Energy From the Wind
Student Guide

NEED
National Energy Education Development Project

Introduction to Wind

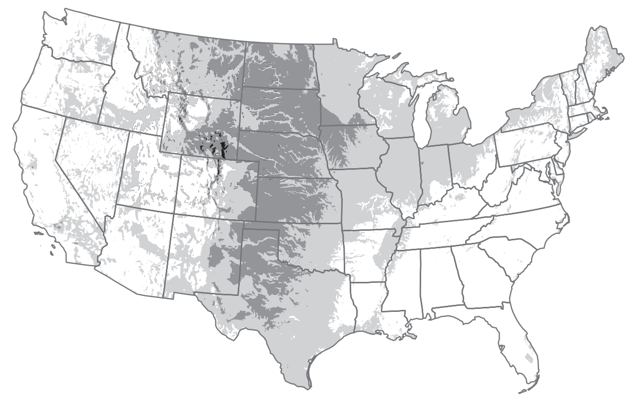
Wind

Wind is moving air. You cannot see air, but it is all around you. You cannot see the wind, but you know it is there.

You hear leaves rustling in the trees. You see clouds moving across the sky. You feel cool breezes on your skin. You witness the destruction of strong winds such as tornadoes and hurricanes. Wind has energy.

Wind resources can be found across the country. Science and technology are providing more tools to accurately predict when and where the wind will blow. This information is allowing people to use wind on small and large scales. Wind is an increasingly important part of the United States' energy portfolio.

AVERAGE WIND SPEED AT 80 METERS



The Beaufort Scale

At the age of 12, Francis Beaufort joined the British Royal Navy. For more than twenty years he sailed the oceans and studied the wind, which was the main power source for the navy's fleet. In 1805, he created a scale to rate the power of the wind based on observations of common things around him rather than instruments.

The Beaufort Scale ranks winds from 0–12 based on how strong they are, with each wind given a name from calm to hurricane. The Beaufort Scale can be used to estimate the speed of the wind.

BEAUFORT SCALE OF WIND SPEED

BEAUFORT NUMBER	NAME OF WIND	LAND CONDITIONS	WIND SPEED (MPH)
0	Calm	Smoke rises vertically	Less than 1
1	Very Light	Direction of wind shown by smoke drift but not by wind vanes	1 - 3
2	Light breeze	Wind felt on face , leaves rustle, ordinary wind vane moved by wind	4 - 7
3	Gentle breeze	Leaves and small twigs in constant motion, wind extends white flag	8 - 12
4	Moderate breeze	Wind raises dust and loose paper, small branches move	13 - 18
5	Fresh breeze	Small trees in leaf start to sway, crested wavelets on inland waters	19 - 24
6	Strong breeze	Large branches in motion, whistling in telegraph wires, umbrellas used with difficulty	25 - 31
7	Near gale	Whole trees in motion, inconvenient to walk against wind	32 - 38
8	Gale	Twigs break from trees, difficult to walk	39 - 46
9	Strong gale	Slight structural damage occurs, chimney pots and slates removed	47 - 54
10	Storm	Trees uprooted, considerable structural damage occurs	55 - 63
11	Violent storm	Widespread damage	64 - 73
12	Hurricane	Widespread damage	Greater than 74

Wind Formation

The energy in wind comes from the sun. When the sun shines, some of its light (**radiant energy**) reaches the Earth's surface. The Earth near the equator receives more of the sun's energy than the North and South Poles.

Some parts of the Earth **absorb** more radiant energy than others. Some parts **reflect** more of the sun's rays back into the air.

The fraction of light striking a surface that gets reflected is called **albedo**.

Some types of land absorb more radiant energy than others. Dark forests absorb sunlight while light desert sands reflect it. Land areas usually absorb more energy than water in lakes and oceans.

When the Earth's surface absorbs the sun's energy, it turns the light into heat. This heat on the Earth's surface warms the air above it.

The air over the equator gets warmer than the air over the poles. The air over the desert gets warmer than the air in the mountains. The air over land usually gets warmer than the air over water. As air warms, it expands. Its molecules get farther apart. The warm air is less dense than the air around it and rises into the atmosphere. Cooler, denser air nearby flows in to take its place.

This moving air is what we call wind. It is caused by the uneven heating of the Earth's surface.

Local Winds

The wind blows all over the planet, but mountainous and coastal areas have more steady and reliable winds than other places. Local winds are affected by changes in the shape of the land. Wind can blow fast and strong across the open prairie. Wind slows down and changes directions a lot when the land surface is uneven, or covered with forests or buildings.

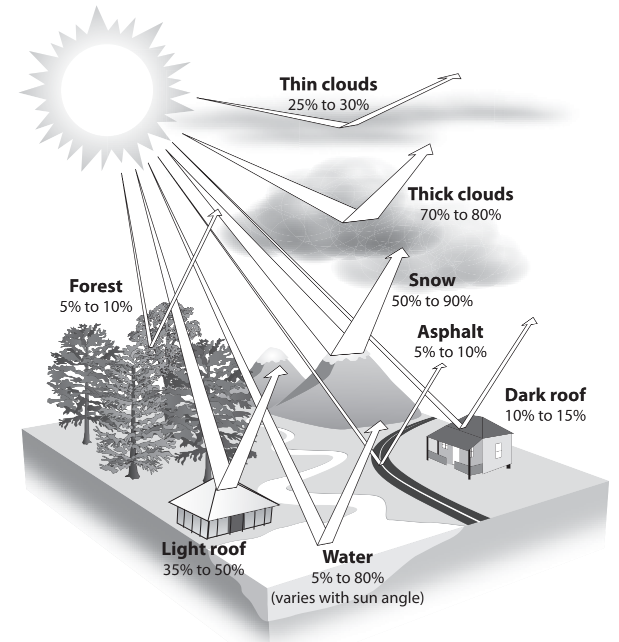
Mountain and Valley Winds

Local winds form when land heats up faster in one place than another. A mountain slope, for example, might warm up faster than the valley below. The warm air is lighter and rises up the slope. Cold air rushes in near the base of the mountain, causing wind to sweep through the valley. This is called a **valley wind**.

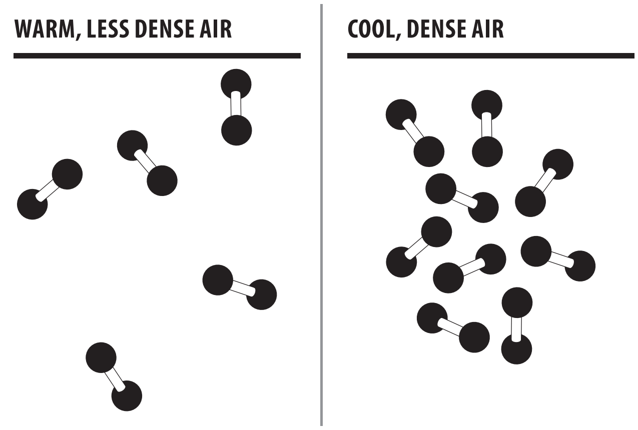
At night, the wind can change direction. After the sun sets, the mountain slope cools off quickly. Warm air is pushed out of the way as cool air sinks, causing wind to blow down toward the valley. This is called a **mountain wind**, or **katabatic winds** (kat-*uh*-**bat**-ik).

