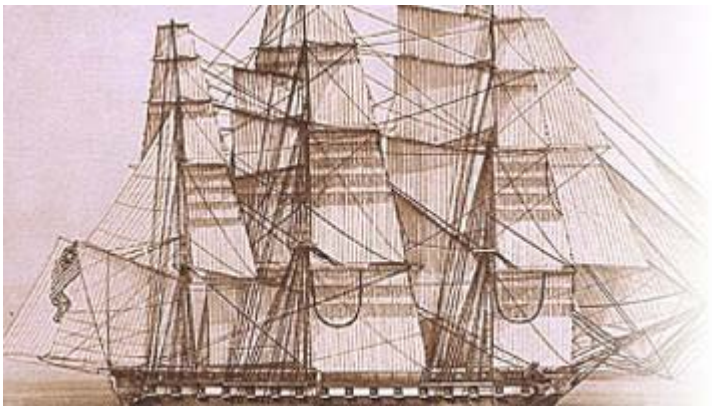
Wind Energy

What is Wind Energy?

People have known how to make use of energy from the wind for centuries. The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy.



When wind fills a boat's sail, the boat is using wind energy to push it through the water.

For many years, farmers have been using wind energy to pump water from wells using windmills.

Windmills have been used countries like Holland for centuries to pump water from low-lying areas.

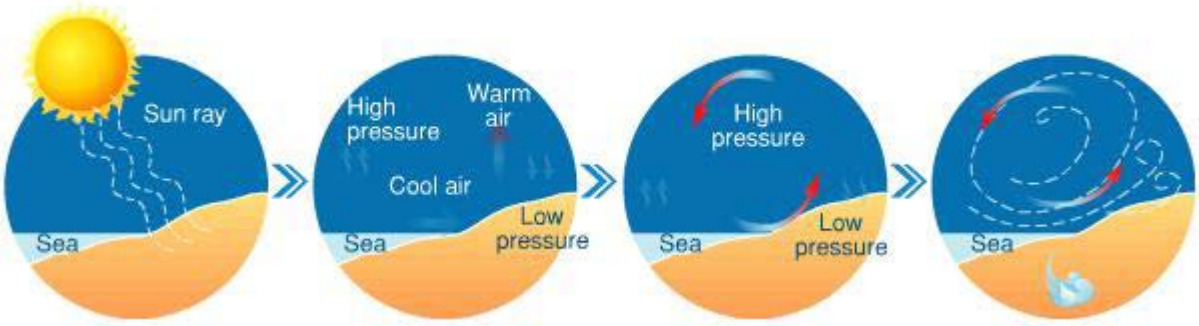
Wind is used to turn grinding stones to grind wheat.

Today, people use wind turbines to generate electricity.

How is Wind Formed?

Theoretically, about 1 to 2% of the sun's radiation turns into wind energy when it arrives at the earth, which is about a hundred times of all the energy consumed on the planet.

The following diagram illustrates how wind is formed:



The sun heats the ground surface of the earth which then heats up the air above it. The degree of solar heating varies at different point at the earth's surface.

Hot air rises, creating low pressure. As hot air rises, it cools, moves horizontally and eventually falls down, creating high pressure at ground level.

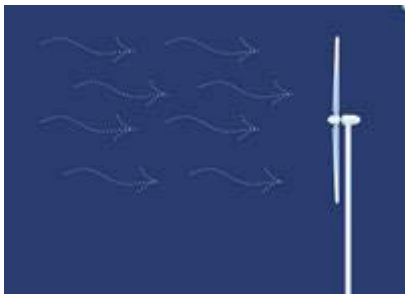
These variations in pressure push the air at ground level to move from high pressure areas to low pressure areas.

The air movement is wind.

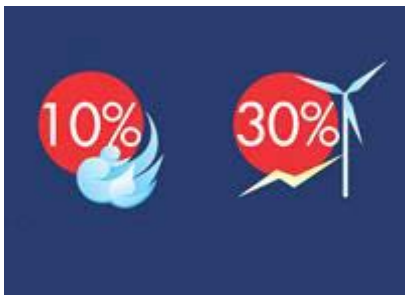
Nature of Wind

Wind is affected by many climatic and geographic factors, and its behaviour is difficult to predict.

