

Unit 4:- Wind Energy



Syllabus...Unit 4

- **Wind Energy:** Wind characteristics, resource assessment, horizontal and vertical axis wind turbines, electricity generation and water pumping, Micro/Mini hydro power system, water pumping and conversion to electricity, hydraulic pump.

Books ...

- Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley - IEEE Press, August 2004.
- Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
- Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

Supplementary Reading:

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

Lecture 2

- Origin of Wind
- Causes of Wind
- Winds Over Earth Surface
- Uneven Heating of Earth Surface
- Coriolis Effect
- Coriolis Regions
- Wind Special Scales
- Wind Types
- Wind Energy Advantages
- Wind Energy Disadvantages

Origin of Wind



- Solar energy is produced by the nuclear fusion of hydrogen (H) into helium (He) in its core. It creates heat and electromagnetic radiation streams in all directions.
- Estimated total solar power received by the earth is approximately 1.8×10^{11} MW. Out of only 2% (i.e. 3.6×10^9 MW) is converted into wind energy and about 35% of wind energy is dissipated within the earth's surface
- Therefore, the wind power that can be converted into an energy is approximately 1.26×10^9 MW.
- This is about 20 times the present global energy consumption,
- Hence, wind energy in principle could meet entire energy needs of the world.

Causes of Wind



Wind moves from

High Pressure → Low Pressure

- Cold Temperature

- Molecules closer together
- "packed tightly"
- More dense = more pressure



- Warmer Temperatures

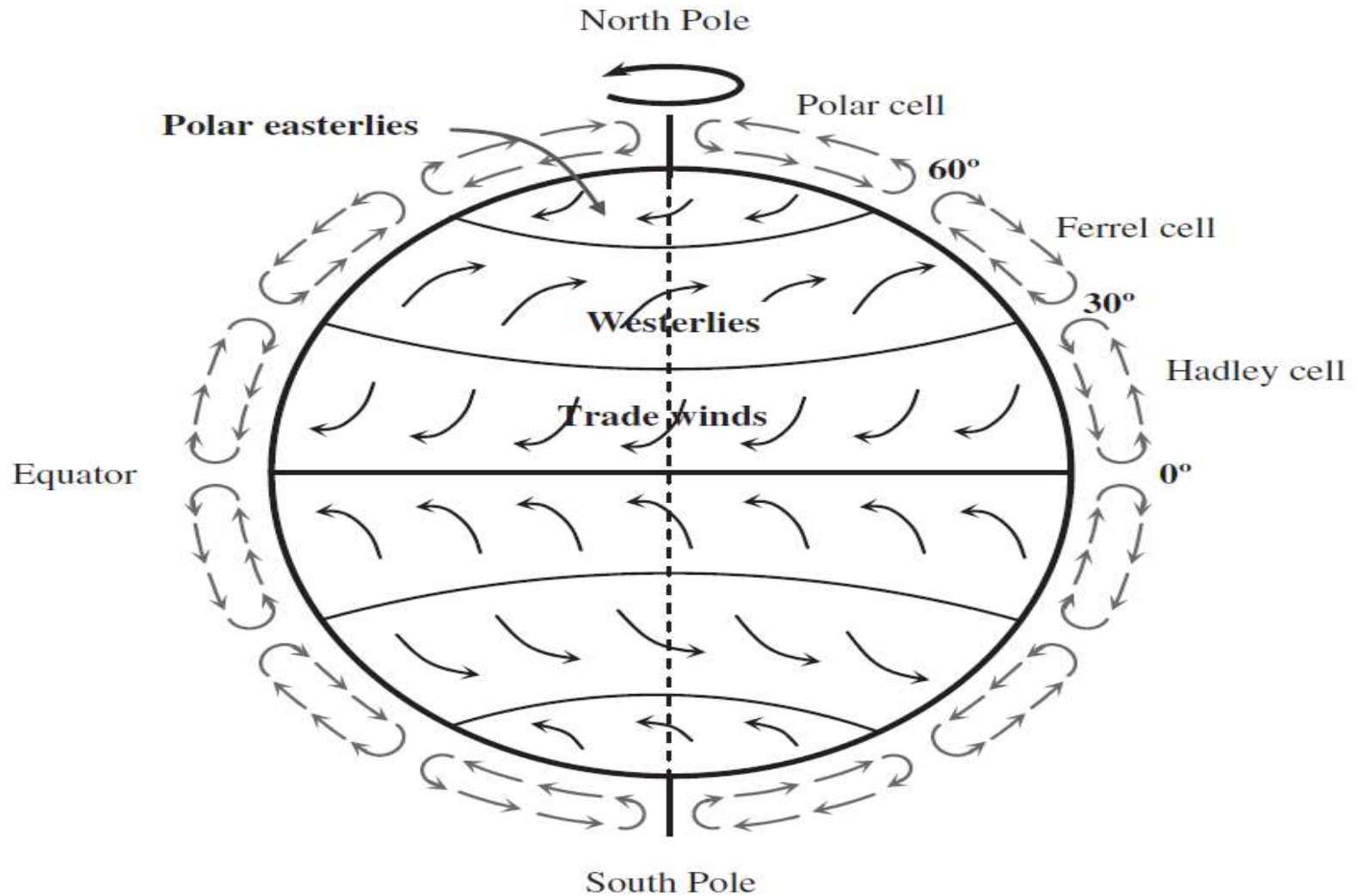
- Molecules further apart
- "unpacked"
- Less Dense = Less Pressure



