Harnessing the Wind's Energy

Evolution of the Windmill

Before we understood electricity, people were capturing the wind to do work. A mill is a machine used to shape materials or perform other mechanical operations. For many years, wind was the power source for mills of all kinds. The earliest European windmills, built in the 1200s, were called postmills. Their purpose was to grind grain between millstones. This is how windmills got their name. Millwrights built postmills out of wood. The entire windmill could be rotated when the wind changed directions. It was the miller's job to rotate the postmill.

In the 1300s, smockmills were invented. The sails are attached to the cap (the top of the windmill) and that is the only part that rotates. The miller still had to physically rotate the cap into the wind when it 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, lightweight sails, which worked well in the lighter winds of southern Europe. They were used to pump water and grind grain. The Dutch began to use drainage windmills in the 1600s to pump water that flooded the land below sea level. Using windmills to dry out the land, they doubled the size of their country.

Windmills made work easier and faster. 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 saw logs at sawmills and create paper at papermills. Wind power created the first Industrial Revolution in Europe.

American Windmills

As Europeans came to America in the mid-1600s, they brought their windmill designs with them and windmills were a common sight in the colonies. In the 1800s, settlers began to explore the West. While there was plenty of space, they soon discovered that the land was too dry for farming. A new style of windmill, one that pumped water, was invented.

In 1854, a mechanic, Daniel Halladay, designed the first windmill specifically for life in the West. The Halladay Windmill, which is still in use today, sits on a tall wooden tower, has more than a dozen thin wooden blades, and turns itself into the wind. This American-style windmill is less powerful than the old European models, but is built to pump water, not grind grain.

As the West was settled, railroads were built across the Great Plains. Steam locomotives burned coal for fuel. They needed thousands of gallons of water to produce steam to run the engines. Windmills were vital in the railroad industry to provide water at railroad stations. A large windmill could lift water 150 feet. It worked in wind speeds as low as six miles per hour. 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 performed many tasks and made life easier. Windmills were used to saw lumber, run the cotton gin, hoist grain into silos, grind cattle feed, shell corn, crush ore, and even run a printing press.

POSTMILL

SMOCKMILL

TOWER WINDMILL

DRAINAGE WINDMILL

In the 1890s, Poul LaCour, an inventor in Denmark, invented a wind turbine generator with large wooden sails that could generate electricity. At this time, lights and small appliances were available in America, but there were no power lines in the West to transmit electricity. Small-scale windmills became popular in rural areas as people connected their windmills to generators to produce small amounts of electricity. They could power lights, the radio, and charge batteries.

Wind power became less popular as power plants and transmission lines were built across America. By the 1940s, fossil fuels became an inexpensive source of power generation. Using wind power to generate electricity was almost abandoned. After the oil crisis of the 1970s, however, the use of wind power began to increase. Scientists and engineers designed new wind machines that could harness the energy in the wind more efficiently and economically than early models. Today, wind is one of the fastest growing sources of electricity in the world.

Modern Wind Machines

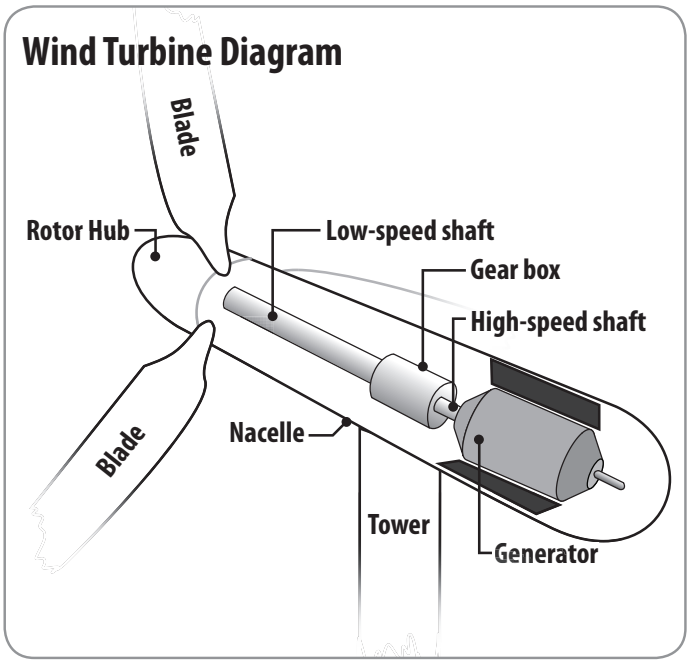
Today, wind is harnessed and converted into electricity using machines called wind turbines. The amount of electricity that a turbine produces depends on its size and speed of the wind. Most large wind turbines have the same basic parts: **blades**, a **tower**, and a **gear box**. These parts work together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

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

Wind turbines are most efficient when they are built in an area where winds blow consistently at a minimum of 5.8 meters per second (m/s) (13 miles per hour). Faster winds generate more electricity. High above ground, winds are stronger and steadier.

There are many different types of wind turbines with different tower and hub heights, as well as varying blade designs and lengths. Wind turbines can be designed to optimize output for specific ranges of wind speed. While one turbine might operate efficiently in winds as low as 2.5 m/s (5.6 mph), another may need winds up to 20 m/s (44.8 mph).

Wind turbines also come in different sizes, based on the amount of electrical power they can generate. Small turbines may produce only enough electricity to power a few appliances in one home. Large turbines are often called utility-scale because they generate enough power for utilities, or electric companies, to sell. Most turbines installed in the U.S. produce one to three megawatts of electricity, enough to power 300 to 900 homes. Large turbines are grouped together into wind farms, which provide bulk power to the electrical grid.



Wind Energy Timeline

5000 B.C.	Early Egyptians use wind to sail boats on the Nile River.
0	The Chinese fly kites during battle to signal their troops.
500-900 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 grain and pump water.
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 would 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.
1200s	Europeans begin to build windmills to grind grain.
	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 price 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	Installed capacity of wind-powered electricity generating equipment 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 at that time, 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 at that time. It has a 735.5 megawatt capacity and is located across 47,000 acres of land in Taylor and Nolan Counties 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 to individuals installing small wind systems. The tax credit will be available through December 31, 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 receives final approval to become the nation's first offshore wind farm.