When katabatic winds blow through narrow valleys between mountains, the speed of the wind increases. This is called the **tunnel effect**. Katabatic winds sometimes have special names throughout the world. In the United States, there are two—the Chinook is an easterly wind in the Rocky Mountains and the Santa Ana is an easterly wind in Southern California.

PERCENTAGE OF SOLAR ENERGY REFLECTED



The Earth's surface and objects reflect different amounts of sunlight.



MOUNTAINS AND VALLEYS

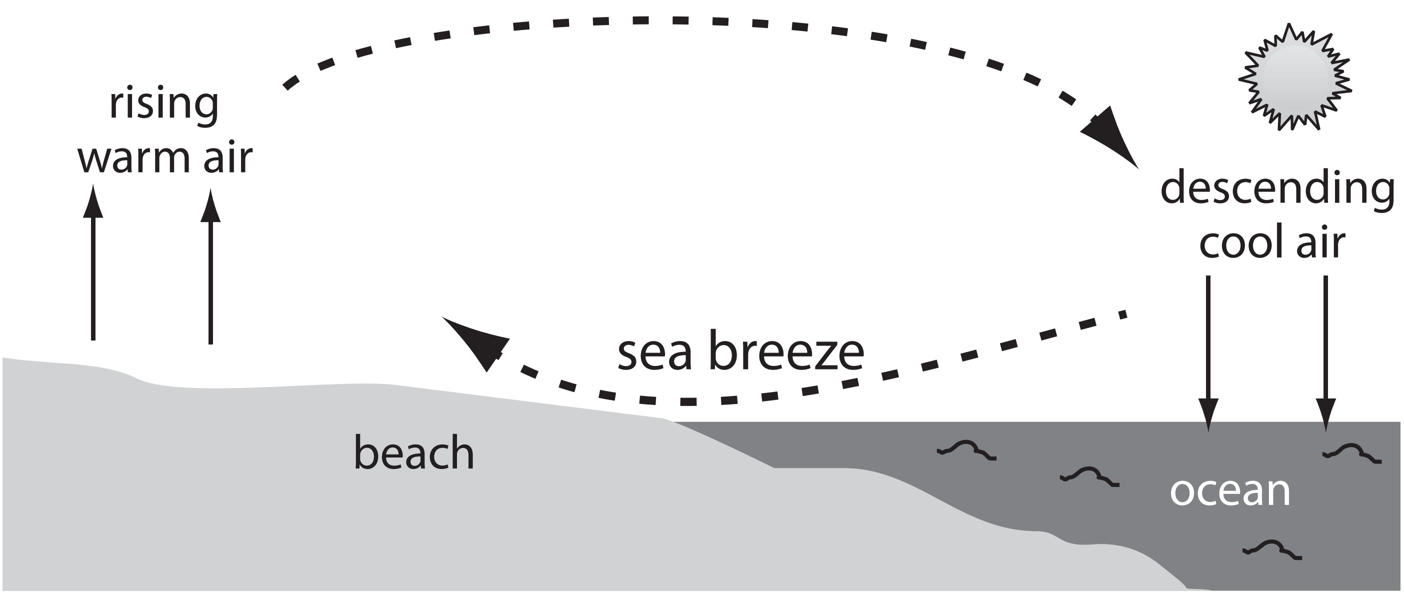
Sea and Land Breezes

During the day, the sun heats both land and water, but not to the same temperature. It takes more energy to heat water than it does land because they have different properties. When the sun shines, the land heats faster than the water. Land also gives up its heat faster than the water at night when the sun is not shining.

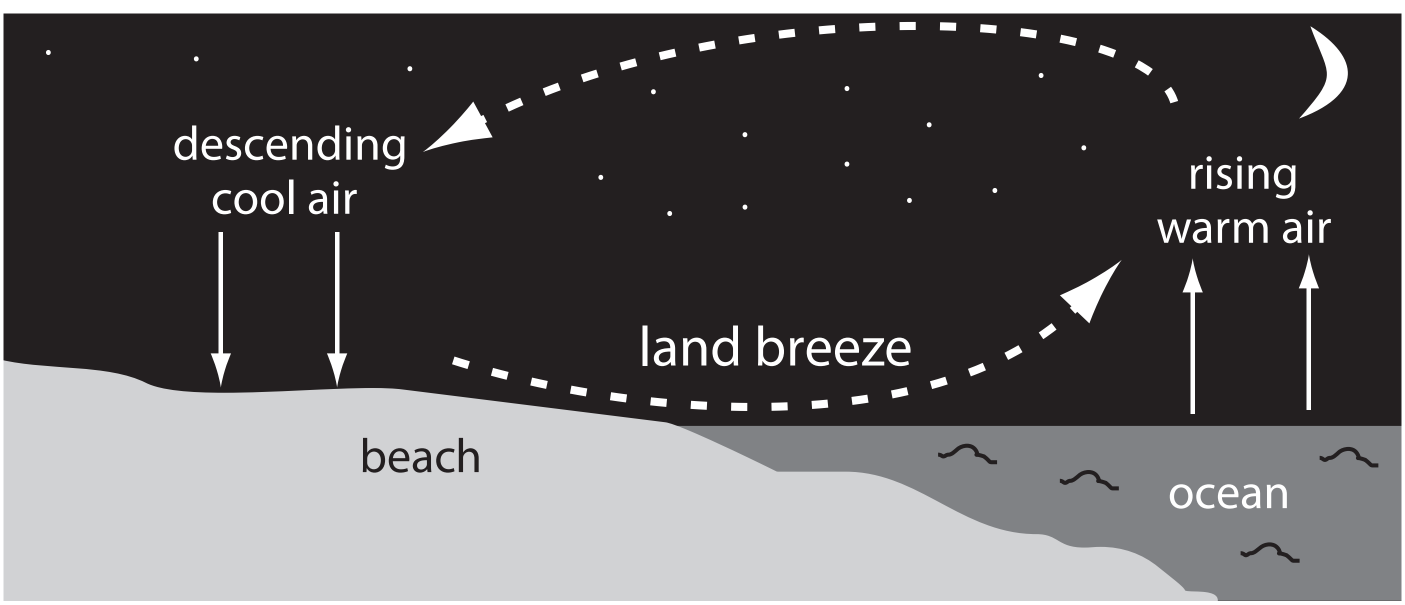
Since land absorbs more heat and releases it more quickly than water, the air above land gets warmer than the air above water. The heated air above land rises, creating an area of low pressure. The air above the water is cooler, creating an area of higher pressure. The cooler air over the water moves to the area of low pressure over land. This is called a **sea breeze** because the breeze is coming from the sea.

At night, the land gives up its heat and cools more rapidly than water, which means the sea is now warmer than the shore. The air over the water becomes warmer than the air over the land. The warm, rising sea air creates an area of low pressure, and the cooler air above land creates an area of higher pressure. The air moves from higher to lower pressure, from the land to the water. This breeze is called a **land breeze**.

SEA BREEZE



LAND BREEZE



Global Wind Patterns

The area near the Earth's equator receives the sun's direct rays. The air over the surface warms and rises. The warmed air moves north and south about 30 degrees latitude, and then begins to cool and sink back to Earth.

▪ Trade Winds

Most of this cooling air moves back toward the equator. The rest of the air flows toward the North and South Poles. The air streams moving toward the equator are called **trade winds**—warm, steady breezes that blow almost all the time. The **Coriolis Effect,** caused by the rotation of the Earth, makes the trade winds appear to be curving to the west.