Molecules want to spread out, yet... still same amount!

- Wind results from the movement of air due to atmospheric pressure gradients.
- Wind flows from regions of higher pressure to regions of lower pressure.
- The larger the atmospheric pressure gradient, the higher the wind speed
- The most important factors for wind generation are
 - ✓ Uneven solar heating
 - ✓ Coriolis force i.e. Effect of the earth's self-rotation
 - ✓ Local geographical conditions

Winds Over Earth Surface



Uneven Heating of Earth Surface

- The equator receives the greatest amount of energy per unit area, with energy dropping off toward the poles
- Due to the spatial uneven heating on the earth, it forms a temperature gradient from the equator to the poles and a pressure gradient from the poles to the equator.
- Hot air with lower air density at the equator rises up to the high atmosphere and moves towards the poles and cold air with higher density flows from the poles towards the equator along the earth's surface.
- The earth's self-rotation induced Coriolis force, the air circulation at each hemisphere forms a single cell, defined as the meridional circulation.

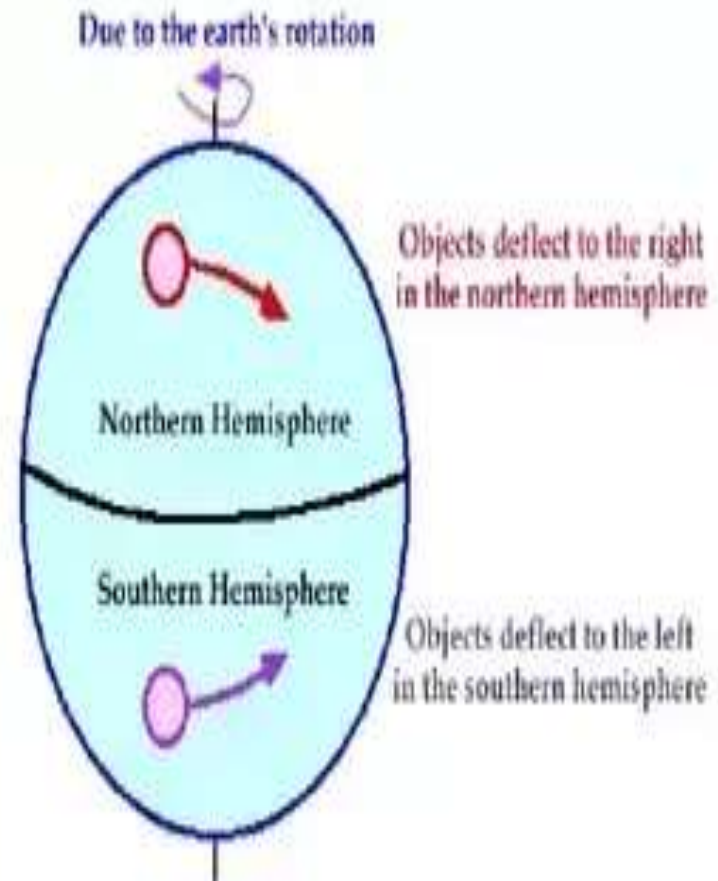
Uneven Heating of Earth Surface

