Introduction to Energy

What Is Energy?

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

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

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

Forms of Energy

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

POTENTIAL ENERGY

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

- **Chemical energy** is energy stored in the bonds of **atoms** and **molecules**. It is the energy that holds these particles together. Foods we eat, biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

  During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are later broken down, the stored chemical energy is released as heat, light, motion, and sound.
- **Elastic energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic energy.
- **Nuclear energy** is energy stored in the nucleus of an atom—the energy that binds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms into helium atoms in a process called **fusion**. In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $E = mc^2$.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

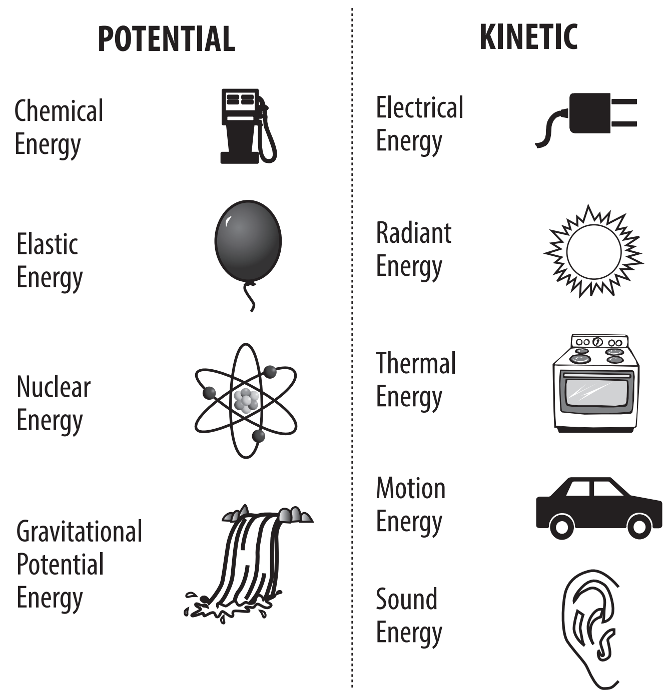
Energy at a Glance, 2014

	2013	2014
World Population	7,098,495,231	7,178,722,893
U.S. Population	316,128,839	318,857,056
World Energy Production	524.501 Q	539.5 Q
U.S. Energy Production	81.942 Q	87.398 Q
• Renewables	9.298 Q	9.6923 Q
• Nonrenewables	72.644 Q	77.706 Q
World Energy Consumption	528.743 Q	537.36 Q
U.S. Energy Consumption	97.785 Q	99.868 Q
• Renewables	9.298 Q	9.656 Q
• Nonrenewables	88.487 Q	90.212 Q

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

Data: Energy Information Administration

Forms of Energy



KINETIC ENERGY

Kinetic energy is motion—the motion of waves, **electrons**, atoms, molecules, substances, and objects.

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

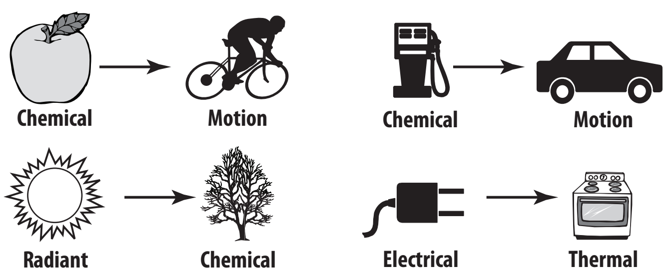
Conservation of Energy

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

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

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

Energy Transformations



Efficiency

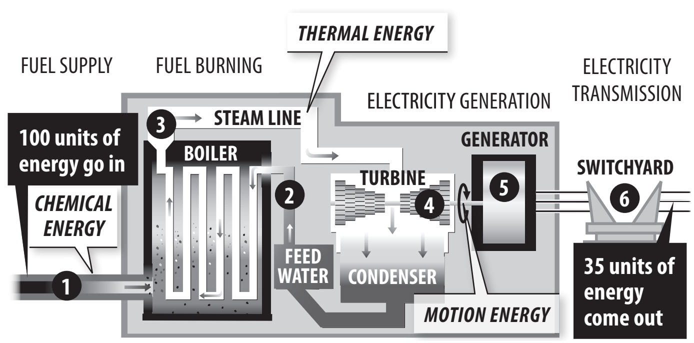
Energy efficiency is the amount of useful energy you can get out of a system. In theory, a 100 percent energy efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of thermal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

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

A traditional incandescent light bulb isn't efficient either. This type of light bulb converts only ten percent of the electrical energy into light and the rest (90 percent) is converted into thermal energy. That's why these light bulbs are so hot to the touch. Their inefficiency is also why many homes now use different, more efficient bulbs.

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



How a Thermal Power Plant Works

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

Introduction to Energy

Sources of Energy

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

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

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

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

These energy sources are called nonrenewable because they cannot be replenished in a short period of time. Petroleum, a fossil fuel, for example, was formed hundreds of millions of years ago, before dinosaurs existed. It was formed from the remains of ancient sea life, so it cannot be made quickly. We could run out of economically recoverable nonrenewable resources some day.