▪ Doldrums

The trade winds coming from the south and the north meet near the equator. As the trade winds meet, they turn upward as the air warms, so there are no steady surface winds. This area of calm is called the **doldrums**.

▪ Prevailing Westerlies

Between 30 and 60 degrees latitude, the air moving toward the poles appears to curve to the east. Because winds are named for the direction from which they blow, these winds are called **prevailing westerlies.** Prevailing westerlies in the northern hemisphere cause much of the weather across the United States and Canada. This means in the U.S., we can look to the weather west of us to see what our weather will be like tomorrow.

▪ Polar Easterlies

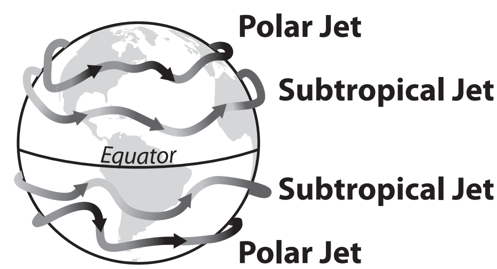
At about 60 degrees latitude in both hemispheres, the prevailing westerlies join with **polar easterlies**. The polar easterlies form when the air over the poles cools. This cool air sinks and spreads over the surface. As the air flows away from the poles, it curves to the west by the Coriolis Effect. Because these winds begin in the east, they are called polar easterlies.

▪ Jet Streams

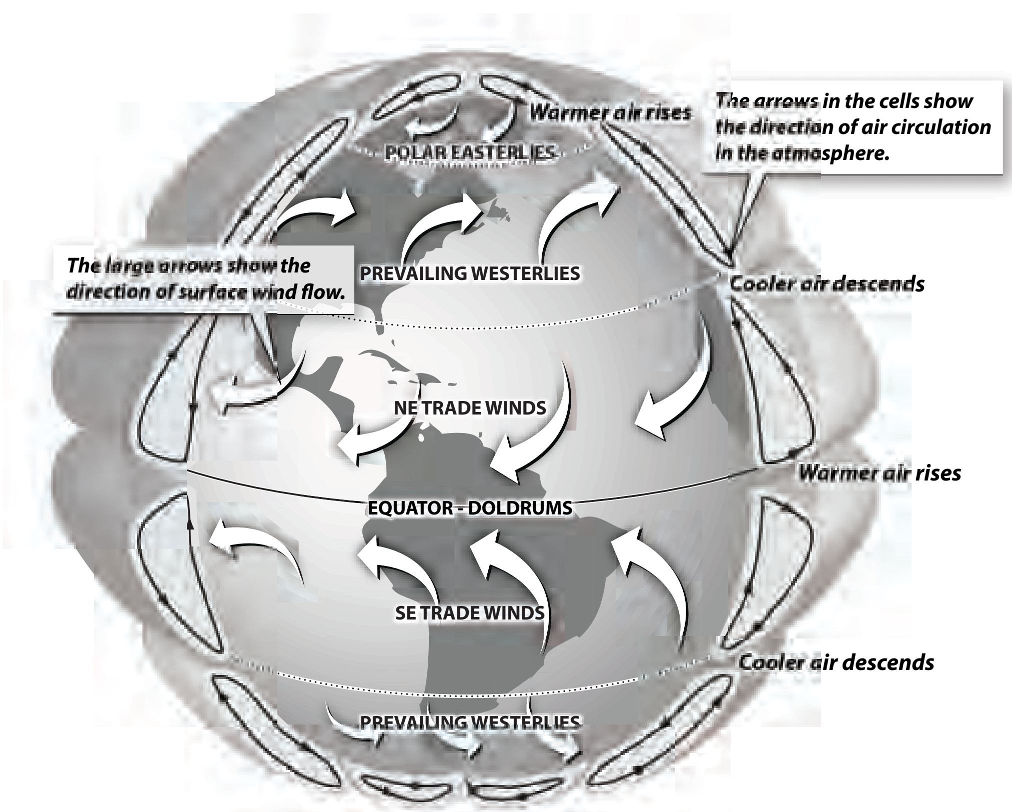
The highest winds are the **jet streams**. They are formed where the other wind systems meet. The jet streams flow far above the Earth where there is nothing to block their paths. These fast moving "rivers of air" pull air around the planet, from west to east, carrying weather systems with them.

These global winds—trade winds, prevailing westerlies, polar easterlies, and the jet streams—flow around the world and cause most of the Earth's weather patterns.

JET STREAMS



GLOBAL WIND PATTERNS



Measuring Wind Direction and Speed

▪ Wind Direction

A weather vane, or **wind vane**, is used to show the direction of the wind. A wind vane points toward the source of the wind. Some people use windsocks to show the direction in which the wind is blowing.

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

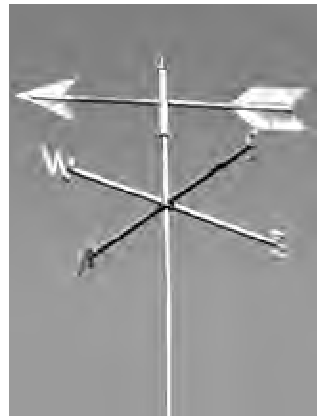
▪ Wind Speed

It is important in many cases to know how fast the wind is blowing. Wind speed can be measured using an instrument called a wind gauge, or **anemometer.**

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 the anemometer counts the number of spins per minute and converts that figure into mph—miles per hour. A display attached to the anemometer shows the speed of the wind.

WIND VANE



ANEMOMETER

Wind Turbines Yesterday and Today

The earliest European windmills, built in the 1200s, were called **postmills**. They were built of wood and designed to grind grain between millstones. The entire postmill could be rotated when the direction of the wind changed. This is how windmills got their name. It was the miller's job to rotate the postmill.

Between 1300 and the late 1500s, **smockmills** were invented. Sails were attached to the cap—or top—of the windmill and only the cap rotated. The miller still had to rotate the cap when the wind changed directions. These mills were bigger, heavier, and stronger since the building didn't move.

In the 1500s, **tower windmills** were built in Spain, Greece and the Mediterranean Islands. Tower windmills were small and made out of stone. They had many small sails that worked well in the lighter winds of Southern Europe. They were used to pump water and grind grain.

In the 1600s, the Dutch began to use **drainage windmills** to pump water. The windmills dried out flooded land below sea level, doubling the size of the country.

In addition to grinding grain, windmills in the 1700s were used to grind cocoa, gunpowder, and mustard. Hulling mills removed the outer layer of rice and barley kernels. Oil mills pressed oil from seeds. Glue mills processed cowhides and animal bones. Fulling mills pounded wool into felt. Paint mills ground pigments for paint as well as herbs and chemicals for medicines and poisons.

Windmills were used for other work too. Miners used windmills to blow fresh air into deep mine shafts. Windmills provided power to run sawmills and paper mills. Sawmills cut logs and paper mills made paper.

POSTMILL

SMOCKMILL

TOWER WINDMILL

DRAINAGE WINDMILL

Windmills in America

As Europeans came to America in the mid-1600s, they brought with them their windmill designs. Windmills were a common sight in the colonies. American colonists used windmills to grind corn and wheat as well as to cut wood at sawmills.

By the 1800s, settlers began to explore the West. Much of the land was too dry for farming. A new style of windmill was invented that pumped water.