- The earth's self-rotating axis has a tilt of about 23.5° with respect to its ecliptic plane. It is the tilt of the earth's axis during the revolution around the sun that results in cyclic uneven heating, causing the yearly cycle of seasonal weather changes.
- The earth's surface is covered with different types of materials such as vegetation, rock, sand, water, ice/snow, etc. Each of these materials has different reflecting and absorbing rates to solar radiation, leading to high temperature on some areas (e.g. deserts) and low temperature on others (e.g. iced lakes), even at the same latitudes.
- Uneven heating of solar radiation is due to the earth's topographic surface. There are a large number of mountains, valleys, hills, etc. on the earth, resulting in different solar radiation on the sunny and shady sides

Coriolis Effect

Coriolis Effect

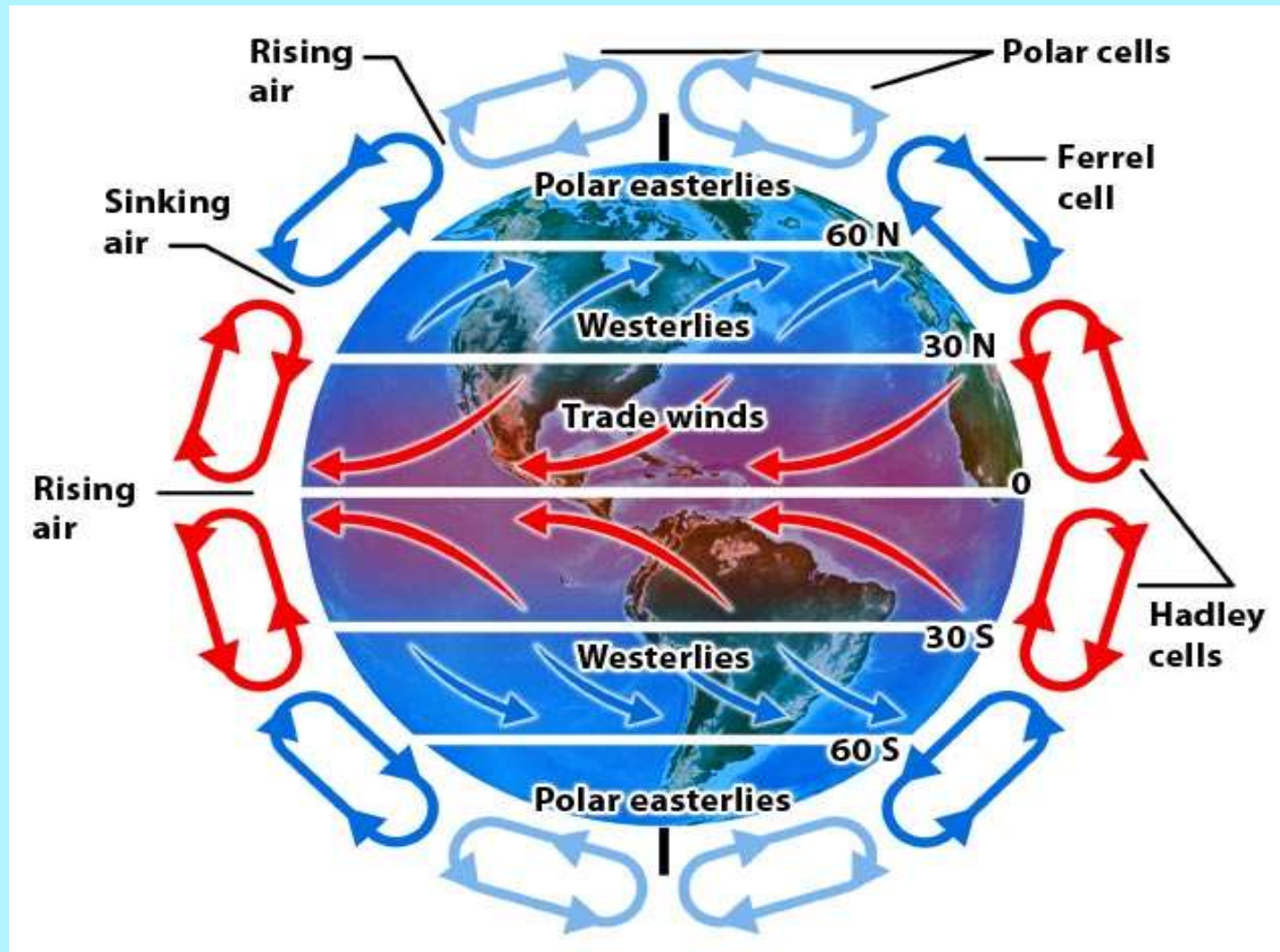
- The rotation of the Earth causes all moving objects in the Northern Hemisphere, including air mass, to deflect to the right and those in the Southern Hemisphere to move to the left.
- This Coriolis effect is absent at the Equator.
- Coriolis Force- prevents a direct simple flow from the Equator to the Poles.
- This is also known as 'Ferrel's Law'.



