Science and Sustainable Energy

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CHAPTER THREE

Clean, Inexpensive Wind Power

"Wind power continues to be one of the most promising renewable energy sources. Over the last decade, the wind industry has seen exponential growth, and wind farms are popping up all over the world."

—Brian Merchant, a reporter who specializes in climate and energy issues

Brian Merchant, "In the Future, Will Wind Turbines Be Everywhere?," HowStuffWorks Science. http://science.howstuffworks.com.

Today one of the most widely used and most promising forms of sustainable energy utilizes the power of the winds that blow through Earth's atmosphere each and every day around the globe. Many people are surprised to learn that wind is an indirect form of solar energy. Sunshine beats down on and heats Earth's atmosphere each day, but that heating process is not uniform. Factors such as the planet's irregular surface features, Earth's constant spinning on its axis, and widespread air pressure differences result in uneven solar heating of the atmosphere. These differences in temperature from one sector of the atmosphere to another set the winds in motion.

Science has revealed that the winds contain huge quantities of kinetic energy. When properly harnessed, that energy can, in theory, provide human civilization with large amounts of clean, relatively inexpensive electricity. Thanks to ongoing scientific advances, today that theory is increasingly becoming a practical reality. The United States, Canada, United Kingdom, Germany,

China, and numerous other nations are progressively pouring money into using wind energy to generate electricity.

The statistics in this regard are telling. In the decade from 2004 to 2014 alone, global wind-powered electrical generation grew from 47 to 369 gigawatts (GW) per day. (1 GW equals 1,000 MW.) At the beginning of 2015, Denmark created 21 percent of its electricity through wind technology, widely acknowledged as an unusually large proportion. That figure was 18 percent in Portugal, 16 percent in Spain, and 14 percent in Ireland. (In the United States, the figure was only 5 percent, but US wind power has been expanding rapidly.) Moreover, in 2017 more than two hundred thousand wind turbines were in operation in more than eighty nations.

The World's First Wind-Powered House

Much of the ongoing revolution in global production of wind-generated power is attributable to the modern scientific understanding of wind and the typical patterns it forms above various regions of the continents. Also important have been steady technological advances in the equipment necessary to harness wind energy. These advances have allowed engineers to construct increasingly large and efficient wind turbines, for example.

Nevertheless, the idea of harnessing the wind to do work is far from new. In the ancient Middle East, for instance, people widely employed simple windmills in food production and other agricultural endeavors. In approximately 1000 CE, during the medieval era, those mechanical means of exploiting wind power spread into several European regions and kingdoms. The Netherlands was particularly receptive to these ideas and built thousands of windmills, many of which operated pumps. These allowed the locals to increase their arable (farmable) land by draining lakes and marshes.

During the 1800s science began to transform wind power into a source for creating electricity to power the swiftly expanding modern civilization. In 1887 Scottish researcher James Blyth built the first windmill that produced electricity. Standing 33 feet (10 m) high, the device featured cloth-covered wooden blades that

Wind turbines in Denmark (shown) were creating 21 percent of that country's electricity at the beginning of 2015, the highest percentage of any country. By 2017 more than two hundred thousand wind turbines were operating around the world.

harnessed the power of the wind. As they spun, they powered a primitive generator, which provided the electricity for the lamps in Blyth's modest cottage. That dwelling was the world's first house with wind-generated electrical power.

How Wind Turbines Work

This impressive feat was not lost on other scientists who saw the potential of wind power. Over time, various inventors and researchers introduced increasingly more advanced and efficient windmills, which came to be called wind turbines. Scientists also studied wind patterns in various locations in North

America and other continents. They found that certain areas—particularly open, fairly flat plains and the entrances to certain mountain passes—were noticeably windier than others. When possible, the experts decided, turbines should be erected on those sites to take advantage of their extraordinarily plentiful winds.

WORDS IN CONTEXT

rotor

In a wind turbine, the blade assembly, usually consisting of two or three blades.

Wherever they are built, and no matter how large or complex they are, all modern wind turbines operate under the same basic principles. These devices feature propeller-like blades that move when they capture swathes of wind. Mounted on a tall and sturdy vertical shaft, the blades—which most often number two or three—are together called a rotor. A National Renewable Energy Laboratory (NREL) researcher explains the scientific concepts involved in a turbine's operation:

> A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called *lift*. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called *drag*. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity.[19]

Wind turbines can be used singly to power a specific house or other structure; farmers and ranchers in remote, windy areas sometimes install such devices to help reduce their electric bills or to pump water from wells. More and more often today wind turbines are employed in groups to produce larger amounts of energy to power grids that supply electricity to entire neighborhoods or towns.

Proper Siting

When multiple turbines are erected in clusters to power a grid, such a cluster has come to be called a wind farm (or wind power plant). At first glance it might seem that building a wind farm is a fairly straightforward proposition. That is, it seems that all a utility or other energy company has to do is acquire the necessary land and begin installing the turbines.

