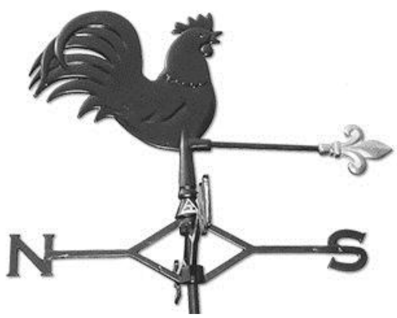
Renewable Energy

Monitoring Wind Direction and Speed

A weather vane, or wind vane, is a device used to monitor the direction of the wind. It is usually a rotating, arrow-shaped instrument mounted on a shaft high in the air. It is designed to point in the direction of the source of the wind. There are also digital instruments that measure wind direction.



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.

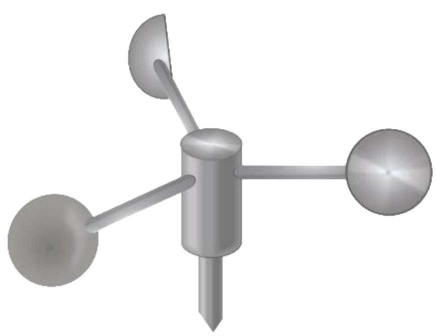
It is important in many cases to know how fast the wind is blowing. Wind speed is important because the amount of electricity that wind turbines can generate is determined in large part by wind speed, or velocity.

A doubling of wind velocity from the low range to optimal range of a turbine can result in eight times the amount of power produced. This is a huge difference and helps wind companies decide where to site wind turbines. Wind power (measured in watts) is determined by air density, the area swept by the turbine blades, and wind velocity, according to the following formula:

Power = ½ pAV^3 (p=air density, A = area, V = velocity)

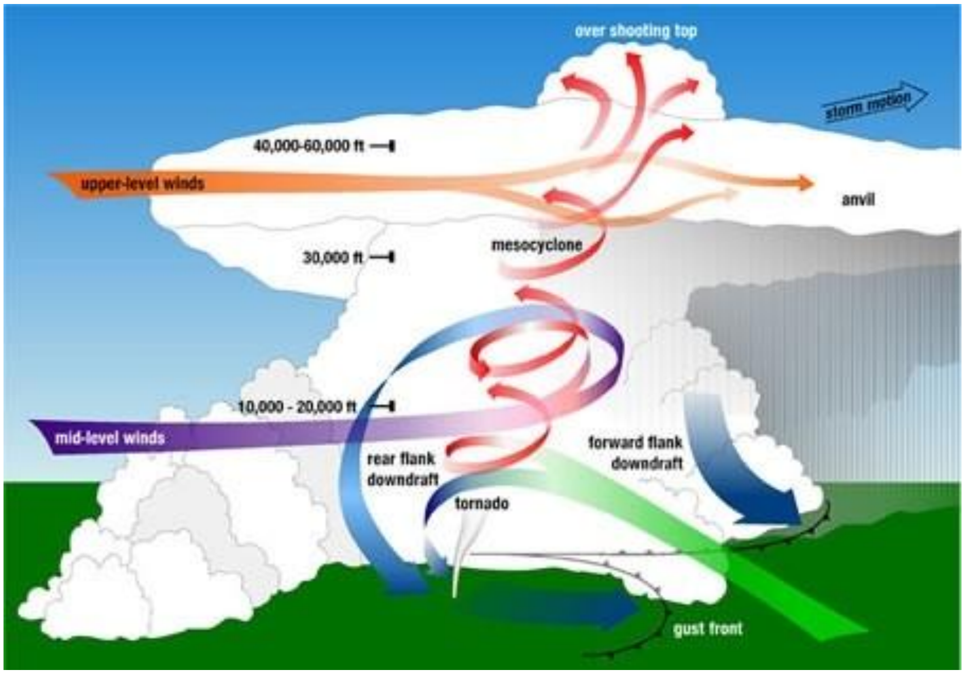
Watts = ½$(kg/m^3) \times (m^2) \times (m/s)^3$

Wind speed can be measured using an instrument called an 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 counts the number of rotations per minute and converts that figure into mph (miles per hour), or m/s (meters per second). A display on a recording device called a data logger shows the speed of the wind. There are also digital anemometers to measure wind speed.