Coriolis Effect

- The Coriolis force, which is generated from the earth's self-rotation, deflects the direction of atmospheric movements.
- In the north atmosphere wind is deflected to the right and in the south atmosphere to the left
- The Coriolis force depends on the earth's latitude; it is zero at the equator and reaches maximum values at the poles.
- The amount of deflection on wind also depends on the wind speed; slowly blowing wind is deflected only a small amount, while stronger wind deflected more.
- The combination of the pressure gradient due to the uneven solar radiation and the Coriolis force due to the earth's self rotation causes the single meridional cell to break up into three convectional cells in each hemisphere: *Hadley cell*, *Ferrel cell*, and *Polar cell*. Each cell has its own characteristic circulation pattern

Coriolis Regions



Wind Special Scales



Planetary scale: global circulation, trade winds

Synoptic scale: weather systems cyclones etc.

(It is also known as large scale or cyclonic scale. It is a horizontal length scale of the order of 1000 kilometers or more.)

Mesoscale: local topographic thunder storms, tornados etc.

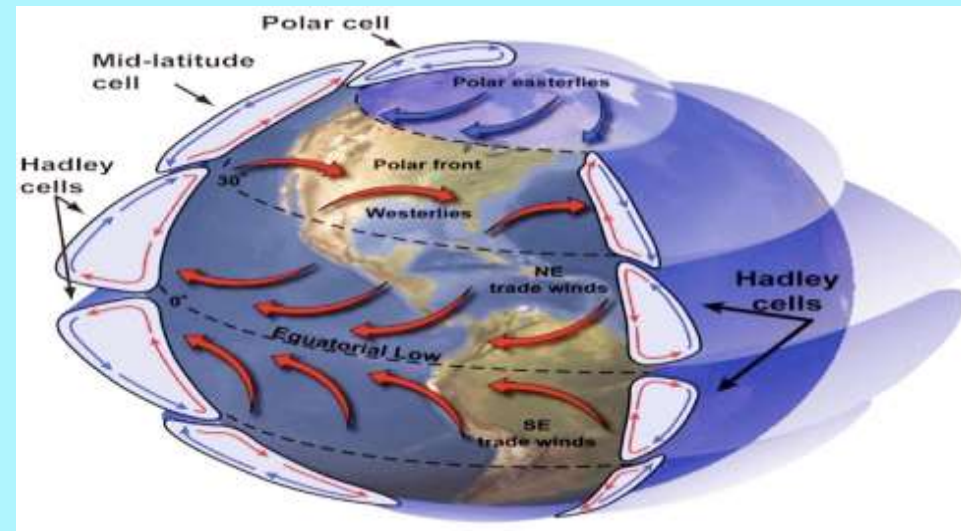
(It is the study of atmospheric phenomena with typical spatial **scales** between 10 and 1000 km)

