state government, not a private company. Passengers walk to a station and board a bus or train that takes them to another station. People might transfer to another bus or train, or they might have arrived at their destination. Many city train systems, especially those that run underground, are electric. Buses have traditionally been fueled by diesel fuel, compressed natural gas (CNG), or propane. New bus technology includes electric buses or those running on hydrogen fuel cells.

Global Energy Consumption

Energy consumption patterns in the United States are not the same in all countries. In fact, from continent to continent and country to country, energy consumption depends greatly on the natural resources available, political stability, economic conditions. China and India have greatly expanded access to energy in recent decades as their economies have grown, increasing energy use per person. Countries with a lot of petroleum or natural gas reserves, like Saudi Arabia and Kuwait, rely heavily on petroleum and natural gas. Japan and South Korea, though, have few domestic energy resources and must import much of the energy they consume. Brazil, a nation with a mix of rural, suburban, and urban populations and a wide range of income levels, obtains about half of its energy from renewable sources, primarily biomass and hydropower. Where poverty, conflict, and political instability are present, access to energy is often limited. In some countries, unrest and violence have hampered the development and maintenance of energy infrastructure so severely that energy consumption has declined dramatically.

With just a little bit more than four percent of the world's population, Americans consume about 15 percent of the world's energy. The United States is not alone among industrialized nations; average world energy use per person continues to grow in many countries, while population also continues to increase. The average American consumes just under four times the world average per capita consumption of energy. Keeping our buildings comfortable, moving ourselves around, and powering all of our appliances and electronics don't just cost a lot of money. They take a toll on the environment.

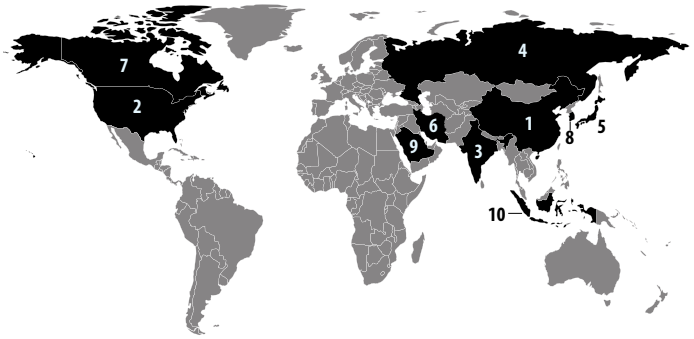


Energy Efficiency and Conservation

Making the Case for Saving Energy

More than 80 percent of the world's energy comes from fossil fuels. Burning fossil fuels releases carbon dioxide into the atmosphere. The buildup of carbon dioxide and other greenhouse gases is the primary cause of the climate change occurring today. As temperatures rise and extreme weather events become more common, energy demands for heating and cooling are also rising. Improving energy efficiency and reducing unnecessary energy consumption conserves resources, lowers energy costs, and reduces greenhouse gas emissions.

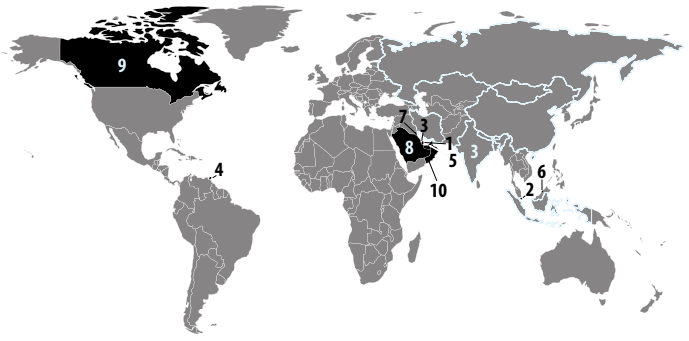
Top Ten Energy Consumers, 2024



1. China
2. United States
3. India
4. Russia
5. Japan
6. Iran
7. Canada
8. South Korea
9. Saudi Arabia
10. Indonesia

Data: EIA

Top Ten Countries, Energy Consumption per Capita, 2024



1. Qatar
2. Singapore
3. Bahrain
4. Trinidad & Tobago
5. United Arab Emirates
6. Brunei
7. Kuwait
8. Saudi Arabia
9. Canada
10. Oman

Data: EIA

Energy Efficiency

All machines use some energy to do work. The amount of useful work done as a percentage of the energy consumed is the efficiency of the machine. The most efficient machines are the ones that use the least amount of energy to do their job.

When professionals search for energy-saving opportunities, they evaluate the efficiency of the heating, cooling, and ventilation (HVAC) system, the lighting, and the other devices that are top energy consumers, such as water heaters and refrigerators. Replacing an existing device for one that is more efficient is known as an upgrade. The amount of energy saved versus the purchase cost is the chief consideration when deciding on an upgrade.

Energy Conservation

Conserving a resource does not mean never using it. Conservation involves wise use, so the resource is available as long as possible. Energy conservation means we are reducing energy consumption by modifying our behavior.

