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.

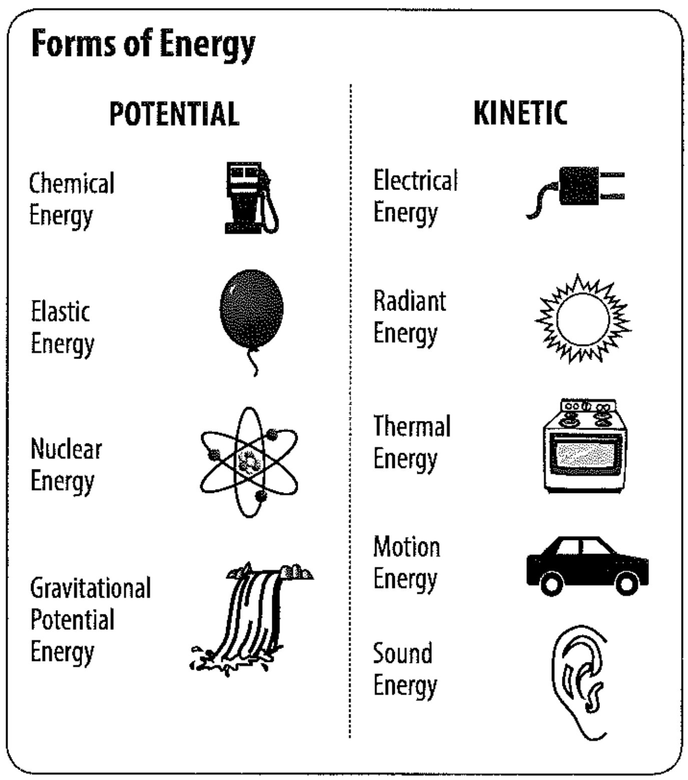
  During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are later broken down, the stored chemical energy is released as heat, light, motion, and sound.
- **Elastic energy** is energy stored in objects by the application of a force. 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, 2013

	2012	2013
World Population	7,020,760,225	7,098,495,231
U.S. Population	313,873,685	316,128,839
World Energy Production	513.695 Q	524.501 Q
U.S. Energy Production	79.219 Q	81.942 Q
• Renewables	8.838 Q	9.298 Q
• Nonrenewables	70.381 Q	72.644 Q
World Energy Consumption	518.086	528.743 Q
U.S. Energy Consumption	96.705 Q	97.785 Q
• Renewables	8.798 Q	9.298 Q
• Nonrenewables	87.907 Q	88.487 Q

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

Data: Energy Information Administration



Forms of Energy

All forms of energy fall under two categories:

POTENTIAL

Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds of atoms and molecules. Gasoline and a piece of pizza are examples.

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

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

GRAVITATIONAL POTENTIAL ENERGY is the energy of place or position. A child at the top of a slide is an example.

KINETIC

The motion of waves, electrons, atoms, molecules, and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Light and x-rays are examples.

THERMAL ENERGY or heat is the internal energy in substances – the vibration or movement of atoms and molecules in substances. The heat from a fire is an example.

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

SOUND is the movement of energy through substances in longitudinal waves. Echoes and music are examples.

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

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** is the movement of objects and substances from one place to another. According to **Newton's Laws of Motion**, objects and substances move when an unbalanced force is applied. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate. The energy is transferred through the substance in a wave.

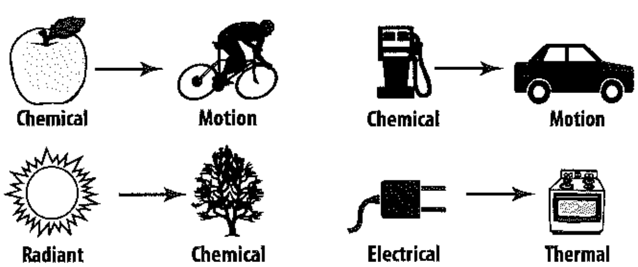
Conservation of Energy

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

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

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

Energy Transformations



Efficiency

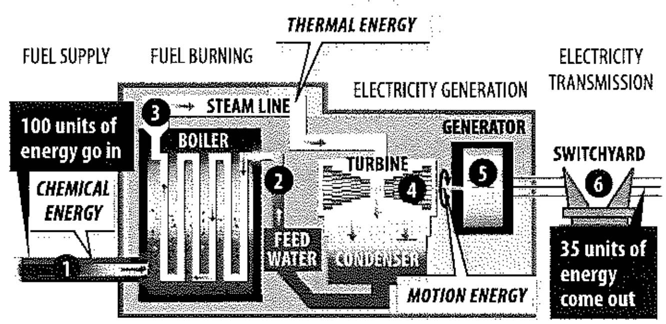
Energy efficiency is the amount of useful energy you can get out of a system. In theory, a 100 percent energy efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of thermal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

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

An incandescent light bulb isn't efficient either. This type of light bulb converts 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.