In 1854, Daniel Halladay, a mechanic from Connecticut, invented the first windmill designed specifically for life in the West. The **Halladay Windmill** sat on a tall wooden tower. It had more than 12 thin wooden blades and turned itself into the wind. This windmill was less powerful than the old European ones. It was built to pump water, not grind grain. It really wasn't a windmill at all, since it did not mill (grind) anything. Everyone called it a windmill anyway.

As the West was settled, railroads were built across the Great Plains. The steam locomotives burned coal for fuel. They needed lots of water to make the steam that ran the engines. Windmills were used to pump water into the locomotives at railroad stations.

Farmers built homemade windmills or purchased them from traveling salesmen. These windmills provided enough water for homes and small vegetable gardens. Ranchers used windmills to pump water for their livestock to drink.

In addition to pumping water, windmills in the American West were used to saw lumber, run cotton gins, hoist grain into silos, grind cattle feed, shell corn, crush ore, and even run printing presses.

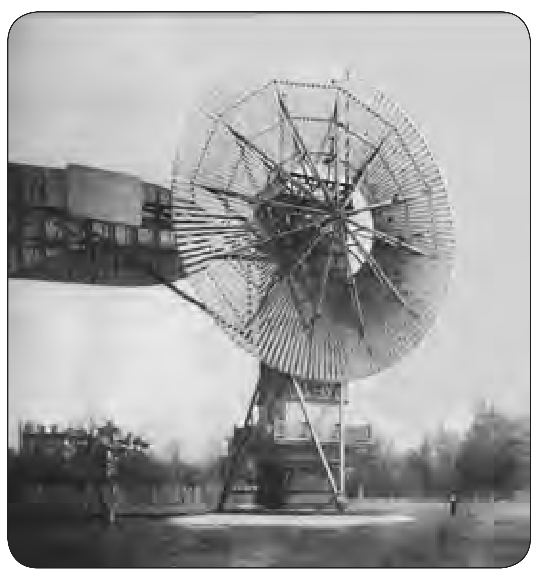
In late 1887, Charles Brush built the country's first wind turbine on his farm in Ohio. The turbine was 60 feet tall and weighed 80,000 tons. With 144 blades, the rotor had a diameter of 17 meters. The shaft inside the tower turned pulleys and belts that ran the dynamo generator he had also built. Brush's turbine generated 12 kW—kilowatts—of electricity, enough to light 350 incandescent lamps, two arc lights, and three electric motors.

While Brush showed that wind energy could be used to generate electricity, the idea did not take hold. In the 1900s, large power plants were built that burned coal and oil. Dams were built across rivers to make electricity from the energy in moving water. Power lines were built across America. People no longer needed individual wind turbines for electricity.

The idea of using wind to make electricity almost disappeared. Then, in the 1970s, when oil prices skyrocketed, people became interested in wind energy as a source for producing electricity once again.

HALLADAY WINDMILL

BRUSH WIND TURBINE



Energy

What is Energy?

Wind is an energy source, but what exactly is energy? Energy makes change; it does things for us. We use energy to move cars along the road and boats over the water. We use energy to bake a cake in the oven and keep ice frozen in the freezer. We need energy to light our homes and keep them a comfortable temperature. Energy helps our bodies grow and allows our minds to think. Scientists define energy as the ability to do work.

Energy is found in six different forms: light, heat, motion, sound, growth, and technology. There are many forms of energy, but they can all be put into two general categories: potential and kinetic.

Potential Energy

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

- **Chemical energy** is energy that is stored in the bonds of atoms and molecules that holds these particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.
- **Nuclear energy** is energy stored in the nucleus of an atom. The energy can be released when the nuclei are combined (fusion) or split apart (fission). In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $E = mc^2$.
- **Stored mechanical energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.
- **Gravitational energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

Kinetic Energy

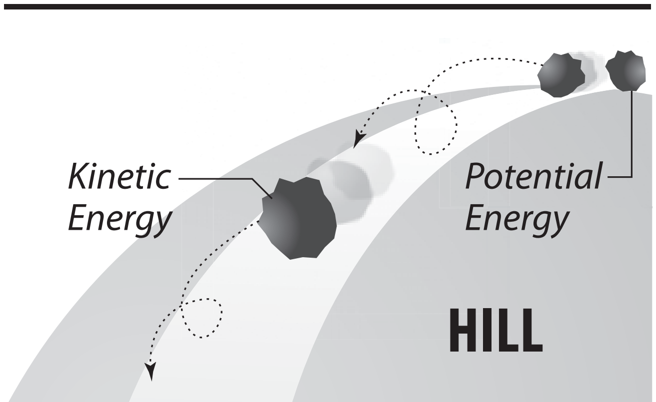
Kinetic energy is motion—the motion of waves, electrons, atoms, molecules, substances, and objects. There are several forms of kinetic energy, including:

- **Radiant energy** is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Solar energy is an example of radiant energy.
- **Thermal energy**, or heat, is the internal energy in substances—the vibration and movement of atoms and molecules within substances. The faster molecules and atoms vibrate and move within substances, 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. Objects and substances move when a force is applied according to Newton's Laws of Motion. 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 and the energy is transferred through the substance in a wave.
- **Electrical energy** is the movement of electrons. Lightning and electricity are examples.

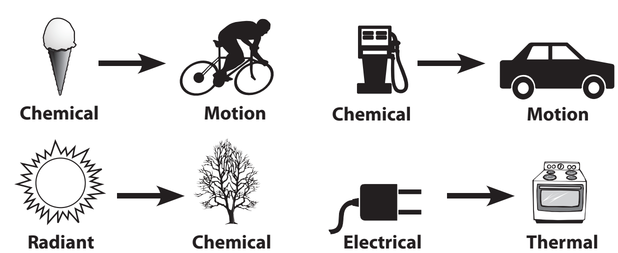
Conservation of Energy

Conservation of energy is not saving energy. The law of conservation of energy says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We simply change it from one form of energy into another. A car engine burns gasoline, converting the chemical energy in gasoline into mechanical energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

POTENTIAL AND KINETIC ENERGY



ENERGY TRANSFORMATIONS



Energy Efficiency

Energy efficiency is the amount of useful energy you get from a system compared to the energy input. A perfect, energy-efficient machine would change all the energy put in it into useful work—an impossible dream. Converting one form of energy into another form always involves a loss of usable energy, often as waste heat.

Most energy transformations are not very efficient. The human body is a good example. Your body is like a machine, and the fuel for your machine is food. Food gives you the energy to move, breathe, and think. Your body is about 5-15 percent efficient at converting food into useful work. The rest of the energy is converted to heat.

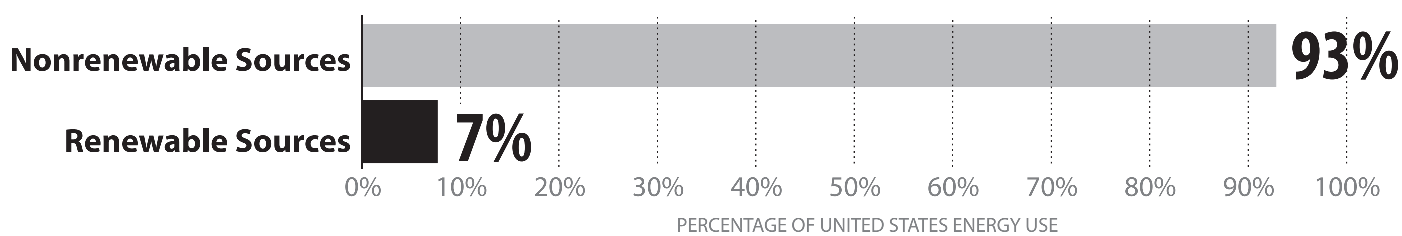
Sources of Energy

We use many different sources to meet our energy needs every day. They are usually classified into two groups—renewable and nonrenewable.