There are times when an energy upgrade is not possible. That does not mean there are no opportunities to reduce energy consumption. Simple behavior modification can often reduce energy consumption by 10 to 15 percent and sometimes as much as 30 percent!

Each sector of the economy has its own actions and choices that can be made to result in energy savings.

Energy and Electricity

Generating electricity consumes more primary energy than any other economic sector. Even though electricity is used by the other four sectors, saving electricity is an important economic and environmental priority. In 2025, 75 percent of electricity was generated in power plants that use thermal energy from nuclear fission or burning a fuel to boil water, creating steam that turns a turbine. That process is only about 35 percent efficient, meaning 65 percent of the energy in those fuels is lost as thermal energy rather than turned into electricity. Saving energy with devices powered by electricity is not just economically smart, it's environmentally smart. The cleanest and cheapest unit of energy is the one that never needs to be produced.

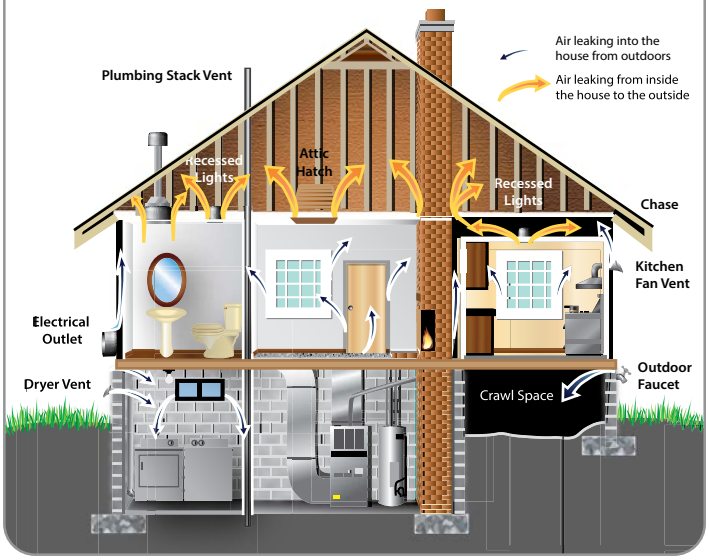
Building Envelope

All buildings, from the tiniest of tiny homes to the largest of factories, have an envelope. Like a paper envelope surrounds documents, a building envelope surrounds the things we want to keep separate from the outdoor environment. The function of the building envelope is to keep the interior comfortable, dry, and protected from intrusions by weather, animals, or people. Walls, windows, doors, roofs, and floors are all parts of the building envelope.

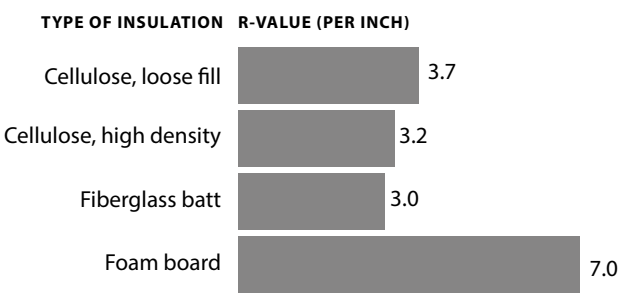
Buildings have breaks that extend through the building envelope. Water, electrical, and cooling system connections are common, and windows and doors are present in all buildings. Without them, the building would not be functional or practical. However, a break in the thermal barrier needs to be sealed well to avoid air infiltration. If outdoor air gets inside, more energy is needed to keep the interior temperature comfortable. Some common causes of air infiltration are poor door and window seals and weatherstripping, cracked or shrunken caulking around window frames, and uninsulated electrical outlet and switch boxes. All of these are relatively simple fixes and can be accomplished in an afternoon. Many utilities offer no-cost weatherization programs for their lower-income or elderly customers, as well as programs for some commerical customers. For commercial buildings like schools, churches, and public buildings, grants and state programs are sometimes available.

One important function of the building envelope is to maintain a healthy interior temperature and humidity level. Buildings rely on good **insulation** with the correct R-value for the location, type of building, and space within the building. **R-value** is the way insulation is rated on its resistance to allowing thermal energy to move through it. High R-value insulation is better at blocking thermal energy transfer than low R-value insulation. As you would expect, some materials are excellent thermal insulators. Expandable and rigid foam, fiberglass, rock wool, and cellulose are common insulating materials.

House as a System



Insulation R-Values





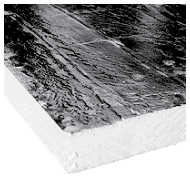
3.0
Fiberglass Batt



3.7
Cellulose, Loose Fill



3.2
Cellulose, High Density



7.0
Foam Board

Building Envelope Tips

Follow these tips to reduce energy consumption in buildings:

- Keep windows and doors closed when the heating or cooling system is turned on.
- Check around exterior doors—daylight means outdoor air is getting in.
- Make sure windows open and close without sticking, and are sealed well.
- Check the insulation in the attic space and add more where necessary.
- Install insulating gaskets behind outlet and switch covers.