However, initiating such a project is far more complicated than that, according to the American Wind Energy Association (AWEA), the national trade organization for the US wind industry. The AWEA has collected extensive data about wind farms, including how they are funded and built. The ultimate success of such a farm, the AWEA explains, relies in large degree on choice of the proper site.

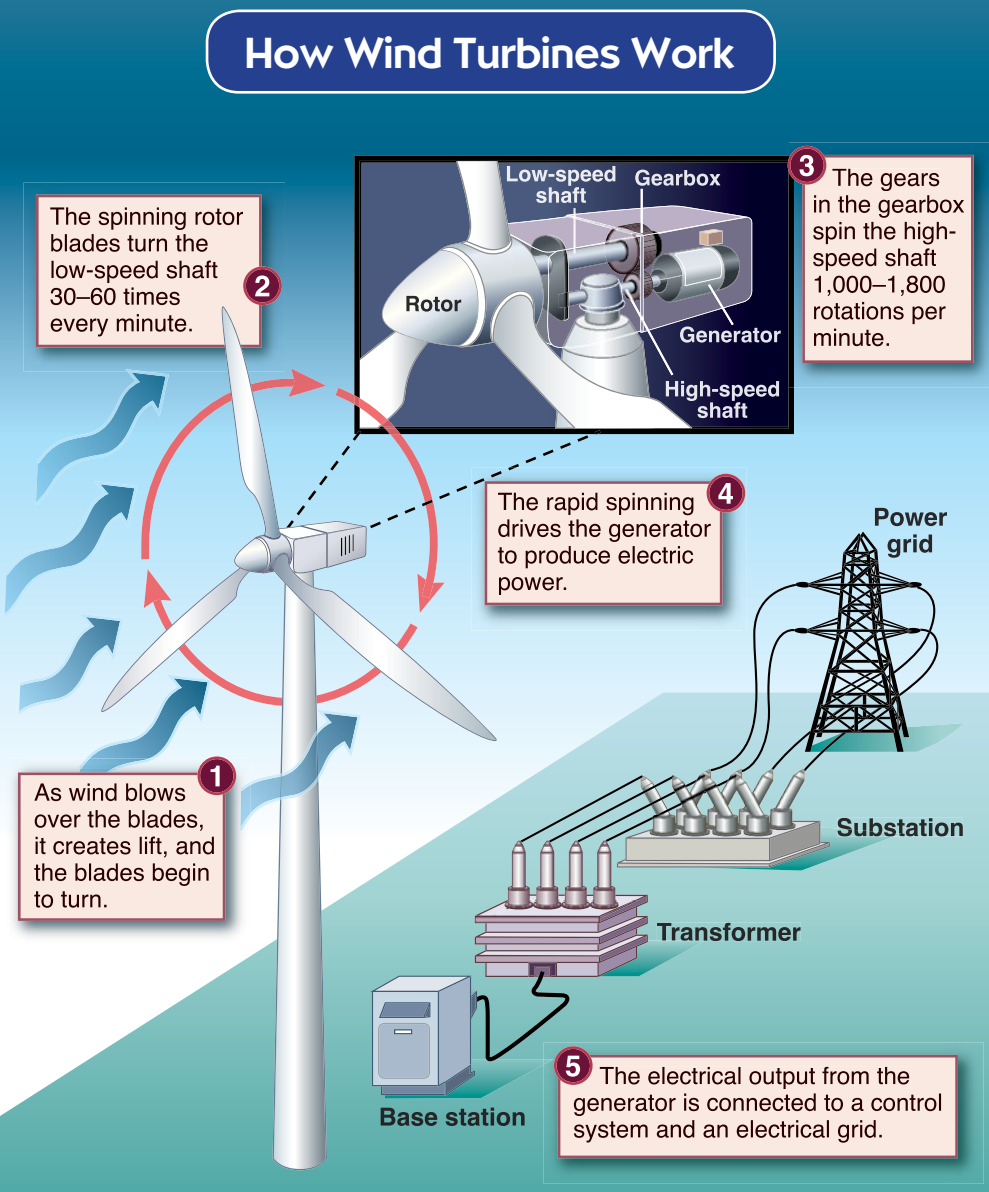
This process, called siting, begins with one or more individuals forming a company that will own and operate the wind farm. The company then must secure investors to fund the project, which can cost in the tens or even hundreds of millions of dollars or more. The company must also find a spot where there is enough wind to keep the turbines running. Plus, that land must be close enough to a major power grid to make daily electrical transmission from the farm to the grid practical. Next, the land must be purchased and any necessary government permits must be acquired. These and other issues need to be addressed, the AWEA says, "to move a wind project from development, through construction, and into operation. Failure to successfully navigate any one of these issues can result in a shelved project. On average, only one in ten projects originally conceived by a developer will actually get constructed and put into operation."[20]

WORDS IN CONTEXT

siting

The process of finding a site on which to build a wind farm.