Measuring Energy

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

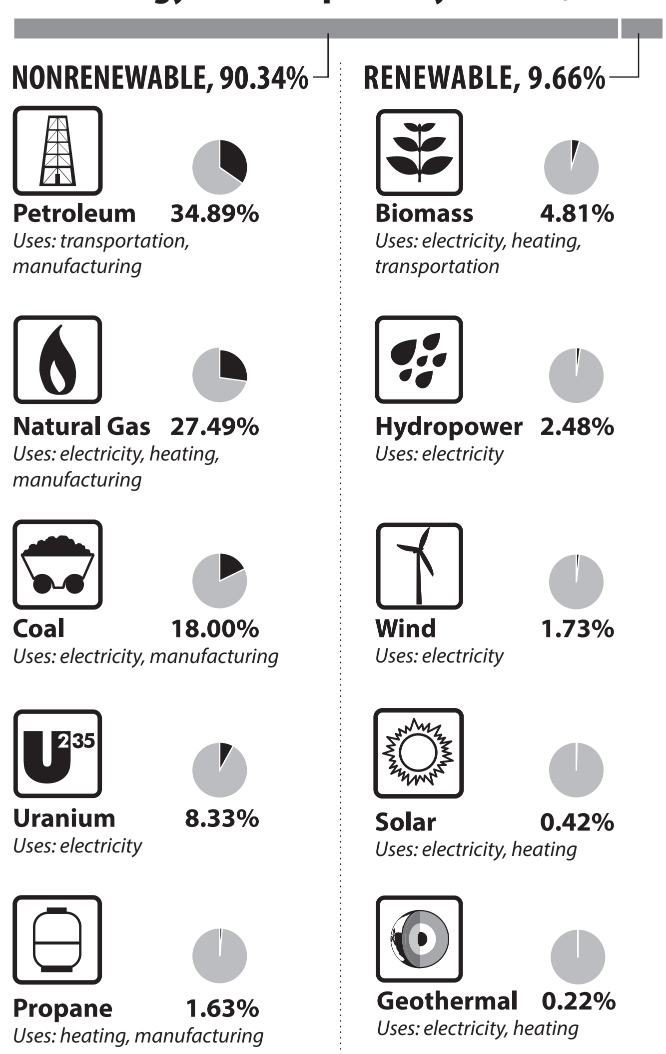
One Btu is the amount of thermal energy needed to raise the temperature of one pound of water one degree Fahrenheit. A single Btu is quite small. A wooden kitchen match, if allowed to burn completely, would give off about one Btu of energy. One ounce of gasoline contains almost 1,000 Btu of energy.

Every day the average American uses about 858,000 Btu. We use the term quad (Q) to measure very large quantities of energy. A quad is one **quadrillion** (1,000,000,000,000,000 or 10^{15}) **Btu**. The United States uses about one quad of energy approximately every 3.7 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high.

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

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

U.S. Energy Consumption by Source, 2014



Data: Energy Information Administration

Energy Use

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

You listen to music on your smart phone as you catch the bus to school. And that's just some of the energy you use to get you through the first part of your day!

Every day, the average American uses about as much energy as is stored in a little more than seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to about 2,600 gallons of gasoline per person. This use of energy is called **energy consumption**.

Energy Users

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

▪ Residential/Commercial

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

The residential/commercial sector of the economy consumed 11.62 percent of the total energy supply in 2014, with a total of 11.44 quads. The residential sector consumed 7.12 quads and the commercial sector consumed 4.32 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 21.39 quads of energy in 2014, which accounted for 21.72 percent of total consumption.

▪ Electric Power

The electric power sector includes electricity generation facilities and power plants. All of the other sectors consume electricity generated by the electric power sector. The electric power sector consumed 39.23 percent of the total energy supply in 2014, more than any of the other sectors, with a total of 38.63 quads.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2014, the U.S. consumed 27.01 quads of energy for transportation, which accounted for 27.43 percent of total consumption. 91.96 percent of this energy was from petroleum products such as gasoline, diesel, and jet fuel.

Energy Use and Prices

Several decades ago, in 1973, Americans faced a major oil price shock due to an **oil embargo**. People didn't know how the country would react. How would Americans adjust to skyrocketing energy prices? How would manufacturers and industries respond? We didn't know the answers.

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

The same thing happened when energy prices shot up again in 1979, 1980, and more recently in 2008—people used less energy. When prices started to drop, energy use began to increase.

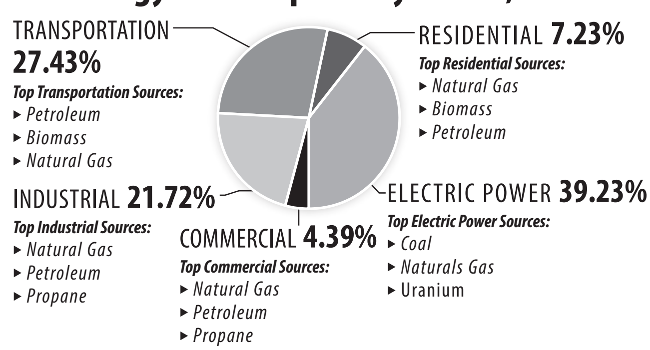
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

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

In 2014, the United States used 32 percent more energy than it did in 1973. That might sound like a lot, but the population has increased by over 50 percent and the nation's **gross domestic product** was 2.53 times that of 1973.

You may wonder why the 1970s are important—it was so long ago. However, the energy crisis during this decade taught us a valuable lesson. If every person in the United States today consumed energy at the rate we did in the 1970s, we would be using much more energy than we are—perhaps as much as double the amount. Energy efficiency technologies have made a huge impact on overall consumption since the energy crisis of 1973.

U.S. Energy Consumption by Sector, 2014



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

Data: Energy Information Administration