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▪ HVAC Systems

Heating, ventilation, and air conditioning systems use a machine to warm or cool air and distribute it within a room or building. Ventilation is usually only used in commercial or industrial buildings. Commercial buildings have more people inside them than homes typically would have, and industrial buildings have a lot of machinery. People and machinery both produce indoor pollutants such as carbon dioxide, fragrances, ozone, or carbon monoxide where natural gas or propane are burned. Fresh air must be brought indoors to keep everyone healthy and alert. If outdoor temperatures are extremely high or low, ventilation may be reduced or suspended in favor of maintaining a good indoor environment.

The two biggest energy wasting concerns with HVAC systems are ducts that have leaks and **thermostats** set too high. If the duct work is leaking, the system needs to work harder to push more air through it. Rooms farther from the furnace or system will not be conditioned as well as closer rooms. They will be hot in summer and cold in winter. Setting the thermostat to a very warm temperature in winter or a very cool temperature in summer uses a lot of energy. Wearing a sweater in winter or using a fan in summer can help save energy.

HVAC System Tips

Follow these tips to reduce energy consumption when heating or cooling:

- In winter, set the thermostat to 68°F or lower. Wear a sweater if you are chilly.
- In summer, set the thermostat to 77°F or warmer. Use a fan if you are too warm.
- Regularly change the air filter.
- Use duct sealing tape to block any leaks in duct work.
- Make sure duct work moving through attics or crawl spaces is insulated.
- Open blinds or curtains in winter to allow sunlight to warm the room. Close them in summer to prevent this.

▪ Lighting

Commercial buildings use much more lighting than residential or industrial buildings, but all three types of buildings use artificial lighting. The most efficient lights are LED lights, though many schools and other commercial buildings still rely on fluorescent lights.

The two biggest energy-wasting concerns with respect to lighting are providing too much artificial light and keeping lights on unnecessarily. The Illuminating Engineering Society of North America has developed a list of recommended light levels, measured in foot-candles, for interior spaces based on the function of the space. For example, school cafeterias should have about 20-30 foot-candles of illuminance, while lighting in a laboratory-style classroom should have 50-75 foot-candles.

Removing light fixtures that are unnecessary saves a lot of energy. At home, where many different kinds of lighting are available, using only what is necessary and leaving other lights off is the best course of action.

Modern technology allows for lighting controls that reduce energy use where the lights are still needed and used regularly. Dimmer switches can be used with many LED lights to provide the right amount of light for the task. Dimmers are commonly used in commercial spaces that have many different functions, such as convention spaces. Less light is needed for events like dinners and receptions, while more light is needed for meetings and training. Many homes have dimmer switches in dining and other spaces where varied light levels might be desirable. Motion-sensing switches detect movement in the room and turn the lights on, while occupancy sensors monitor motion in the room and turn the lights off when no motion has been detected for a specified length of time.

Of course, using daylight consumes the least amount of energy. Opening blinds or curtains to take advantage of free daylight can save up to 100 percent of the energy used by lighting if no artificial light is required! If it is a particularly hot summer day, or sunlight will warm the room too much, this might not be the best energy management strategy. Consider all aspects—heating or cooling, as well as lighting—before arbitrarily opening blinds or curtains.

Lighting Tips

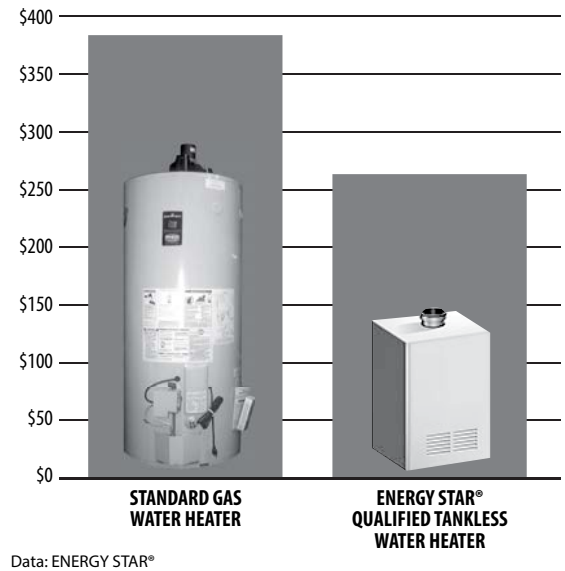
Follow these tips to reduce energy used for artificial lighting:

- Do not overlight spaces. At home, only turn on the lights you need. Use light bulbs or light fixtures that provide the right amount of light.
- Do not leave lights on when a room is empty. Turning them off saves 100 percent of the energy the lights were using!
- Install LED light bulbs or light fixtures to get the brightest light using the least amount of electricity (but don't overlight!).
- Use daylight through windows and skylights instead of turning lights on.