As wind moves across the Earth's surface, it is slowed by friction. Friction is caused when wind runs into and flows around obstacles or meets other air systems. Friction also affects the direction of the wind. Higher in the atmosphere, away from land, the wind meets fewer obstacles, and therefore, less friction is produced. Winds at higher altitudes tend to be smoother and faster.



Wind shear is defined as an abrupt change in wind speed and/or wind direction at different heights in the atmosphere or within a short distance. It can be in a horizontal direction, a vertical direction, or in both directions. Some wind shear is common in atmosphere. Larger values of wind shear exist near fronts, cyclones, and the jet stream. Wind shear in an unstable atmospheric layer can result in turbulence.

Turbulence is defined as a disturbance in the speed and direction of the wind that results in random, disordered movement of air molecules. It occurs when the flow of wind is disturbed, and the direction or speed is changed. Trees, mountains, and buildings can all cause wind turbulence. When wind mixes warm and cold air together in the atmosphere, turbulence is also created. This turbulence is felt as a bumpy ride during an airplane flight.

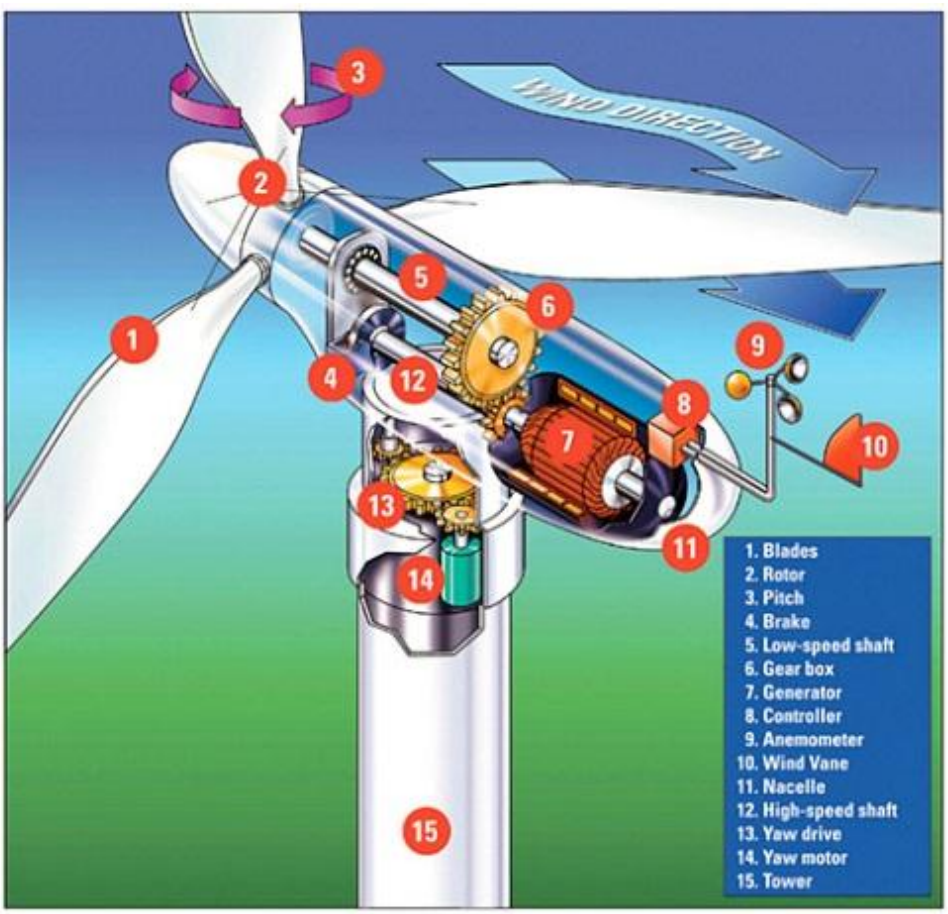
Wind shear and turbulence are concerns to wind turbine engineers because they can affect the operation and output of turbines, and even cause them to fail.

