U.S. Department of Energy - Energy Efficiency and Renewable Energy
Wind and Hydropower Technologies Program

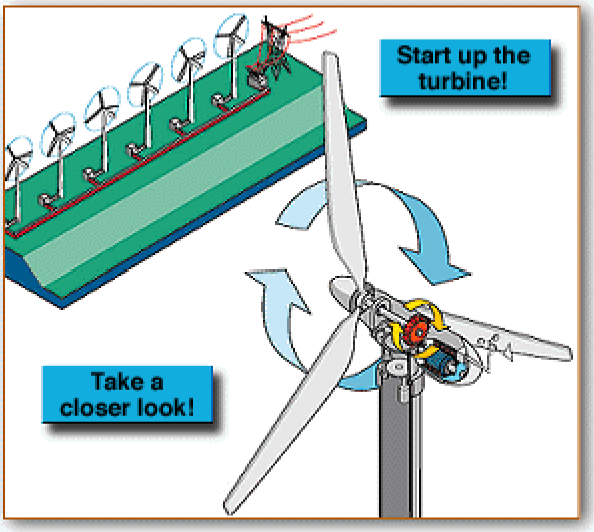
How Wind Turbines Work

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetation. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity.

The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

So how do wind turbines make electricity? Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Take a look inside a wind turbine to see the various parts. View the wind turbine animation to see how a wind turbine works.

This aerial view of a wind power plant shows how a group of wind turbines can make electricity for the utility grid. The electricity is sent through transmission and distribution lines to homes, businesses, schools, and so on.



Learn more about wind energy technology:

- Types of Wind Turbines
- Sizes of Wind Turbines
- Inside the Wind Turbine

Types of Wind Turbines

Modern wind turbines fall into two basic groups: the horizontal-axis variety, as shown in the photo, and the vertical-axis design, like the eggbeater-style Darrieus model, named after its French inventor.

Horizontal-axis wind turbines typically either have two or three blades. These threebladed wind turbines are operated "upwind," with the blades facing into the wind.

Many wind farms have sprung up in the Midwest in recent years, generating power for utilities. Farmers benefit by receiving land lease payments from wind energy project developers.

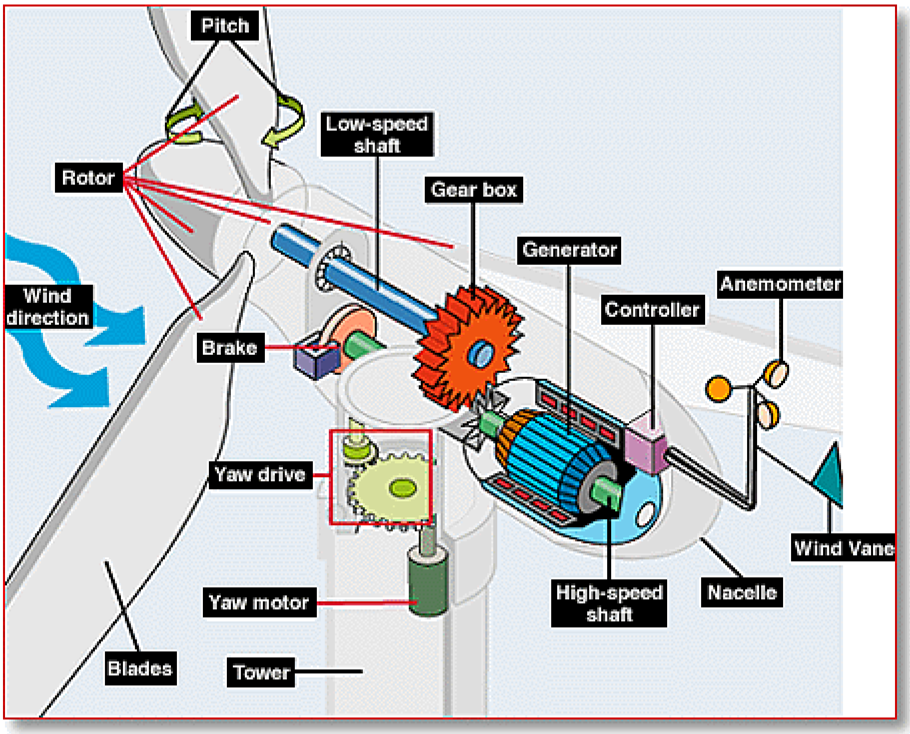
Sizes of Wind Turbines

Utility-scale turbines range in size from 100 kilowatts to as large as several megawatts. Larger turbines are grouped together into wind farms, which provide bulk power to the electrical grid.

GE Wind Energy's 3.6 megawatt wind turbine is one of the largest prototypes ever erected. Larger wind turbines are more efficient and cost effective.

Single small turbines, below 100 kilowatts, are used for homes, telecommunications dishes, or water pumping. Small turbines are sometimes used in connection with diesel generators, batteries, and photovoltaic systems. These systems are called hybrid wind systems and are typically used in remote, off-grid locations, where a connection to the utility grid is not available.

Inside the Wind Turbine



Anemometer:
Measures the wind speed and transmits wind speed data to the controller.

Blades:
Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.

Brake:
A disc brake, which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.

Controller:
The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they might be damaged by the high winds.

Gear box:
Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.

Generator:
Usually an off-the-shelf induction generator that produces 60-cycle AC electricity.

High-speed shaft:
Drives the generator.

Low-speed shaft:
The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle:
The nacelle sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough for a helicopter to land on.

Pitch:
Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor from turning in winds that are too high or too low to produce electricity.

Rotor:
The blades and the hub together are called the rotor.

Tower:
Towers are made from tubular steel (shown here), concrete, or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

Wind direction:
This is an "upwind" turbine, so-called because it operates facing into the wind. Other turbines are designed to run "downwind," facing away from the wind.

Wind vane:
Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

Yaw drive:
Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

Yaw motor:
Powers the yaw drive.