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.

Biomass

Biomass at a Glance, 2013

Classification:
- renewable

Major Uses:
- electricity, transportation fuel, heating

U.S. Energy Consumption:
- 4.613 Q
- 4.73%

U.S. Energy Production:
- 4.614 Q
- 5.63%

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

Data: Energy Information Administration

What Is Biomass?

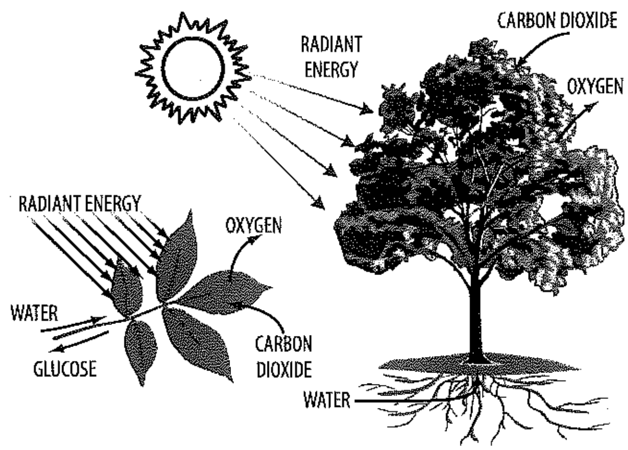
Biomass is any organic matter—wood, crops, seaweed, animal wastes—that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food.

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

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

Photosynthesis

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



water + carbon dioxide + sunlight ⟶ glucose + oxygen

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

Types of Biomass

We use several types of biomass today, including wood, agricultural products, solid waste, landfill gas and biogas, and biofuels. The uses for alcohol fuels, like ethanol, will be discussed in depth in the coming pages.

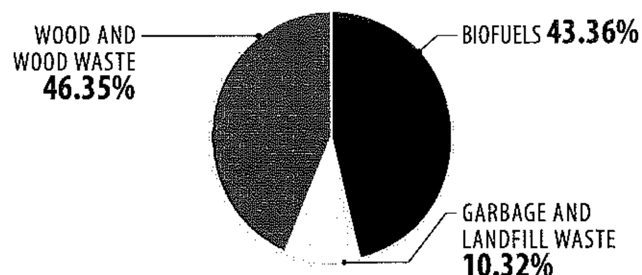
▪ Wood

Most biomass used today is home grown energy. Wood—logs, chips, bark, and sawdust—accounts for about 46 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corncobs.

Wood and wood waste are used to generate electricity. Much of the electricity is used by the industries making the waste; it is not distributed by utilities, it is a process called **cogeneration.** Paper mills and saw mills use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they need to buy additional electricity from utilities.

Increasingly, timber companies and companies involved with wood products are seeing the benefits of using their lumber scrap and sawdust for power generation. This saves disposal costs and, in some areas, may reduce the companies' utility bills. In fact, the pulp and paper industries rely on biomass to meet 63 percent of their energy needs. Other industries that use biomass include lumber producers, furniture manufacturers, agricultural businesses like nut and rice growers, and liquor producers.

U.S. Sources of Biomass, 2013



Data: Energy Information Administration

▪ Solid Waste

Burning trash turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas.

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

Coal

Coal at a Glance, 2013

Classification:
- nonrenewable

Major Uses:
- electricity, industry

U.S. Energy Consumption:
- 18.084 Q
- 18.52%

U.S. Energy Production:
- 19.988 Q
- 24.39%

Data: Energy Information Administration

What Is Coal?

