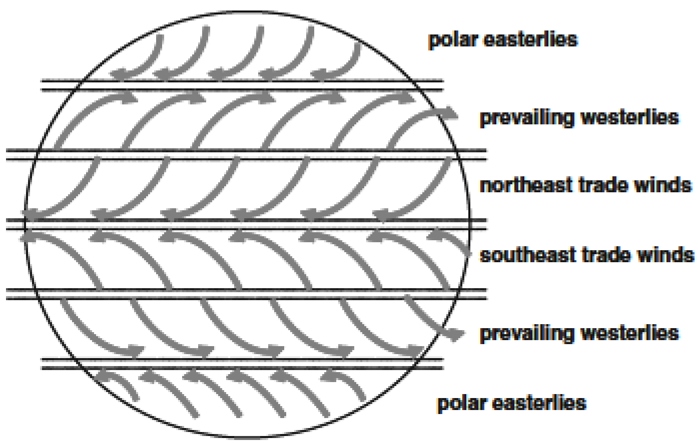
Wind Energy

The wind is a clean, free, and readily available renewable energy source. The terms wind energy or wind power describes 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. Daily, slightly more than 2%, of the total solar power received by the Earth, or 3.46 $x10^{12}$ kW solar power, is converted to wind power. The total solar radiation energy converted into the mechanical energy of the wind is more than $1.1x10^{17}$ MJ per year. This is more than two million times than the total energy that has been used by the human population in 2010. An immediate conclusion that may be drawn from these numbers is that wind power is an important alternative energy source, which, if properly harnessed, is capable to supply a significant fraction of the energy demand of the Earth's population.

Wind Patterns

It may be arguably said that wind power is a byproduct of solar energy. The uneven heating of different parts of the globe causes hot air to rise in regions that receive higher amounts of insolation. The rise of hot air creates a small pressure differential, which induces colder air from the surrounding regions to rush in. Thus, horizontal air currents and the wind patterns on the Earth's surface are created.

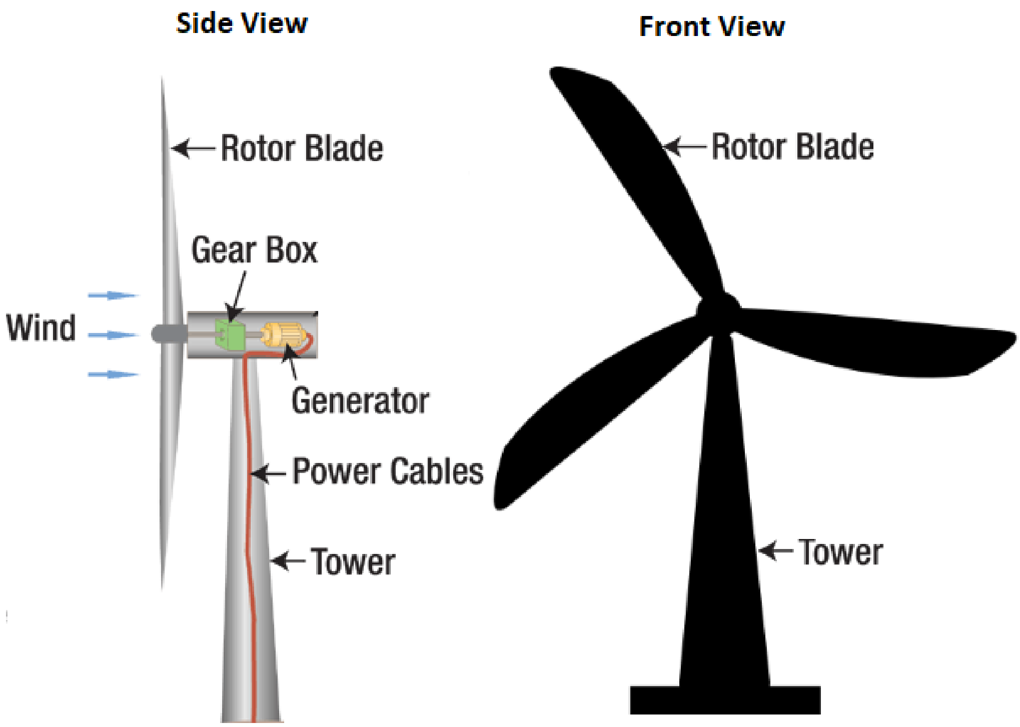


Depending on the origin and effects of these currents, the currents are classified as planetary and local. Planetary winds affect very large regions of the Earth, encompass large masses of air and are primarily caused by the higher amount of solar radiation received by the land masses near the equator. The hotter land masses near the equator cause the air at the tropical regions to rise and move towards the poles. This upward motion of the air masses is affected by the rotational motion of the Earth. The Coriolis force with its components on the horizontal plane is developed on the rising masses of air in both the northern and the southern hemisphere. As a result, the air rushing from the temperate zones to fill the relative vacuum at the equatorial zone develops a motion towards the west. This westerly motion causes the north–east trade winds in the northern hemisphere and the south–east trade winds in the southern hemisphere.