▪ Water Heating

Just like heating the interior of a building uses a lot of energy, so too does heating water. The energy to heat water is not something we think about until we do not have it. Cold showers are no fun for anyone. The approach to saving energy on water heating in homes as compared to commercial or industrial buildings is different, because the way hot water is used in each environment is different.

Water Heater Comparison



Data: ENERGY STAR®

Any commercial building with a kitchen, like a school or restaurant, needs to provide very hot water for the kitchen—160°F! Tableware and cookware must be thoroughly cleaned and sanitized, which requires water much hotter than is needed at home. Industrial processes might need water at near-boiling, as high as 200°F or more. Industrial and commercial buildings have water heating equipment that is much larger and uses significantly more energy than residential equipment. When people are in commercial spaces like schools, hotels, and restaurants, they can help use less energy by not leaving hot water running unnecessarily.

Most homes have a water heater with a tank that keeps the water at a specific temperature. Most water heaters are 40-50 gallons, but some can be as small as 20 gallons for smaller homes or apartments. Adding an insulating jacket to the water heater keeps thermal energy from being transferred to the area around the water heater, and insulating the pipe carrying the hot water to the fixtures also helps.

Tankless water heaters are now available that only turn on when hot water is needed. While running, they consume tremendous amounts of energy, but if no hot water is needed, they do not run at all. Most of the time, a tankless system uses less energy than a residential system with a tank. As with anything, there are exceptions.

The temperature of hot water in a home should never be higher than 140°F, and ideally kept at 120°F. Young children can be seriously injured if the water temperature is above 120°F, and everyone will be scalded if it exceeds 140°F. Occasionally, households of many people will keep the temperature higher so there is enough hot water for everyone. In this case, the mixing valve for showers and bath tubs should be adjusted so the water never exceeds 120°F.

Water Heating Tips

Follow these tips to reduce energy used for heating water:

- Take short showers instead of baths. Showers use significantly less water.
- Set the water heater so it delivers water at 120°F. If you are going to be away from home for an extended period of time, turn it to its lowest setting – often "vacation" or "pilot." Remember to turn it up when you get back home.
- Wash clothes in cold water. Modern detergents are formulated for cold-water washing.
- Fill a sink or wash basin with soapy water to wash dishes, then rinse them all at once or in batches. Do not let the hot water run while washing dishes.
- Install an insulating jacket around the water heater and make sure pipes delivering hot water are also insulated.

Plug Loads

This rather large, diverse category of energy-users includes anything that plugs into an electrical outlet. Appliances, electronics, lamps, and charging cords are included. If it plugs in, it's a plug load. While the way these devices are used is very different, some common principles around saving energy apply to all of them. First, and probably the most obvious, don't allow something to run if it is not needed. The most common culprits are lights and fans, but if you "pause" your gaming system rather than saving and shutting it down, it uses a lot of energy waiting for you to resume game play. Another way to save energy is by purchasing devices that use less energy while operating.

Plug Load Tips

Follow these tips to reduce energy consumed by appliances and electronics:

REFRIGERATORS

- Make sure the gasket around the door seals completely. If a piece of paper or dollar bill can easily slide out from behind it, replace it.
- Do not allow the door to stay open longer than necessary. Help organize the groceries in groups to minimize the amount of time it takes to put them away. Close the door while you pour a beverage.
- Fill empty milk jugs or soda bottles with water and use them to fill empty spaces in the back of the refrigerator.
- Keep the area around and under the refrigerator clear and dust-free so the compressor operates at its best.
- Empty and unplug second refrigerators. Only plug in and operate when absolutely necessary.

WASHING MACHINES

- Set the washing machine appropriately for what you are washing. Aim for a full load of laundry when possible, as it will save water and energy.
- Use cold water for washing.

CLOTHES DRYERS

- Clean the lint filter after every load. Encourage or assist the adults in your home to make sure lint is cleaned from the interior of the dryer and dryer duct.
- Use the lowest heat setting possible.
- Hang clothes to dry outside when possible and use free solar energy.

DISHWASHERS

- Turn off the heated dry and allow dishes to air-dry. Opening the door when the cycle is complete will help.
- Run the dishwasher with the proper cycle or settings for the load size and dirt level of the dishes. Most modern dishwashers will use less water than hand-washing, even for smaller loads, if settings are chosen correctly.

TELEVISIONS, AUDIO AND GAMING SYSTEMS, AND RELATED DEVICES

- Plug devices into a smart strip surge protector that senses when the TV or primary device is off and cuts power to other items plugged into it. It also has the option for keeping some items, like a cable box, powered all the time.
- Use energy-saving settings and sleep timers to reduce electricity when possible.

OFFICE EQUIPMENT

- Power down devices when they are not being used for extended periods of time.
- Disable screen savers, as they use more electricity than sleep mode.
- Keep printers and scanners off until they are needed.
- Power down monitors when devices are off. Monitors that remain on will waste electricity.