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

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

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

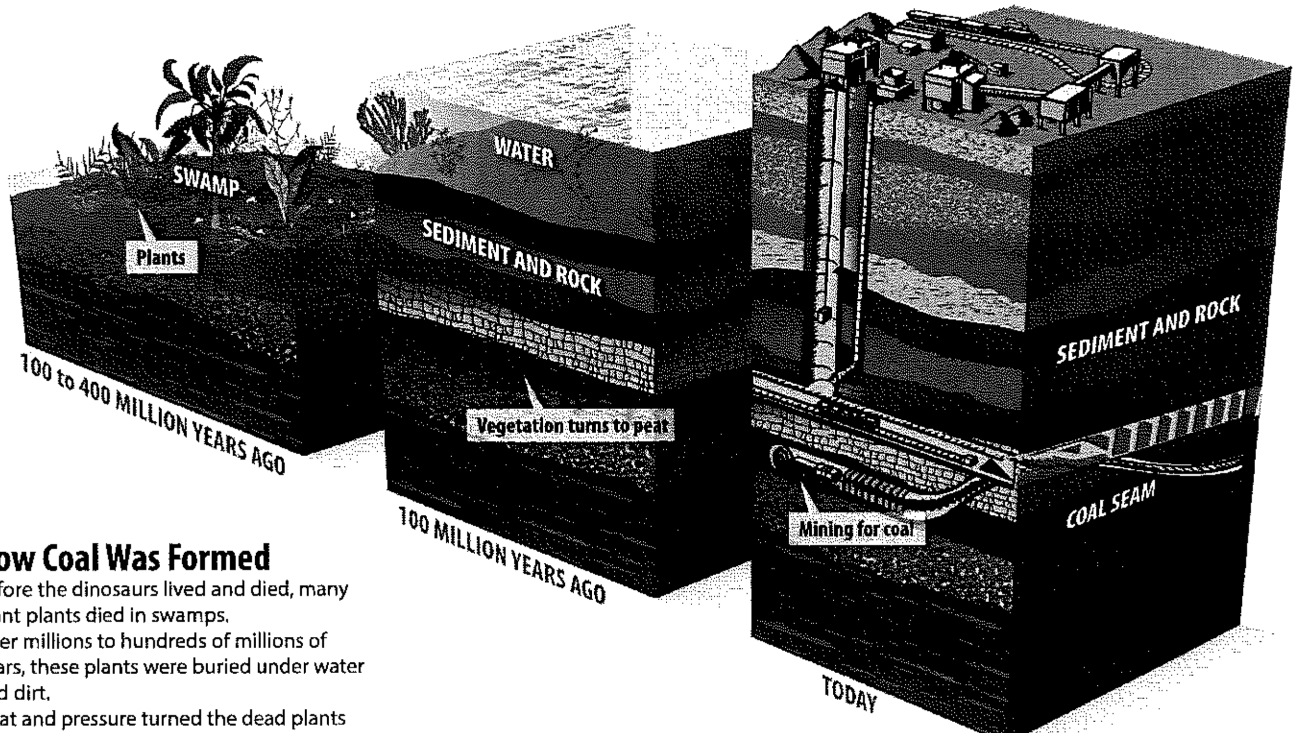
Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

History of Coal

Native Americans used coal long before the first settlers arrived in the New World. Hopi Indians, who lived in what is now Arizona, used coal to bake the pottery they made from clay. European settlers discovered coal in North America during the first half of the 1600s. They used very little at first. Instead, they relied on water wheels and wood to power colonial industries.

Coal became a powerhouse by the 1800s. People used coal to manufacture goods and to power steamships and railroad engines. By the American Civil War, people also used coal to make iron and steel. And by the end of the 1800s, people even used coal to make electricity.

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



How Coal Was Formed

Before the dinosaurs lived and died, many giant plants died in 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.

Note: not to scale

Geothermal

Geothermal at a Glance, 2013

Classification:
- renewable

Major Uses:
- electricity, heating

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

U.S. Energy Production:
- 0.221 Q
- 0.27%

Data: Energy Information Administration

What Is Geothermal Energy?