- Wind is intermittent in nature.
- Wind occurs both on land and at sea.
- Wind speed is affected by topography.
- Wind speed increases with altitude.



Wind speed is very important to the operation and efficiency of a wind turbine. A minimum wind speed of 3 m/s is normally needed to drive a wind turbine and generate electricity.



Broadly speaking, a 10% increase in wind speed will lead to an approximately 30% increase in power output from a wind turbine.

How to Extract Wind Energy?

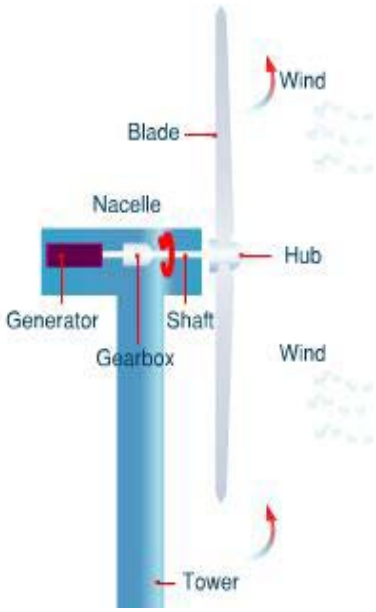
All moving objects contain kinetic energy. The kinetic energy contained in wind, which is air in motion, can be transferred to other objects, such as boat sails, or transformed into electrical energy through wind turbine generators.

Wind turbines:
Once wind drives the turbine, making the rotor rotate faster than the cut-in speed, the generator will produce electricity.
Courtesy: DOE/NREL
Credit: TVIG, Inc.

Wind farms:
Nowadays, onshore and off shore wind farms are growing in popularity as a means of generating electricity.
Photo Courtesy of Shell Wind Energy

How is electricity generated by wind turbine?

Major Component	Function
Nacelle	This contains the key components of the wind turbine, including the gearbox and the electrical generator. Service personnel can enter the nacelle from the wind turbine tower.
Rotor blades	Rotor blades capture the wind and rotate the shaft, transferring power to the rotor hub. The built-in yaw control system senses wind direction using the wind vane and rotates the turbine assembly so that the blades face the wind.
Tower	The tower holds the nacelle and the rotor. It is better to have a high tower since wind speed increases with altitude.
Hub	The hub of the rotor is attached to the shaft of the wind turbine.
Shaft	The shaft connects the rotor hub to the gearbox. The shaft rotates and drives the electrical generator.



How does it work?

- Wind blowing over the angled blades creates pressure differences across the blade sections, resulting in a turning force.
- The turning force on the rotor will turn the shaft, gearbox and generator, which are all connected.
- The gearbox increases the rotational speed, enabling the generator to produce electricity.
- The yaw control enables the wind turbine to capture the maximum wind energy by turning the rotor and nacelle to face the wind.

Horizontal and Vertical Axis Wind Turbines

Horizontal axis wind turbine (HAWT)

- HAWT needs a yaw control system to keep its rotor facing the wind.
- HAWTs are more common than vertical axis wind turbines since they have better performance coefficient.

Horizontal axis wind turbine (HAWT)
Courtesy: DOE/NREL
Credit: Milligan, Michael

Vertical axis wind turbine (VAWT)

- VAWTs can accept wind from any direction. They are usually small in scale. The small tower and ground-mounted generators on VAWTs make them easier to maintain.
- VAWTs are not as efficient as HAWTs because they require a motor for start up and have a lower performance coefficient based on present technology.

Vertical axis wind turbine (VAWT)
Courtesy: DOE/NREL
Credit: Thresher, Bob

Wind Farms

Wind farms can be built onshore or offshore.

Onshore wind farms

Onshore wind farms continue to make up the majority of wind farms around the world.

- ### Advantages

  Lower construction costs compared with offshore wind farms, easy access for maintenance, relatively convenient to connect to power grids.

- ### Constraints

  Height restrictions for hilltop wind turbines, unsteady wind conditions, concerns over noise and visual impact on the environment.