Harnessing the Wind for Electrical Power

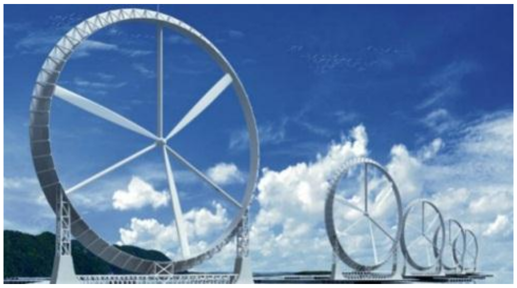
Today, wind is harnessed and converted into electricity using machines called wind turbines. The amount of electricity that a turbine produces depends on its size and speed of the wind. Most large wind turbines have the same basic parts: blades, a tower, a gearbox, and a generator. These parts work together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

Basic steps of how a turbine works:

1. The moving air spins the turbine blades.
2. The blades are connected to a low speed shaft. When the blades spin this internal shaft turns.
3. The low speed shaft is connected to a gearbox. Inside the gearbox, a large slow moving gear turns a small gear quickly.
4. The small gear turns another shaft at higher speeds.
5. The high speed shaft is connected to a generator. As the high speed shaft turns the generator, it produces electricity.
6. The electrical 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 where winds blow consistently at least 5.8 m/s or 13 miles per hour. Some large turbines do not begin to generate electricity until the wind is blowing at least 20 miles per hour. Faster winds generate more electricity and winds high above ground are stronger and steadier, so increasing the height of the turbine is critical to good turbine design. Engineers are working to find light-weight materials which are strong enough to withstand severe wind shear. Using these strong, light-weight materials allows turbine manufacturers to build taller, more efficient blades, and stands.



There are many different types of wind turbines with different blade shapes. 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, another may need winds up to 20 m/s.

Wind turbines also come in different size, based on the amount of electrical power they are designed to generate. Small turbines may produce only enough electricity to power a few appliances in one home. Large turbines are often called utility-scale turbines because they generate enough power for utility companies to power large communities. The largest turbines in the U.S. produce 2.5 to 3.5 Megawatts (MW), enough electricity to power up to 1,750 homes. Large turbines are grouped together into what is known as a wind farm. These wind farms are typically owned and operated by large utility companies.

Which design is best? Engineers and scientists continue to debate which design is most efficient, stronger, and best suited for different scenarios.

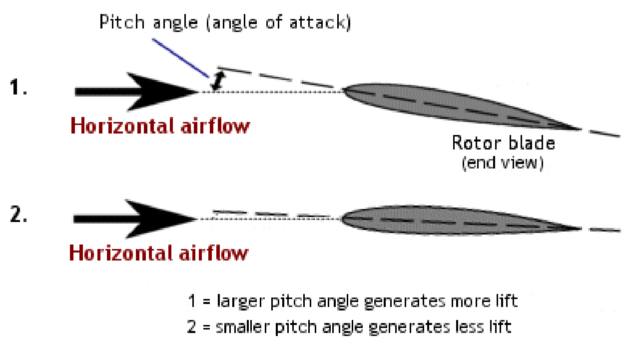
Aerodynamics

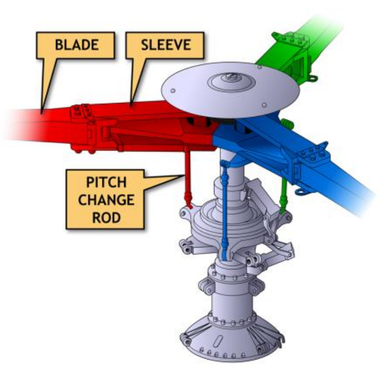
Efficient blades are a key part of generating power from a wind turbine. The blades are turned by the wind and spin the motor drive shaft while, at the same time, they experience drag. This mechanical force slows down the entire system, reducing the amount of power that is generated.

Drag is defined as the force on an object that resists its motion through a fluid (such as air). When the fluid is a gas, the force is called aerodynamic drag, or air resistance. Aerodynamic drag is important when objects move rapidly through the air, such as the spinning blades on a wind turbine. Wind turbine engineers who design rotor blades are concerned with designing blades that decrease aerodynamic drag.

There are many ways to reduce drag on wind turbine blades:

Change the pitch: the angle of the blades dramatically affects the amount of drag. On a helicopter, adjusting the pitch can create more lift. The same technology can be used to reduce drag.





Use fewer blades: each blade compounds the total amount of aerodynamic drag. Scientists and engineers experiment with two, three, and four blade configurations to determine the optimum number of blades for the highest efficiency.

Based on your observations of turbines, what have you found to be the most efficient number of blades?

Use light-weight materials: reduce the mass of the blades by using less material or lighter material. Use smooth surfaces: rough surfaces, especially on the edges, can increase drag. Optimize blade shape: the tip of a blade moves faster than the base; wide, heavy tips increase drag.