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

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

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

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

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

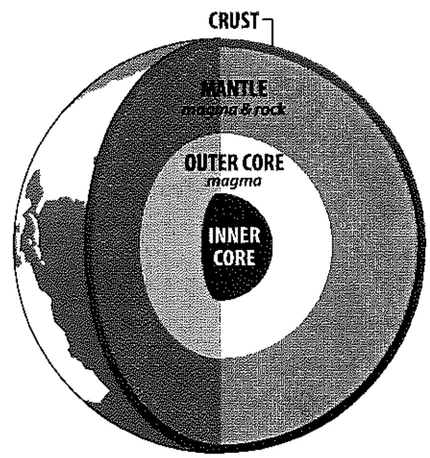
Geothermal energy is called a **renewable** energy source because the water is replenished by rainfall, and the heat is continuously produced within the Earth by the slow radioactive decay of particles that naturally occur in all rocks.

History and Uses of Geothermal Energy

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

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

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

Hydropower

What Is Hydropower?

Hydropower (from the Greek word *hydor,* meaning water) is energy that comes from the force of moving water. The fall and movement of water is part of a continuous natural cycle called the **water cycle**.

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

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

History of Hydropower

Hydropower has been used for centuries. The Greeks used water wheels to grind wheat into flour more than 2,000 years ago. In the early 1800s, American and European factories used the water wheel to power machines.

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

In the late 19th century, the force of falling water was used to generate electricity. The first hydroelectric power plant was built on the Fox River in Appleton, WI in 1882. In the following decades, many more hydroelectric plants were built. At its height in the early 1940s, hydropower provided 33 percent of this country's electricity.

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

Hydro Dams

It is easier to build a hydropower plant where there is a natural waterfall. That's why both U.S. and Canada have hydropower plants at Niagara Falls. Dams, which are artificial waterfalls, are the next best way.

Dams are built on rivers where the terrain will produce an artificial lake or **reservoir** above the dam. Today there are about 84,000 dams in the United States, but less than three percent (2,200) were built specifically for electricity generation. Most dams were built for recreation, flood control, fire protection, and irrigation.

Hydropower at a Glance, 2013

Classification:
- renewable

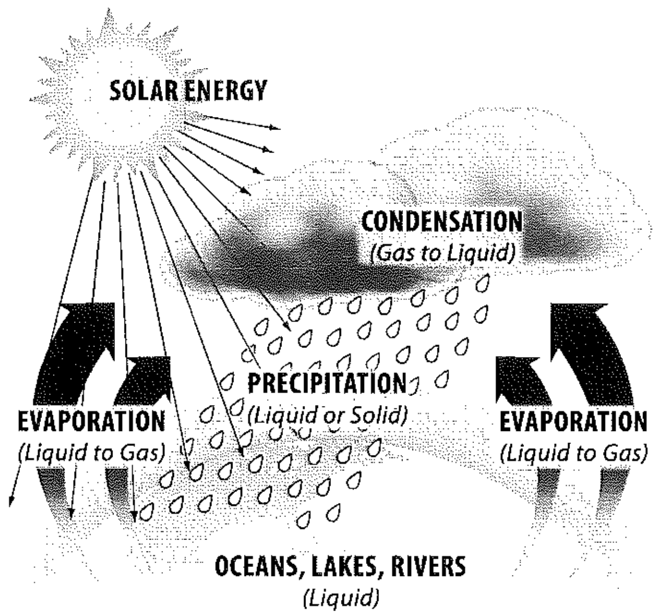
Major Uses:
- electricity

U.S. Energy Consumption:
- 2.561 Q
- 2.62%

U.S. Energy Production:
- 2.561 Q
- 3.13%

Data: Energy Information Administration

The Water Cycle



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

Hydropower Plants

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

Hydroelectric power plants are different. They use modern turbine generators to produce electricity, just as thermal (coal, natural gas, nuclear) power plants do, except they do not produce heat to spin the turbines.

How a Hydropower Plant Works

A typical hydropower plant is a system with three parts:

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

To generate electricity, a dam opens its gates to allow water from the reservoir above to flow down through large tubes called **penstocks**. At the bottom of the penstocks, the fast-moving water spins the blades of turbines. The turbines are connected to generators to produce electricity. The electricity is then transported via huge transmission lines to a local utility company.