A revealing example of this daunting process in action was the construction of the largest wind farm in the United States—the Alta Wind Energy Center (AWEA). It is located near Tehachapi Pass, about 75 miles (121 km) north of Los Angeles, California.



Source: US Department of Energy, "The Inside of a Wind Turbine." www.energy.gov.

According to the AWEA, it took the company that launched the project close to a decade to raise the $1.2 billion in funding, secure the land, and get the necessary government permits.

The company also found a utility—Southern California Edison—willing to buy and distribute the electricity the wind farm would eventually generate. Construction on the first of ten groups

CHOOSING WHERE TO BUILD WIND FARMS

Among the leading criteria that energy engineers and scientists look for when siting a wind farm's turbines are wind frequency and wind speeds in a potential site. The US Energy Information Administration here provides some details, including the physical setting of the Alta Wind Energy Center near California's Tehachapi Pass.

> Wind power plant owners must carefully plan where to position wind turbines and must consider how fast and how often the wind blows at the site. Wind speed typically increases with altitude and increases over open areas without windbreaks. Good sites for wind turbines include the tops of smooth, rounded hills; open plains and water; and mountain gaps that funnel and intensify wind. Wind speeds vary throughout the United States. Wind speeds also vary throughout the day and from season to season. In Tehachapi, California, the wind blows more frequently from April through October than it does in the winter. This fluctuation is a result of the extreme heat of the Mojave Desert during the summer months. As the hot air over the desert rises, the cooler, denser air above the Pacific Ocean rushes through the Tehachapi mountain pass to take its place. In a high altitude Great Plains state like Montana, strong winter winds channeled through the Rocky Mountain valleys create more intense winds during the winter.

US Energy Information Administration, "Renewable Wind." www.eia.gov.

of turbines began in 2010. Each group started producing electricity as soon as it was completed. When the last group is finished in 2019, the farm as a whole will create more than 1,500 MW (1.5 GW) of electricity per day, enough to power hundreds of thousands of homes.

Increasingly Large Arrays

The Alta Wind Energy Center is in several ways the natural offspring of earlier outsized arrays of wind turbines built in the United States. In fact, US energy companies and the scientists they hired pioneered the world's first large-scale wind farms. The original prototype was the Crotched Mountain Wind Farm in southern

New Hampshire. When it was built in 1980, wind power was still viewed by most Americans as a fringe idea; few thought it could realistically compete with coal and oil.

Not widely known at the time was that some scientists had long been working on the technology needed for wind farms. During the late 1970s they finally found a company willing to give that idea a try—US Windpower, formed by a group of recent graduates of the University of Massachusetts. The farm's twenty turbines, each of which generated only .3 MW of electricity, were quickly installed on the mountain. The onsite manager, Regina Wdowiak, proudly announced, "I definitely think this is the wave of the future. We are really caught in the infancy of this industry. No more is wind the funky energy that hippies are putting up."[21]

Although the Crotched Mountain farm went out of business a few years later, it had shown that using multiple wind turbines to help power a grid was both practical and promising. This encouraged others to take a chance, and several more wind-power companies formed between 1980 and 1984. One of these outfits, Fayette Manufacturing Corporation, constructed a huge wind farm in Altamont Pass in northern California. It opened in 1985 at partial capacity (because at that point only some of the turbines had been installed). When completed a while later, it featured 4,930 turbines, at the time making it the world's largest wind farm. Indeed, at that moment fully half of the world's wind energy was generated in Altamont Pass.

As arrays of turbines rapidly grew larger, many other huge wind farms, some of them in other countries, were soon constructed. Some, like the Alta and Altamont farms, were onshore, or erected on land. One of the biggest of the new onshore facilities is the Whitelee Wind Farm located about 9 miles (15 km) from Scotland's largest city, Glasgow. It began operation in 2008 and is now the United Kingdom's biggest wind farm, with 215 turbines that together create 539 MW of electricity daily.

Huge Offshore Facilities

During the same period in which the onshore Whitelee farm's turbines were installed, many of the other new wind farms were

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US Office of Energy Efficiency and Renewable Energy, "Fuel Cells" (https://energy.gov/eere/fuelcells/fuel-cells). Here, a branch of the US Department of Energy presents a clear picture of what fuel cells are and how they work, along with plenty of links to articles on hydrogen production, hydrogen storage, the uses of hydrogen in manufacturing, and more.

US Office of Energy Efficiency and Renewable Energy, "How Do Wind Turbines Work?" (https://energy.gov/eere/wind/how-do-wind-turbines-work). This site provides helpful diagrams showing how wind turbines work as well as numerous links to articles on the history of turbines, research and development, wind farms, and much more.