Wind is energy in motion—kinetic energy—and it is a renewable energy source. Along with wind, renewable energy sources include biomass, geothermal energy, hydropower, and solar energy. They are called renewable sources because they are replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. Renewable sources only make up 7 percent of the United States' energy portfolio. We mainly use renewable energy sources to make electricity.

In the United States, 93 percent of our energy comes from nonrenewable sources. Coal, petroleum, natural gas, propane, and uranium are nonrenewable energy sources. They are used to make electricity, heat our homes, move our cars, and manufacture all kinds of products. They are called nonrenewable because their supplies are limited. Petroleum, for example, was formed millions of years ago from the remains of ancient sea plants and animals. We cannot make more crude oil in a short time either.

U.S. CONSUMPTION OF ENERGY BY SOURCE, 2008



Nonrenewable Energy Sources and Percentage of Total Energy Consumption

PETROLEUM 37%
Uses: transportation, manufacturing

COAL 23%
Uses: electricity, manufacturing

NATURAL GAS 24%
Uses: heating, manufacturing, electricity

URANIUM 9%
Uses: electricity

PROPANE 1%
Uses: heating, manufacturing

Renewable Energy Sources and Percentage of Total Energy Consumption

BIOMASS 4%
Uses: heating, electricity, transportation

HYDROPOWER 3%
Uses: electricity

GEOTHERMAL <1%
Uses: heating, electricity

WIND <1%
Uses: electricity

SOLAR <1%
Uses: heating, electricity

Source: Energy Information Administration

Electricity

Electricity is a secondary energy source. We use primary energy sources, including coal, natural gas, petroleum, uranium, solar, wind, biomass, and hydropower, to convert kinetic energy to electrical energy. In the United States, coal generates 48.5 percent of our electricity. In 1989 wind contributed less than one thousandth to the electricity portfolio. Even though wind still represents a small fraction of electricity generation at 1.3 percent, wind generation increased 60.7 percent from 2007 to 2008. At the same time, electricity generation from coal and natural gas each decreased by 1.5 percent.

Most people do not usually think of how electricity is generated. We cannot see electricity like we see the sun. We cannot hold it like we hold coal. We know when it is working, but it is hard to know exactly what it is. Before we can understand electricity, we need to learn about atoms.

Atoms

Everything is made of **atoms**—every star, every tree, every animal, every person. The air and water are too. Atoms are the building blocks of the universe. They are very, very tiny particles. Millions of atoms would fit on the head of a pin.

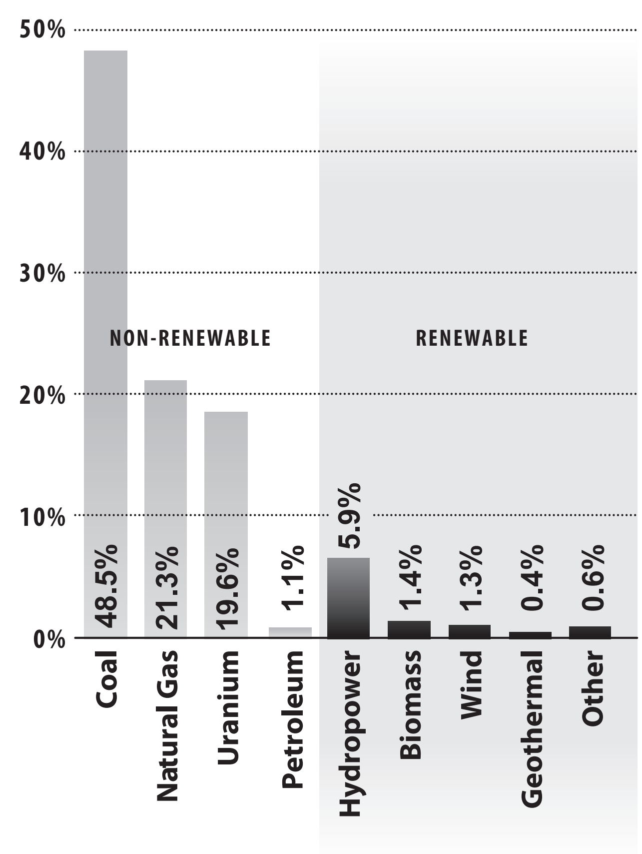
An atom looks like the sun with the planets spinning around it. The center is called the **nucleus**. It is made of tiny **protons** and **neutrons**. **Electrons** move around the nucleus in clouds, or levels, far from the nucleus.

Electrons stay in their levels because a force holds them there. Protons and electrons are attracted to each other. We say protons have a positive charge (+) and the electrons have a negative charge (-). Opposite charges attract each other.

▪ Electricity is Moving Electrons.

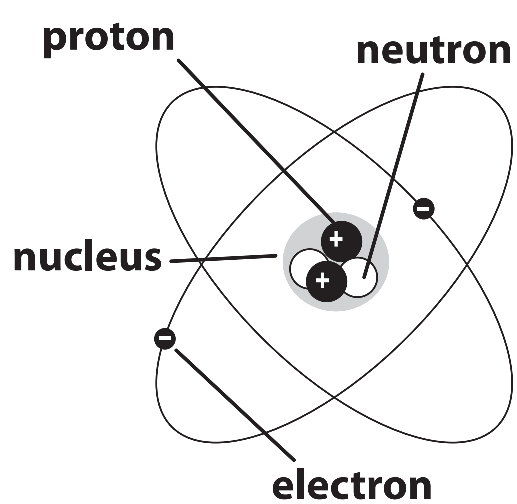
The electrons near the nucleus are held tight to the atom. Sometimes, the ones farthest away are not. We can push some of these electrons out of their levels. We can move them. Moving electrons is called electricity.

PRODUCTION OF U.S. ELECTRICITY BY SOURCE, 2008



Source: Energy Information Administration

PARTS OF AN ATOM



Magnets

In most objects, all the atoms are in balance. Half of the electrons spin in one direction; half spin in the other direction. They are spaced randomly in the object.

Magnets are different. In magnets, the atoms are arranged so that the electrons are not in balance. The electrons do not move from one end to the other to find a balance. This creates a force of energy, called a **magnetic field**, around a magnet. We call one end of the magnet the **north (N) pole** and the other end the **south (S) pole**. The force of the magnetic field flows from the north pole to the south pole.

Have you ever held two magnets close to each other? They do not act like most objects. If you try to push the two north poles together, they **repel** each other. If you try to push the two south poles together, they repel each other.

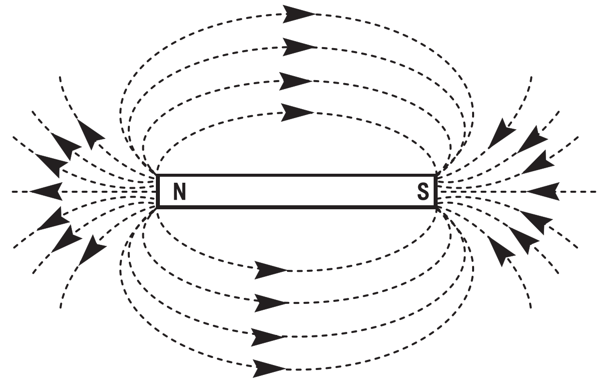
Turn one magnet around and the north and the south poles attract. The magnets stick to each other with a strong force. Just like protons and electrons, opposites attract.