Micro scale: urban topography

Chaotic motions dust devils, small localized breezes

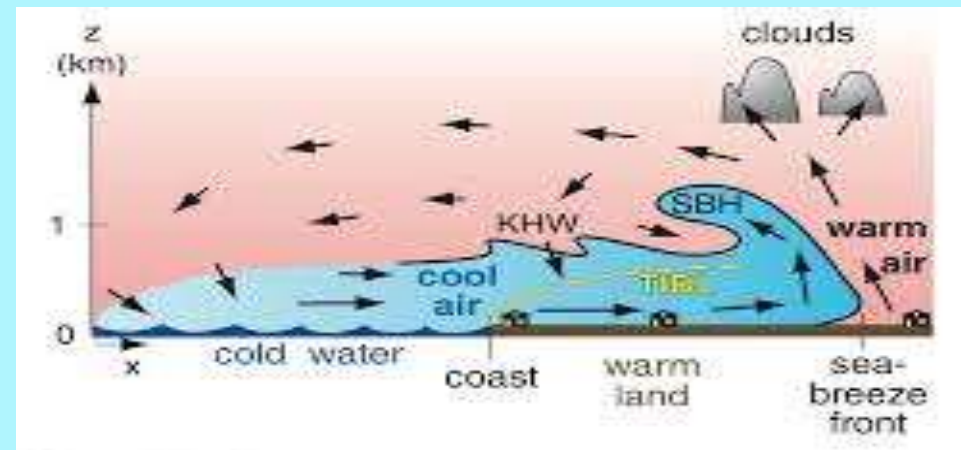


Wind Types



- **Planetary circulations:**

- Jet streams
- Trade winds
- Polar jets



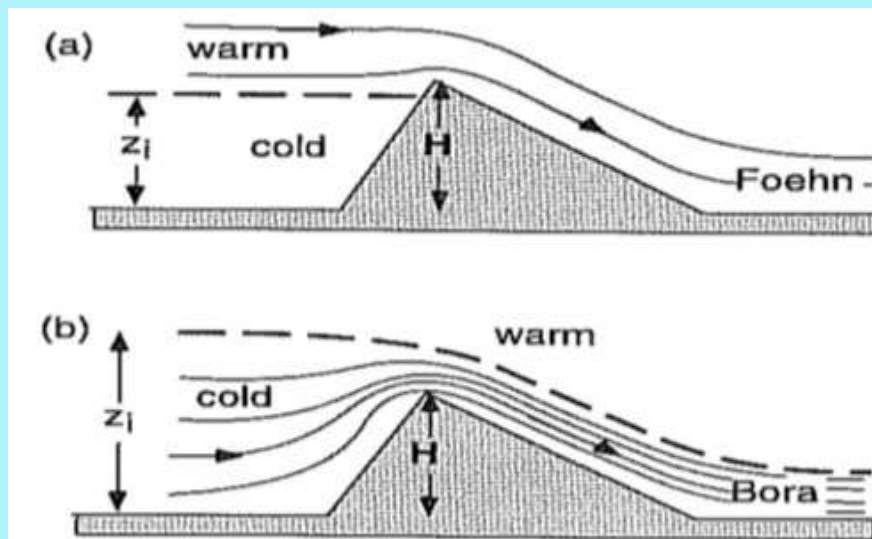
- **Geostrophic winds**

- Thermal winds
- Gradient winds

Wind Types

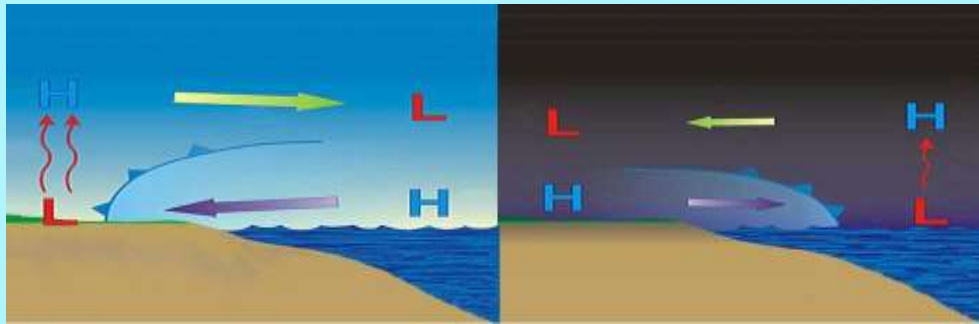


- Katabatic / Anabatic winds – topographic winds



- Bora / Foehn / Chinook – downslope wind storms

Wind Types



- Sea Breeze / Land Breeze

They are essentially the same type of weather phenomenon. It only depends on **WHERE** the storm forms and happens.

- HURRICANE** Northeast Pacific Ocean and Atlantic Ocean
- TYPHOON** Northwest Pacific Ocean
- CYCLONE** South Pacific Ocean and Indian Ocean.