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EnergyGuide and ENERGY STAR®

Every appliance purchased in the United States has a yellow-and-black label called the EnergyGuide. It tells you approximately how much it costs to operate the appliance for one year so you can compare expenses appropriately. Some EnergyGuide labels have the ENERGY STAR® logo, indicating that in their class, this appliance uses much less energy. Similar devices are compared to each other, and electronics can also earn the ENERGY STAR® rating even though most electronics do not have EnergyGuide labels.

Frequently, ENERGY STAR®-rated appliances have a higher purchase price than less-efficient models of similar size and design. However, because they use less energy over time, the overall cost may be less. The **payback period** of an appliance is the amount of time it takes for the money saved through reduced energy costs to equal to the difference in purchase price. When looking at the payback period, it is important to consider the amount of time the appliance is expected to last. A payback period of 15 years for a water heater will not likely pay off, as water heaters typically last ten years or less before they need to be replaced. Most of the time, though, a more efficient model costs less to operate than a cheaper, less-efficient version.

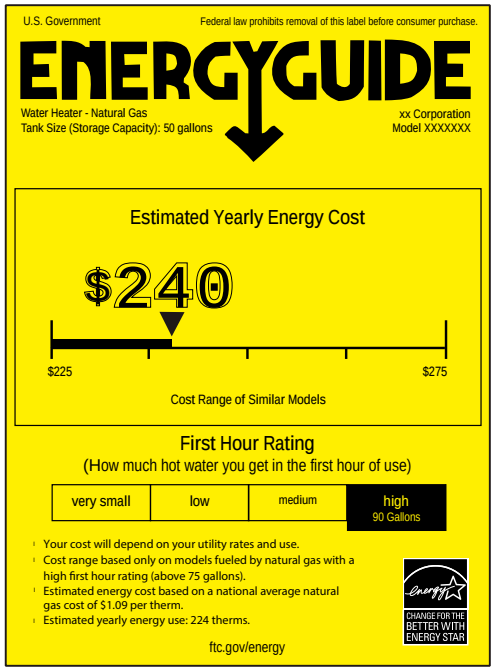
There are times when purchasing a new device is not possible. Perhaps a newer, energy-efficient refrigerator is just not within a household's budget. The household can reduce the energy consumption of that refrigerator by making sure they limit the amount of time the door remains open, and by filling empty spaces with bottles or jugs of water. Full refrigerators run less frequently than empty ones. If the whole space is not always filled, keeping jugs of water in the back will help it run less often.

ENERGY STAR® Logo

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

CHANGE FOR THE BETTER WITH ENERGY STAR

EnergyGuide Label



Appliance Energy Consumption

Appliance	Average annual expenditure	kWh/yr
Electric stove, oven or range	$38	290
Ceiling fan	$29	226
Clothes dryer	$87	680
Clothes washer	$9	69
Dishwasher	$15	112
Microwaves	$15	107
Refrigerator	$87	617
Second freezer	$74	632
TV and related components	$87	760

Data: EIA 2020 RECS
*Average yearly consumption data accounts for devices used in different modes, i.e., idle, charging, etc.

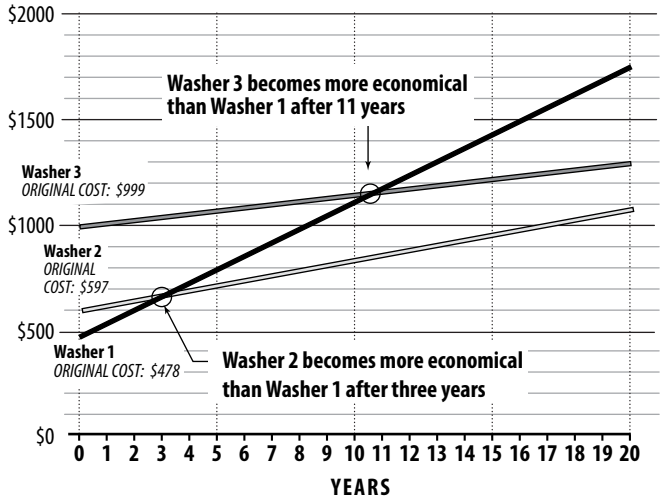
Washing Machine Payback Period

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



	WASHER 1	WASHER 2	WASHER 3
Original Cost	$478	$597	$999
Estimated Annual Electricity Use	427 kWh	160 kWh	102 kWh
Price of Electricity (per kWh)	$0.15	$0.15	$0.15
Operating Cost per Year	$64.05	$24.00	$15.30

COST OVER THE LIFETIME OF THE MACHINE



Data: NEED analysis of washing machine EnergyGuide labels

Phantom Loads

Some devices are always using power, even when they are turned off. This constant trickle of energy consumption is called a phantom load or a vampire load. You can use a plug-in meter that measures power consumption to determine if a device has a phantom load. Anything that has a clock or LED on it, or that is operated with a remote control, has a phantom load. You can use a power strip or physically unplug the device when you are not using it. Single-serving hot beverage machines are notorious for having really high phantom loads.