Electromagnetism

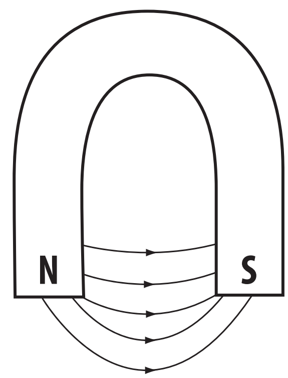
We can use magnets to make electricity. A magnetic field can pull and push electrons to make them move. Some metals, like copper, have electrons that are loosely held. They are easily pushed from their levels.

Magnetism and electricity are related. Magnets can create electricity and electricity can produce magnetic fields. Every time a magnetic field changes, an **electric field** is created. Every time an electric field changes, a magnetic field is created. Magnetism and electricity are always linked together; you cannot have one without the other. This phenomenon is called **electromagnetism**.

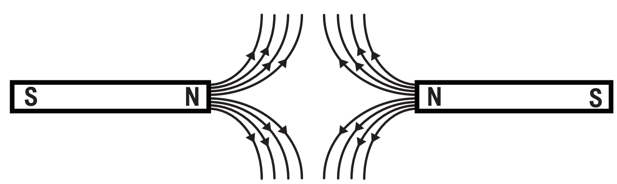
BAR MAGNET



HORSESHOE MAGNET

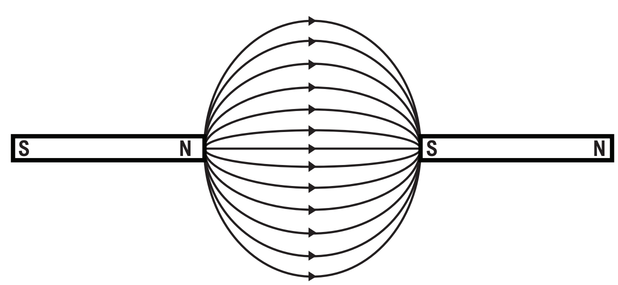


LIKE POLES



Like poles of magnets (N-N or S-S) repel each other.

OPPOSITE POLES



Opposite poles of magnets (N-S) attract each other.

Generators

A **generator** is a device that converts kinetic energy—the energy of motion—into electricity. Power plants use generators with magnets and coils of copper wire to produce electricity.

Inside a generator is a **turbine**. A turbine is a machine that uses a flow of energy to turn blades attached to a **shaft**.

There are also magnets and coils of copper wire inside the generator. The magnets and coils can be designed in two ways—the turbine can spin the magnets inside the coils or it can spin coils inside the magnets. Either way, the electrons in the wire are moved by the magnetic field.

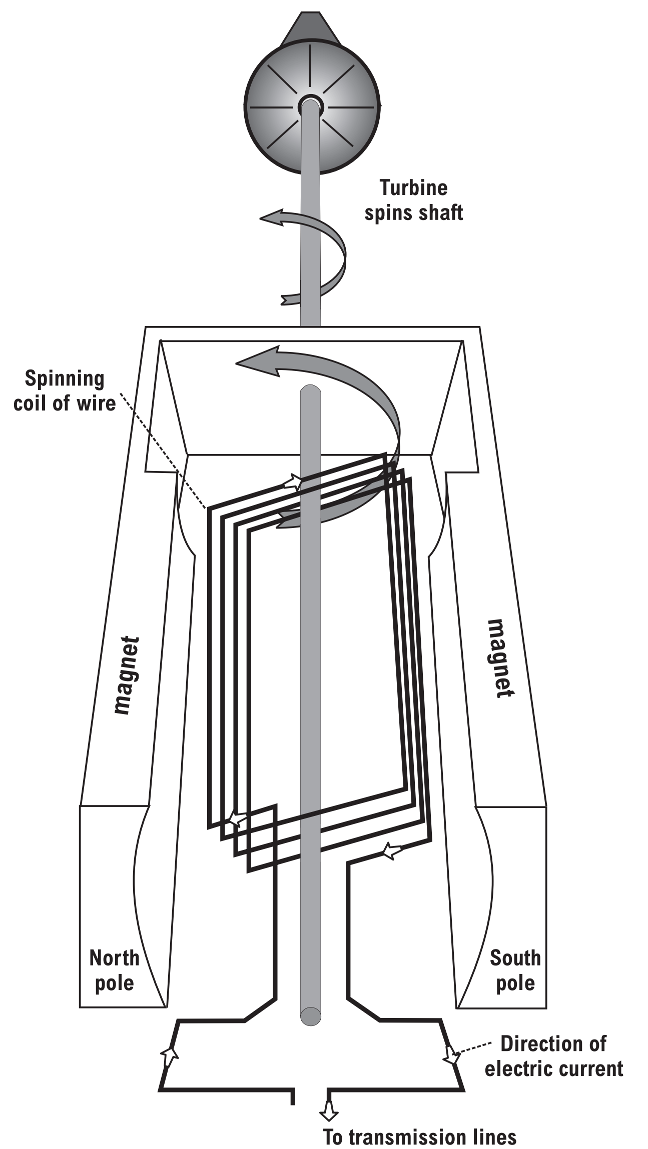
In the picture on the right, coils of copper wire are attached to the turbine shaft. The shaft spins the coils of wire inside two magnets. The magnet on one side has its north pole to the front. The magnet on the other side has its south pole to the front.

The magnetic fields around these magnets push and pull the electrons in the copper wire as the wire spins. The electrons in the coil flow into **transmission lines**.

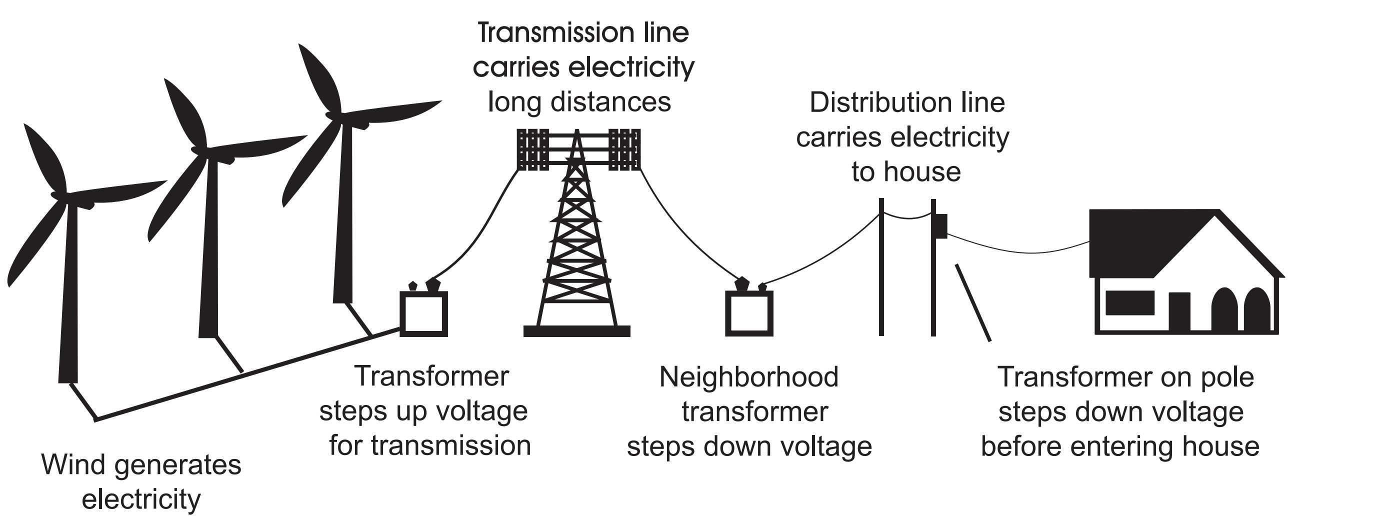
These moving electrons are the electricity that flows to our houses. Electricity moves through the wire very fast. If there was a transmission line that went around the middle of the Earth, electricity could travel around the world seven times.