Head and Flow

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

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

Storing Energy

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

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

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

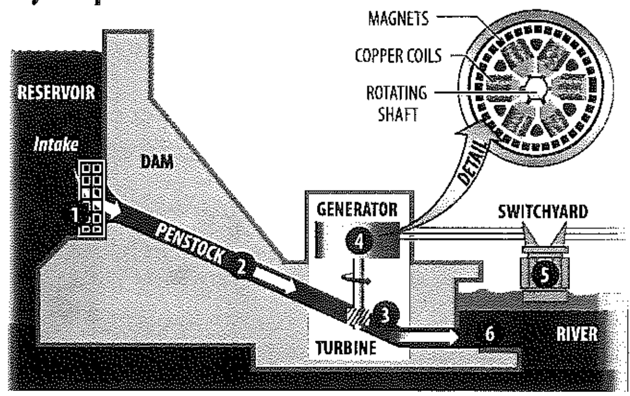
Pumped Storage Systems

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

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

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

Hydropower Plant



1. Water in a reservoir behind a hydropower dam flows through an intake screen, which filters out large debris, but allows fish to pass through.
2. The water travels through a large pipe, called a penstock.
3. The force of the water spins a turbine at a low speed, allowing fish to pass through unharmed.
4. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
5. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.
6. Water flows out of the penstock into the downstream river.

Hydropower Production

How much electricity do we get from hydropower today? Depending on the amount of rainfall, hydro plants produce from five to ten percent of the electricity produced in this country. In 1997, 10.21 percent of electricity came from hydropower—a historical high. However, in the last 15 years, electricity has ranged as low as 5.81 percent in 2001 to 7.79 percent in 2011, a recent high. In Oregon, Washington, and Idaho, hydropower accounts for more than half (56 to 69 percent) of each state's electricity generation.

Today, there is about 78,000 megawatts of conventional hydro generating capacity in the United States, and about 98,000 megawatts when including pumped storage. That's equivalent to the generating capacity of 80 large nuclear power plants. The biggest hydro plant in the U.S. is located at the Grand Coulee Dam on the Columbia River in northern Washington State. The U.S. also gets some hydropower generated electricity from Canada. Some New England utilities buy this imported electricity.

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

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

Concept Sheet
Energy Transformations

PS.6: **The student will investigate and understand states and forms of energy and how energy is transferred and transformed.**

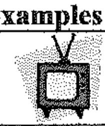
1. **Energy** is the ability to do work (apply a force through a distance). The many forms of energy include **mechanical (including sound), electrical, thermal, light (radiant), chemical**, and **nuclear**.

   - **Kinetic energy** is the energy of a moving object. The amount of kinetic energy depends on the mass and velocity of the moving object. *Examples: An apple falling from a tree, wind, and a bird flying to its nest.*
   - **Potential energy** is the stored energy of an object based on its position. *Examples: A rock at the top of a hill has potential energy based on its position.*

   The chemical energy in fossil fuels is also a form of potential energy. Coal, oil, gasoline, and natural gas have potential energy because of their chemical composition.

2. Energy can change from one type to another. This is called an **energy conversion** or **energy transformation.**
   - The *Law of Conservation of Energy* states that energy can change form, but it cannot be created or destroyed. Therefore, the total amount of energy stays the same.
   - In energy transformations, some energy is always lost to the environment as thermal energy.

Examples of energy transformations and their uses:

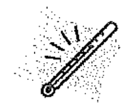
	A television changes electrical energy into sound and light energy.
	A toaster changes electrical energy into thermal energy and light.
	A car changes chemical energy from fuel into thermal energy and mechanical energy.
	A flashlight changes chemical energy from batteries into light energy.
	When you speak into your telephone, sound energy from your voice is changed into electrical energy. The electrical energy is then converted back into sound energy on another phone, allowing someone to hear you.
	Light energy is converted into electrical energy using solar panels.
	Campfires convert chemical energy stored in wood into thermal energy, which is useful for cooking food and staying warm.
	Nuclear energy generates a tremendous amount of thermal energy, which can be converted into electrical energy in a nuclear power plant.

PS.7: The student will investigate and understand temperature scales, heat, and heat transfer.

3. **Thermal energy** is the total kinetic energy of a substance's atoms and molecules. Atoms and molecules are constantly in motion. When thermal energy causes particles to move faster and farther apart, the result is a **phase change** (or change of state). *During a phase change, the thermal energy is being used to break bonds between molecules. Even though thermal energy continues to be absorbed, the temperature does not rise.*

Heat is the transfer of thermal energy from a substance of higher temperature to a substance of lower temperature.