At the same time, the rising warm air moves towards the poles, cools in the upper atmosphere and descends at approximately 30^o latitude in both the northern and the southern hemispheres. The downward motion at these latitudes in combination with the Coriolis force develops a general air motion in the temperate zones from the western to the eastern direction, which manifests itself as the prevailing westerlies, in both the northern and the southern hemispheres between 30 and 60^o latitude. The pattern of the planetary winds is completed with the polar easterlies, which blow in both the south and the north Polar Regions.

Local winds have local effects and are usually caused by the uneven heating of neighboring masses of land or of land and sea. Well known among local winds is the sea breeze, which is caused by the higher temperatures of the land in comparison to a neighboring water surface: as part of the water evaporates, the surface of the water remains cooler than that of the surrounding land. As a result, the air close to the surface of the land rises, a pressure differential—or partial vacuum—is created and cooler air over the water surface rushes to fill this partial vacuum. A lesser known mechanism of air current development is caused by the differential heating on the hills and mountain sides, which causes the air to rise during the day time when solar heating is high and to descend during the early evening hours when the mountain or hill sides cool faster than the neighboring areas. In addition, mountains and hills create their own wind patterns by deflecting masses of air, which is already in motion. Other types of local winds are established according to the type of surface cover, the heating patterns, the climate, and the weather of a region.

Power Generation Systems: Parts of Common Wind Turbines



Two or three-blade wind turbines are now used almost exclusively for the production of electric power. The main parts of the systems that comprise these wind turbines are

1. The tower: Since velocities close to the ground are very low and there must be good clearance between the lower part of the blades and the ground, the wind turbines are placed on top of a tower at a significant height above the ground. The height of the tower depends on the diameter of the blade and is of the order of magnitude of the blade diameter, D, allowing a clearance of D/2, between the ground and the lower part of the blade. Thus, towers are between 30 and 100 m high. The tower is a simple structural element, usually made of reinforced concrete, which is designed to withstand the axial force and resulting moment generated by the wind turbine. It is typically thicker at the lower part and is usually designed as a hollow structure to allow easy access to the top for engine repairs at the turbine hub.

2. The yaw bearings and yaw break: Because the wind turbine must rotate to face the instantaneous direction of the wind, the entire electricity producing system is pivoted on strong bearings that allow the rotation of the system around a vertical axis.

3. The rotor blades: They are the most important part of the generating system, where the wind energy is imparted to the engine. They are very long, typically 30 to 100 m in diameter. The rotor blades are designed aerodynamically and they are made of low weight and strong materials. Low density materials are now typically used for the turbine blades, which are typically hollow. The blades are connected to the hub, which extends to a horizontal metal shaft that becomes the prime mover of the engine. The shaft is supported by a series of bearings.

4. The gear box: In order to minimize the centrifugal stresses, the rotational speed of the blades at operating conditions is fairly low, typically of the order of 100 rpm. A gearbox steps up the rotational speed of the prime mover to reach a range 2000 to 3000 rpm and transmits the power to a secondary high rpm shaft, which is connected to the generator. A small fraction of the blade power is dissipated in the gear box by friction. For this reason, larger wind power engines may require a cooling system for their gearbox.

5. The generator: The generator is used to convert the rotational mechanical energy in to electrical energy.

Environmental Effects

Wind power is one of the most benign and most environmentally friendly forms of electric energy production. It does not involve any chemicals and does not produce any harmful emissions or thermal pollution. The materials that make the towers and the components of the engines are commonly used structural and engineering materials. Hence, the construction and operation of the wind turbines does not impose any environmental threat. There are a few rather minor environmental issues associated with wind power, which are as follow:

1. Noise pollution: A rotating engine always produces noise and wind turbines are no exception, especially the parts that operate at higher rpm's. However, large wind turbines are typically located in remote, rural areas with low population density. This mitigates the effect of the noise to human populations, but may have a significant effect on the wildlife in the nearby areas, which migrate because of the noise. Wind farms even if they are located in remote areas disturb the balance of the local ecosystem. Noise pollution is also the limiting factor for the expansion and more widespread use of small engines in urban or suburban environments.

2. Bird injuries and mortality: Flying birds may be caught by the rotating blades and be killed. This may have a significant effect on migrating species of birds.

3. Aesthetic pollution: The aesthetic pollution has raised significant opposition to the development of wind power, especially in areas with tourist interest.

4. Radio and TV signal interference: Given that many wind turbines are located near the top or the sides of hills and mountains, their operation interferes with the transmission of television and radio signals, especially with television retransmission towers. This effect is mitigated by two trends: a) the location of the vast majority of wind turbines is in remote areas, where very few signals need to be transmitted, and b) the recent trend in communications is to transmit signals via fiber optic wires, at least in the most populated areas. This trend will become the norm in the future for all urban areas.

It is apparent that, while not insignificant, the environmental problems associated with wind power are much less harmful to the environment and the ecosystems than the effects of most other renewable energy sources. The further expansion of wind power and the substitution of conventional power sources by wind would be benevolent to the environment