Wattle Point Wind Farm, next to the coast of Edithburgh in South Australia, commissioned in 2005 with an installed capacity of 91 MW.

Offshore wind farms

Offshore wind farms are typically constructed in regions with high population densities and scarcity of suitable sites.

An offshore wind farm located at Rodsand of Denmark, with 72 wind turbines, total installed capacity of 165.6 MW.
Source: Nysted Offshore Wind Farm

- ### Advantages

  Steadier and stronger supply of wind than onshore wind farms, less visual impact, less likely to be affected by height restrictions than hilltop wind turbines.

- ### Constraints

  Higher construction costs, subject to water depth restrictions (Most existing off-shore installations are in waters shallower than 20 metres. Special consideration is needed for installation at 30-metre water depth and above), less convenient access for maintenance.

Site Selection

A wind turbine or wind farm can share the land it occupies with other ground-level activities such as farming. However, building structures or even tall trees obstruct wind flow, affecting the effectiveness of the wind turbine.

In general, wind farm developers usually favour sites with the following characteristics:

- Strong and consistent wind.
- Open land without obstacles to block wind flow. Distance between two wind turbines has to be at least five to seven times the rotor diameter.
- Proximity to a suitable transmission network.
- Suitable geology for transportation and turbine foundations.
- Minimum impact on the environment.

Installed Wind Power Capacity Worldwide

The US, Germany and Spain currently lead the world in terms of total installed wind power capacity.

Rank	Country	Installed Capacity (MW)	% of National Electricity Demand
1	USA	25,369	1.9
2	Germany	23,902	6.5
3	Spain	16,740	11.7

Information as at end of 2008

USA
Brazos Wind Farm, Texas,
with installed capacity: 160 MW.

Germany
Windpark Butendiek, Hamburg,
with installed capacity: 240 MW.

Spain
El Marquesado Wind Farm, Granada,
with installed capacity: 198 MW.

Source: IEA Wind Energy Annual Report 2008

Case Study

China

With its substantial wind potential, China's wind power industry has boomed in recent years to make China a new global leader in terms of total installed capacity. At the end of 2008, China ranked 4th in the world with a total installed capacity of 12,210 MW.

In 2008, HK electric partnered with Huaneng New Energy Industrial Co., Ltd for the development of wind farms in Yunnan Province and Hebei Province.

Wind farm in Yunnan Province

The wind farm in Dali of Yunnan Province is located at 2400-2800 metres above sea level, is one of the highest altitude wind farms in China. The wind farm consists of 64 turbines with a total installed capacity of 48 MW. It was put into operation in early 2009.

Wind farm in Hebei Province

The wind farm in Leting of Hebei Privince contains 33 wind turbines, each of 1.5 MW, with a total installed capacity of 49.5 MW. It was commissioned in December 2009.

Benefits of Wind Energy

- It is clean and does not pollute the air
  Wind turbines do not emit greenhouse gases or contribute to global warming.
- It does not deplete resources
  Every 1 million units of electricity generated by a wind turbine can offset approximately 350 tonnes of coal.
- It is more cost-effective than other forms of renewable energy
  As wind energy technology matures, construction and operating costs continue to drop, providing greater cost effectiveness.

Challenges of Wind Energy

- It is intermittent and unpredictable
  Electricity cannot be stored economically in large quantities. It has to be generated to match the demand. As wind is unpredictable in terms of speed and direction, wind turbine generator outputs are not controllable or predictable. Wind energy alone cannot be relied upon as the sole source of electricity.
- Wind farms occupy large areas
  Places with high population densities and land limitation often have difficulty finding the necessary space for wind farms.
- Wind turbines can impose adverse impact on the environment
  Turbines may endanger migrating birds or create visual and noise disturbances.

Courtesy: DOE/NREL
Credit: Spink, Todd

Wind Energy Through the Years

People have been raising sails to capture wind energy and push their boats through the water.

Wind has been used to produce electricity since the 19th century. One of the earliest wind turbines was built at Cleveland, Ohio in 1888 by Charles F.Brush. It featured 144 rotor blades of cedar, and had a 12kW capacity.

As at 2008, the largest wind turbine is installed in Emden, Germany, with a capacity of 6 MW.