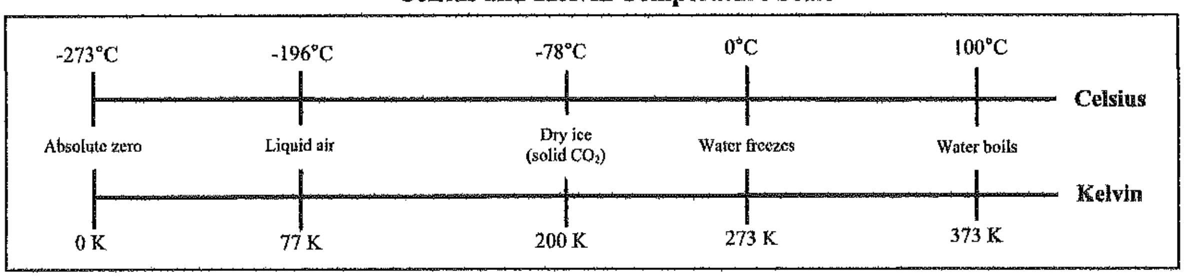
- **Vaporization** (boiling and evaporation) is a change from a liquid state to a gas.
- **Condensation** is a change from gas to liquid.
- **Freezing** is a change from liquid to solid.
- **Melting** is a change from solid to liquid.



Temperature is a measure of the **average** kinetic energy of the atoms and molecules in a substance.

- The temperature at which liquids change to solids is their **freezing** point (water: 0 °C).
- The temperature at which solids change to liquids is their **melting** point (water: 0 °C).
- The temperature at which liquids change to gases is their **boiling** point (water: 100 °C).
- The temperature at which gases change to liquids is their **condensation** point (water: 100 °C).
- A temperature of **absolute zero** (-273 °C/0 K) is a <u>theoretical</u> point at which molecules stop moving.

Celsius and Kelvin Temperature Scale



Note: the Kelvin temperature scale does not use the degree (°) symbol.

4. **Thermal energy** can be **transferred** from warmer to colder particles in three ways:
    1. **Conduction** is the heating of an object from direct contact between a heat source and the object. An example is a pan getting hot from the stove.
    2. **Convection** is heating of an object through the movement of a fluid (a gas or liquid). Examples are the thermal currents in the ocean or in the atmosphere.
    3. **Radiation** is the heating of an object by radiant energy traveling through space by electromagnetic waves. An example is the thermal energy coming to the Earth from the Sun through infrared waves.

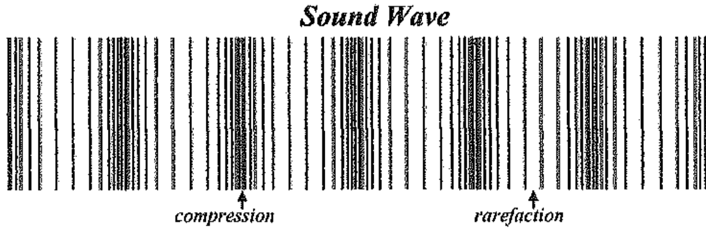
Some applications of thermal energy transfer include: heat engines (cars, lawn mowers), thermostats, refrigerators, and heat pumps.

PS.8: **The student will investigate and understand characteristics of sound and the technological applications of sound waves.**

5. A **wave** is a disturbance that transfers energy through matter or space. **Sound** is a form of mechanical energy produced by vibrations. It travels in longitudinal (compression) waves and moves much slower than the speed of light. In longitudinal waves, matter vibrates in the same direction as the waves are traveling.

    Sound waves require a medium (solid, liquid, or gas) through which to travel. Longitudinal waves cause molecules of a medium to vibrate "back and forth" in the same direction that the wave is traveling. The speed of sound depends on the type of medium (how dense) it is passing through and the temperature of the medium.

Sound Wave



Sound waves are used in sonar, medical ultrasonography imaging, and ultrasonic cleaners.

Doctors use sonography machines to "see" inside a person's body. The machine emits high frequency sound waves (inaudible by the human ear) which are reflected off of hard objects in the body. A computer interprets the data and creates an image of the area being studied. Sonograms are often used to monitor the development of unborn babies. Doctors also use sonography to see internal organs which helps them make a medical diagnosis.