Power plants use turbine generators to make the electricity we use in our homes and businesses. Power plants use many fuels to spin a turbine. They can burn coal, oil, or natural gas to make steam to spin a turbine. Or, they can split atoms of uranium to heat water into steam to spin a turbine. They can also use the power of rushing water from a dam or the energy in the wind to spin a turbine.

TURBINE GENERATOR



TRANSPORTING WIND ENERGY



Wind and Electricity

Wind Can Produce Electricity

When the wind blows, it pushes against the blades of the wind turbine, making them spin. They power a generator to produce electricity. Most turbines have the same basic parts: blades, shafts, gears, a generator, and a cable. (Some small turbines do not have gear boxes.) These parts work together to convert the wind's energy into electricity.

1. The wind blows and pushes against the blades on top of the tower, making them spin.
2. The turbine blades are connected to a low-speed shaft. When the blades spin, the shaft turns. The shaft is connected to a gear box. The gears in the gear box increase the speed of the spinning motion on a high-speed shaft.
3. The high-speed shaft is connected to a generator. As the shaft turns inside the generator, it produces electricity.
4. The electricity is sent through a cable down the turbine tower to a transmission line.

The amount of electricity a turbine produces depends on its size and the speed of the wind. Wind turbines come in many different sizes. A small turbine may power one home. Large wind turbines can produce enough electricity to power up to 1,000 homes. Large turbines are sometimes grouped together to provide power to the **electricity grid**. The grid is the network of power lines connected together across the entire country.

Wind Farms

Wind power plants, or **wind farms**, are clusters of wind turbines grouped together to produce large amounts of electricity. These wind farms are usually not owned by public utilities like most coal and nuclear power plants are. Private companies own most wind farms and sell the electricity to utility companies.

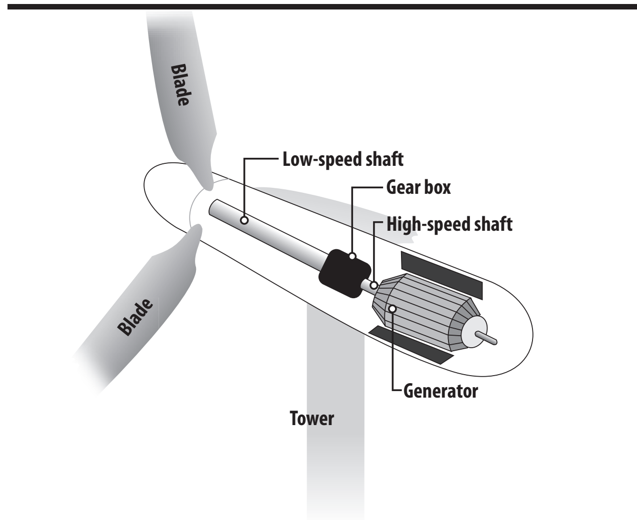
Choosing the location of a wind farm is known as **siting** a wind farm. The wind speed and direction must be studied to determine where to put the turbines. As a rule, wind speed increases with height, and over open areas with no windbreaks, objects that decrease the force of the wind.

Turbines are usually built in rows facing into the prevailing wind. Placing turbines too far apart wastes space. However, if turbines are too close together, they block each other's wind.

The site must have strong, steady winds. Experts measure the winds in an area for one–to–three years before choosing a site. The best sites for wind farms are on hilltops, on the open plains, through mountain passes, and near the coasts of oceans or large lakes. There are other things to think about when siting a wind farm, such as:

- *What is the weather like? Are there tornadoes, hurricanes, or ice storms in the area?* Any of these may damage the wind turbines and other equipment.

WIND TURBINE



WIND FARM

Land around a wind farm can continue to be used for growing crops or grazing for animals.

- *Can workers reach the area? Do new roads need to be built?* It is very expensive to build new roads.
- *Can the site be connected to existing power lines?* It is expensive to build power lines to get electricity to where people live.
- *Will the wind farm impact wildlife in the area?* Wind farms cannot be built near large populations of birds or in areas where there are endangered species.

Offshore Wind Farms

Because cool air from the water is always moving inland to take the place of warm air that has risen, the wind blows stronger and steadier over water than over land. There are no obstacles on the water to block the wind. There is a lot of wind energy available offshore.

Offshore wind farms are built in the shallow waters off the coast of major lakes and oceans. Offshore turbines produce more electricity than turbines on land, but they cost more to build and operate. Some challenges for offshore wind farms include the costs and difficulties involved with water based construction and maintenance of parts.

Europe is currently leading the offshore wind farm industry. Denmark, Belgium, Sweden, Finland, Germany, the United Kingdom, the Netherlands, and Ireland all have offshore wind turbines. France, Italy, Norway, Poland, and Spain are developing projects that are planned to be in place by 2015.

In April 2010, the first offshore wind farm in the United States was approved. The Cape Wind Project on Nantucket Sound (MA) will consist of 130 wind turbines with a capacity to produce 420 megawatts of electricity. With average winds this electricity will provide 75 percent of the electricity needs of Cape Cod, Martha's Vineyard, and Nantucket Island. It is expected that the project will begin generating electricity in 2012.

OFFSHORE WIND FARM, DENMARK

Small Wind Systems

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

Siting a small wind turbine is similar to siting a large wind turbine. Potential small wind users need to make sure that there is plenty of unobstructed wind. The tip of the turbine blades need to be at least 20 feet higher than the tallest wind obstacle. Sometimes this can be a little challenging 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 250–500 foot radius. Specific siting recommendations can be obtained from the turbine manufacturer.

SMALL WIND SYSTEM

A Valuable Resource

Today, people use wind energy to make electricity. Wind is a renewable energy source because the wind will blow as long as the sun shines. Wind is a clean source of energy that causes no air or water pollution and wind is free. The Energy Information Administration forecasts that wind will be generating four percent of the nation's electricity in 2035, but wind has the potential to provide up to 20 percent of U.S. electricity.

One of the problems with wind energy is that it is dependent on the weather. When there is not enough, or too much wind, the turbines do not produce much electricity. In some areas, people are concerned that birds and bats might be injured flying into wind turbines. Some people do not like the sound made by spinning turbines and some think turbines affect their view of the landscape. Wind power is not the total answer to global energy needs, but it is a valuable part of the energy portfolio.