Transportation

Personal vehicles come in all shapes, sizes, and levels of efficiency. Most vehicles run on gasoline. The efficiency of vehicles is determined by the number of miles the vehicle can travel on one gallon of gasoline. Larger vehicles with big engines use more gasoline than smaller vehicles with small engines. The type of vehicle you purchase depends on a lot of factors—cargo space, towing capacity, and number of passengers are three examples.

The transportation sector emits the most carbon dioxide into the atmosphere than any other sector—almost one-third of CO_2 emissions in 2025! Gasoline has become expensive, and the CO_2 emitted from using it is having a significant impact on our climate. A better fuel efficiency rating of your personal vehicle can help you reduce fuel costs and shrink CO_2 emissions.

The cost of new cars and trucks has grown significantly in recent years, so purchasing a more fuel-efficient vehicle might not be within your budget. There are some low- and no-cost things you can do to stretch the gasoline you put into the fuel tank. A properly maintained vehicle uses the least amount of fuel, and some good driving habits can stretch that fuel even further.

Driving Tips

Follow these tips to reduce the amount of gasoline your vehicle consumes:

- Change the air filter and oil regularly. Keep the engine well-tuned and in good operating order.
- Remove excess weight from the cargo area.
- Keep the tires inflated to recommended pressures.
- Avoid hard stops and starts. Apply the brakes or accelerator gently.
- Avoid idling in drive-thru lines or while waiting. Shut off the vehicle and go inside where applicable.

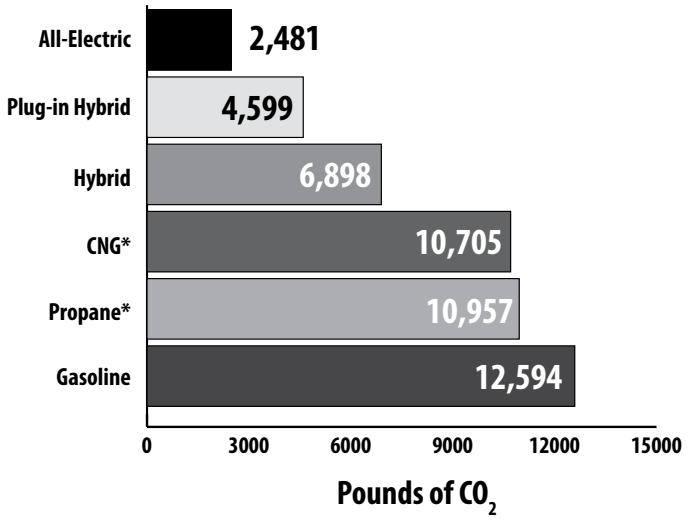
Follow these tips to reduce the amount of energy for transportation you use:

- Carpool with others going the same place as you.
- Take public transportation.
- Walk or ride your bike.
- Combine errands into one longer trip.
- When shopping online, order several things at once that **can** be shipped together. Order well enough in advance that overnight air freight is not necessary.

Carbon Emissions

Some vehicles are designed to run on compressed natural gas, propane, or other alternative fuels. Most of these vehicles are fleet vehicles, owned by a private company or municipal corporation. However, some homes have been equipped with a compressed natural gas filling system so homeowners can drive a car with a compressed natural gas engine. Electric vehicles use a battery and electric motor to move the vehicle. Hybrid cars combine a gasoline engine and electric motor. A plug-in hybrid vehicle has the ability to recharge the battery by plugging into a charger rather than using gasoline, but can use gasoline when needed. These vehicles all release significantly less CO_2 into the atmosphere than gasoline-powered vehicles.

U.S. CO_2 Emissions per Vehicle, 2024



*Calculated based on estimate from Argonne National Laboratory
Data Source: Alternative Fuels Data Center

Materials and Manufacturing

Saving energy in industry is not achieved only at the manufacturing site. Consumers have the ability to greatly reduce the energy consumed for making materials and products. Beyond the energy consumed just to make materials like steel, aluminum, and paper is the energy needed to transport the products and dispose of the waste. Disposable, single-use items are one of the biggest consumers of energy in the realm of materials and manufacturing. Industry leaders are working on adopting improved technology and recovering waste heat from processes to reduce the energy their facilities consume.

Saving energy for individuals and businesses is not limited to their own buildings and utility bills. It is also tied into the products they use and how they use those products. You've probably heard of the 4 Rs—Reduce, Reuse, Repair, and Recycle. Those practices are directly tied to energy saving in the industrial sector because a product that does not need to be re-made is the least expensive, best energy-saving option available.