Wind Energy Timeline

3200 B.C.	Early Egyptians use wind to sail boats on the Nile River.
0	The Chinese fly kites during battle to signal their troops.
700s	People living in Sri Lanka use wind to smelt (separate) metal from rock ore. They would dig large crescent-shaped furnaces near the top of steep mountainsides. In summer, monsoon winds blow up the mountain slopes and into a furnace to create a mini-tornado. Charcoal fires inside the furnace could reach 1200°C (2200°F). Archaeologists believe the furnaces enabled Sri Lankans to make iron and steel for weapons and farming tools.
950 A.D.	The first windmills are developed in Persia (present-day Iran). The windmills look like modern day revolving doors, enclosed on two sides to increase the tunnel effect. These windmills grind corn and pump water.
1200s	Europeans begin to build windmills to grind grain.
1200s	The Mongolian armies of Genghis Khan capture Persian windmill builders and take them to China to build irrigation windmills. Persian-style windmills are built in the Middle East. In Egypt, windmills grind sugar cane. Europeans built the first postmills out of wood.
1300s	The Dutch invent the smockmill. The smockmill consists of a wooden tower with six or eight sides. The roof on top rotates to keep the sails in the wind.
1500s	The tower windmill is developed in Spain, Greece, Southern Europe, and France.
1600s	The Dutch began to use drainage windmills to pump water. The windmills dried out flooded land below sea level, doubling the size of the country. European settlers begin building windmills in North America.
1700s	By the early 1700s, both the Netherlands and England have over 10,000 windmills.
	As a boy, Benjamin Franklin experiments with kites. One day, he floats on his back while a kite pulls him more than a mile across a lake.
1854	Daniel Halladay builds and sells the Halladay Windmill, which is the first windmill designed specifically for the West. It has thin wooden blades and turns itself into the wind.
1888	Charles F. Brush, a wealthy inventor and manufacturer of electrical equipment in Cleveland, OH, builds a giant windmill on his property. The windmill generates power for 350 incandescent lights in his mansion. In the basement, a battery room stores 408 battery cells (glass jars) filled with chemicals that store the electricity generated by the windmill. In later years, General Electric acquires Brush's company, Brush Electric Co.
Late 1880s	The development of steel blades makes windmills more efficient. Six million windmills spring up across America as settlers move west. These windmills pump water to irrigate crops and provide water for steam locomotives.
1892	Danish inventor Poul LaCour invents a Dutch-style windmill with large wooden sails that generates electricity. He discovers that fast-turning rotors with few blades generate more electricity than slow-turning rotors with many blades. By 1908, Denmark has 72 windmills providing low-cost electricity to farms and villages.
1898-1933	The U.S. Weather Service sends kites aloft to record temperature, humidity, and wind speed.
1900s	Wilbur and Orville Wright design and fly giant box kites. These experiments lead them to invent the first successful airplane in 1903.
1920s	G.J.M. Darrieus, a French inventor, designs the first vertical axis wind turbine.
1934-1943	In 1934, engineer Palmer Putman puts together a team of experts in electricity, aerodynamics, engineering, and weather to find a cheaper way to generate electrical power on a large scale. In 1941, the first large-scale turbine in the United States begins operating. In 1941, the Smith-Putnam wind turbine is installed on Grandpa's Knob, a hilltop in Rutland, VT. The turbine weighs 250 tons. Its blades measure 175 feet in diameter. It supplies power to the local community for eighteen months until a bearing fails and the machine is shut down in 1943.
1945-1950s	After World War II ends in 1945, engineers decide to start the Smith-Putnam turbine up again, even though it has formed cracks on the blades. Three weeks later, one of the blades breaks off and crashes to the ground. Without money to continue his wind experiments, Putman abandons the turbine. By the 1950s, most American windmill companies go out of business.
1971	The first offshore wind farm operates off Denmark's coast.

1973	The Organization of Petroleum Exporting Countries (OPEC) oil embargo causes the prices of oil to rise sharply. High oil prices increase interest in other energy sources, such as wind energy.
1974	In response to the oil crisis, the National Aeronautics and Space Administration (NASA) develops a two-bladed wind turbine at the Lewis Research Center in Cleveland, OH. Unfortunately, the design does not include a "teetering hub"—a feature very important for a two-bladed turbine to function properly.
1978	The Public Utility Regulatory Policies Act (PURPA) requires utility companies to buy a percentage of their electricity from non-utility power producers. PURPA is an effective way of encouraging the use of renewable energy.
1980	The Crude Oil Windfall Profits Tax Act further increases tax credits for businesses using renewable energy. The Federal tax credit for wind energy reaches 25 percent and rewards businesses choosing to use renewable energy.
1980s	The first wind farms are built in California, as well as Denmark, Germany and other European countries. Many wind turbines are installed in California in the early 1980s to help meet growing electricity needs and take advantage of incentives.
1983	Because of a need for more electricity, California utilities contract with facilities that qualified under PURPA to generate electricity independently. The price set in these contracts is based on the costs saved by not building planned coal plants.
1984	A large vertical axis turbine, Project École, is built in Quebec, Canada. It is 110 meters high (360 ft.).
1985	By 1985, California wind capacity exceeds 1,000 megawatts, enough power to supply 250,000 homes. These wind turbines are very inefficient.
1988	Many of the hastily installed turbines of the early 1980s are removed and later replaced with more reliable models.
1989	Throughout the 1980s, Department of Energy funding for wind power research and development declines, reaching its lowest point in fiscal year 1989. More than 2,200 megawatts of wind energy capacity are installed in California—more than half of the world's capacity at the time.
1992	The Energy Policy Act reforms the Public Utility Holding Company Act and many other laws dealing with the electric utility industry. It also authorizes a production tax credit of 1.5 cents per kilowatt-hour for wind-generated electricity. U.S. Windpower develops one of the first commercially available variable-speed wind turbines, over a period of 5 years. The final prototype tests are completed in 1992. The $20 million project is funded mostly by U.S. Windpower, but also involves Electric Power Research Institute (EPRI), Pacific Gas & Electric, and Niagara Mohawk Power Company.
1994	Cowley Ridge in Alberta, Canada becomes the first utility-grade wind farm in Canada.
1999-2000	Capacity of wind-powered electricity generating equipment installed exceeds 2,500 megawatts. Contracts for new wind farms continue to be signed.
2003	North Hoyle, the largest offshore wind farm in the United Kingdom, is built.
2005	The Energy Policy Act of 2005 strengthens incentives for wind and other renewable energy sources.
	The Jersey-Atlantic wind farm off the coast of Atlantic City, NJ, begins operating in December. It is the United States' first coastal wind farm.
2006	The second phase of Horse Hollow Wind Energy Center is completed, making it the largest wind farm in the world. It has a 735.5 megawatt capacity and is located across 47,000 acres of land in Taylor and Nolan Counties is in Texas.
2008	The U.S. Department of Energy releases the *20% Wind Energy by 2030* report detailing the challenges and steps to having 20 percent of U.S. electricity produced by wind by the year 2030. The Emergency Economic Stabilization Act of 2008 provides a 30 percent tax credit (up to $4,000) to individuals installing small wind systems. The tax credit will be available through December 16, 2016
2009	The Bureau of Ocean Energy Management, Regulation, and Enforcement is given responsibility to establish a program to grant leases, easements, and rights-of-way for the development of offshore wind farms on the Outer Continental Shelf.
2010	Cape Wind on Nantucket Sound, MA is approved to become the nation's first offshore wind farm.

Science Notebook

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