▪ Reduce What You Buy

There is little question that we live in a consumer-based society. Many of the things we buy have a limited lifespan and will one day be thrown away. By reducing the amount of stuff you buy and ultimately throw away, you save money and energy. Reducing your consumption does not necessarily mean going without. A large bag of potato chips and several small bags have the same number of chips, but the large bag has less packaging. A jacket that has a zip-out lining can be used in cold weather as well as just slightly chilly weather and removes the need for two different coats. A pair of good quality shoes that might cost a little more will last longer than two or three less expensive but also less durable pairs. A large, water-filtering pitcher eliminates the need for plastic bottles of water.

▪ Reuse What You Have

Which uses less energy, cleaning with paper towels every week, or using a cloth rag and washing it for reuse? If you said the cloth rag, you are correct. Over time, less energy is needed to wash a cleaning rag than to produce and transport paper towels. A refillable water bottle and reusable plastic containers and lunch bags save energy every time they are used in place of bottled water, zip-top plastic bags, or paper lunch sacks. Purchasing clothes from thrift shops, swapping sports equipment, and repurposing bottles and jars for other uses are other ways to reuse someone else's things. As far as those zip-top plastic bags go, they often can be rinsed and re-used one more time.

▪ Repair What You Own

Jane had a laptop that worked well and did everything she wanted it to do. It was occasionally a little slow, but otherwise was fine. When the screen stopped working, though, she thought it was time for a new computer. Her older brother suggested she see if the screen could be repaired. At the repair shop, the technician said she definitely could repair the laptop by replacing one part of the screen. She also suggested adding some more RAM to help it run faster. Jane agreed and was even more pleased when she learned the repair and upgrade would cost 80 percent less than buying a new laptop. Jane saved money and kept valuable electronic components out of the trash.

Torn clothes can be sewn, parts of a bike can be replaced, and a new watch band can be attached to your smart watch. Repairing items and keeping them in service means a new item does not have to be made and transported to replace it.

▪ Recycle What You Can

All good things come to an end, and at some point, things are too worn to repair or reuse and they end up being thrown away. Before you put something in a trash bag destined for a landfill, consider whether it is recyclable. Steel and aluminum cans, plastic beverage bottles, milk jugs, cardboard boxes, and a lot of plastic containers and packaging can be recycled. Even textiles like jeans, towels, and fleece pullovers can be recycled into new thread for new fabric. Before you toss a container in the recycling bin, make sure it is clean and you have removed any loose plastic films, like clear plastic "windows" in boxes that display the product inside. One of the biggest hurdles for recycling products is that an entire load of material can be rejected if it is not clean enough.

The availability of recycling programs varies from one community to another, so be sure you know what your recycling program will accept. That does not mean you cannot recycle items your local program does not take. There are some companies that, for a small fee, will send a bag or box to collect items, like snack food wrappers, that are typically not taken by community programs. Rechargeable batteries and electronics are often collected at home improvement stores, electronics repair shops, and other locations and sent to recycling centers. Some communities hold recycling drives for hard-to-recycle items like paint, plastic films, and chemicals. Recycling saves a lot of energy compared to using raw materials like iron ore, wood pulp, or bauxite.

▪ The Reality of the 4 Rs

There is not always a recycling option for everything sold as "recyclable." Manufacturers are always looking for ways to make their products more sustainable. Packaging is trending toward recyclable or biodegradable, so it breaks down quickly. However, on the post-consumer end of the product stream, not all materials collected in recycling programs are actually recycled. Steel and aluminum are almost always recycled, but plastic containers are much less often recycled. The supply of recyclable materials is huge; the number of companies and programs actually taking those recyclable materials is few. Companies that make things from recycled glass or plastic can have access to a nearly unlimited supply of materials right now because so few businesses take them.

Recycling Tips

There are a few things we as individuals and community members can do to improve recycling.

- Make sure you are following all of the guidelines for your community program.
- Put your trash in the trash can and your recyclables in the recycling bin.
- Make sure you clean containers of major food residues before recycling them.
- Write or call your elected officials, especially local government representatives like the mayor or city council. Explain the importance of recycling as it relates to saving energy, reducing landfill waste, and saving money.
- Purchase products made from recyclable materials to encourage businesses to keep making them.
- Think about starting a business that makes something needed in your community from materials recycled in your community. A local recycling stream saves energy when materials and products do not need to be transported great distances.

Looking to the Future

We are never going to eliminate our need for energy, and we are not going to abruptly end making, purchasing, and disposing of things. What we can do, though, is make sure the energy we use is necessary. If we treat energy like a finite resource the way we do money and time, and manage it well, there will be enough to meet all of our needs. A sustainable future is not out of reach. It might take a little extra effort or a different way of thinking about things. When we work together, though, there is little we cannot achieve.

Glossary

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

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

d

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

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

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

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

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

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

	smelting	producing a metal from its ore, separating the metallic parts of an ore
	solar cell	an electric cell that changes radiant energy from the sun into electrical energy by the photovoltaic process
	solar energy	the radiant energy of the sun, which can be converted into other forms of energy, such as thermal energy or electricity
	solar power tower	the conceptual method of producing electrical energy from solar rays; involves the focusing of a large number of solar rays on a single source (boiler), usually located on an elevated tower, to produce high temperatures; a fluid located in or passed through the source changes into steam and is used in a turbine generator to produce electrical energy
	sound energy	energy that travels in longitudinal waves
	space heating	the heating of an area for comfort
	spent fuel	irradiated fuel that is permanently discharged from a nuclear reactor
	spillway gate	a gate or apparatus at a dam that helps to control the water level of a reservoir; gates release excess water following heavy rainfall
	steam generator	a generator in which the prime movers (turbines) are powered by steam
	steam reforming	a process to create hydrogen through the heating of a fuel (typically fossil fuels)
	superconductivity	having little to almost no electrical resistance
	surface mining	takes place within a few hundred feet of the surface; earth above or around the coal (overburden) is removed to expose the coal bed, which is then mined with surface excavation equipment
t	**tank farm**	an installation used by trunk and gathering pipeline companies, crude oil producers, and terminal operators (except refineries) to store crude oil
	thermal energy	the total potential and kinetic energy associated with the random motions of the atoms and molecules of a material; the more the molecules move and vibrate the more energy they possess
	thermostat	a device that adjusts the amount of heating and cooling produced and/or distributed by automatically responding to the temperature in the environment
	tide	rising and falling of sea level due to the gravitational force of the moon and sun, as well as the rotation of the Earth
	transformer	a device that converts the generator's low-voltage electricity to higher-voltage levels for transmission to the load center, such as a city or factory
	transmission line	a set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points
	transmutation	changing one element into another; can be accomplished through fusion
	transportation sector (of the economy)	the part of the economy having to do with how people and goods are transported (moved) from place to place; the transportation sector is made up of automobiles, airplanes, trucks, ships, trains, etc.
	turbine	a device with blades, which is turned by a force, such as that of wind, water, or high pressure steam; the mechanical (motion) energy of the spinning turbine is converted into electricity by a generator
u	**underground (deep) mining**	coal mining that takes place several hundred feet below the surface of the Earth; workers and coal enter and exit through a vertical shaft; see *longwall mining* or *room-and-pillar mining*
	uranium	a heavy, naturally-occurring, radioactive element of which isotopes can be used for nuclear fission
	uranium fuel cycle	the series of steps involved in supplying fuel for nuclear power reactors; it includes mining, refining, the making of fuel elements, their use in a reactor, chemical processing to recover spent (used) fuel, re-enrichment of the fuel material, and remaking into new fuel elements
v	**volt (V)**	the International System of Units (SI) measure of electric potential or electromotive force; a potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance; reduced to SI base units, 1 V = 1 kg times m2 times s-3 times A-1 (kilogram meter squared per second cubed per ampere) 1 kgm^2/s^3A

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



YOUTH AWARDS PROGRAM FOR ENERGY ACHIEVEMENT

NEED's annual Youth Awards Program for Energy Achievement rewards students for their efforts in energy outreach and student leadership.

The Youth Awards Program is great for all schools—new to energy education, or veteran. Projects and outreach completed for the program provide opportunity for enrichment and engagement, as well as an opportunity for your students, classroom, and school to shine. Youth Awards projects can be completed by afterschool/out-of-school time programs, community groups, and even families!

What's involved?

Students and teachers set goals and objectives and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects are uploaded to the online submission site.

Check out:

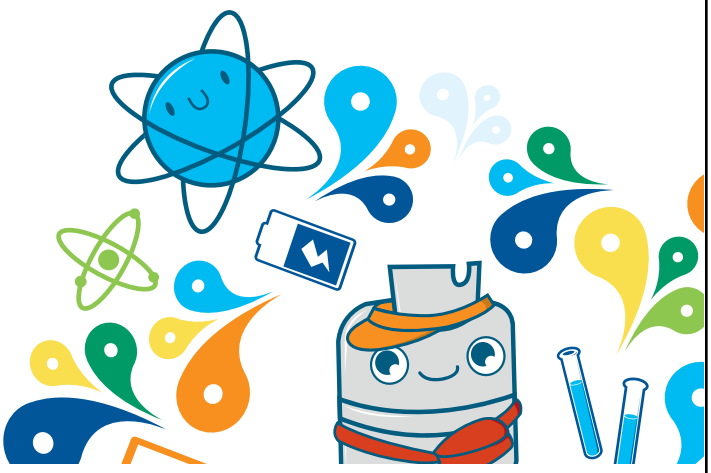
For more information and project submission details, we invite you to visit **https://youthawards.NEED.org**. Be sure to explore the site to view past winning projects and garner inspiration!

YOUTH ENERGY CONFERENCE & AWARDS

The NEED Youth Energy Conference and Awards gives students more opportunities to learn about energy and to explore energy in STEM (science, technology, engineering, and math).

The annual June conference has students from across the country working in groups on an Energy Challenge designed to stretch their minds and energy knowledge. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info:
www.NEED.org/youthenergyconference



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