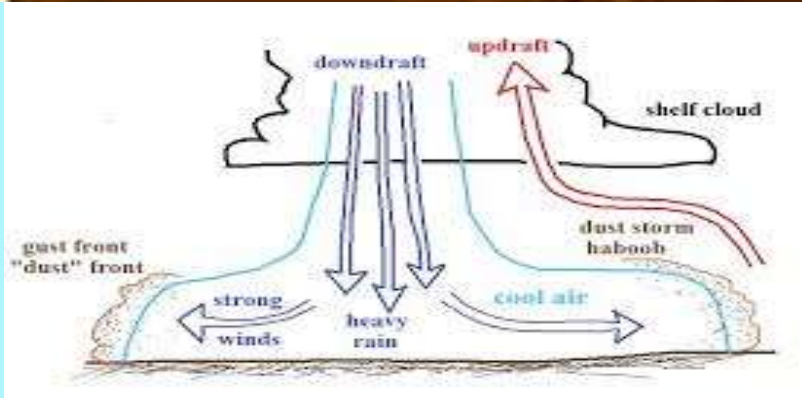


- Convective storms /
Downdrafts
- Hurricanes/ Typhoons
/Cyclone

Wind Types



Tornadoes

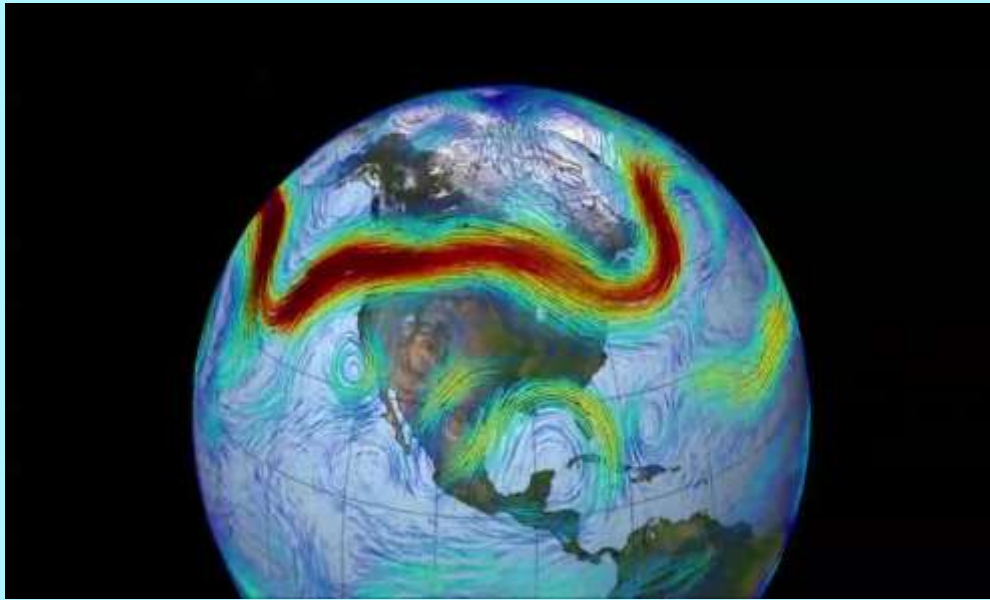


- Gusts

Dust devils /
Microbursts



Wind Types

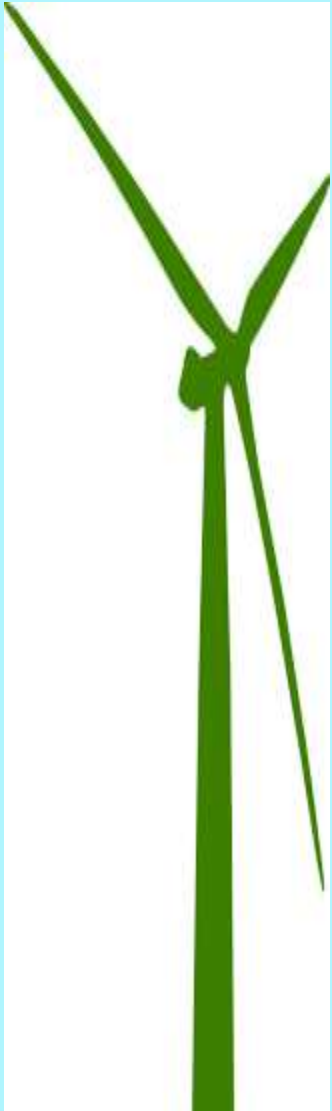


Nocturnal Jets

- Atmospheric Waves

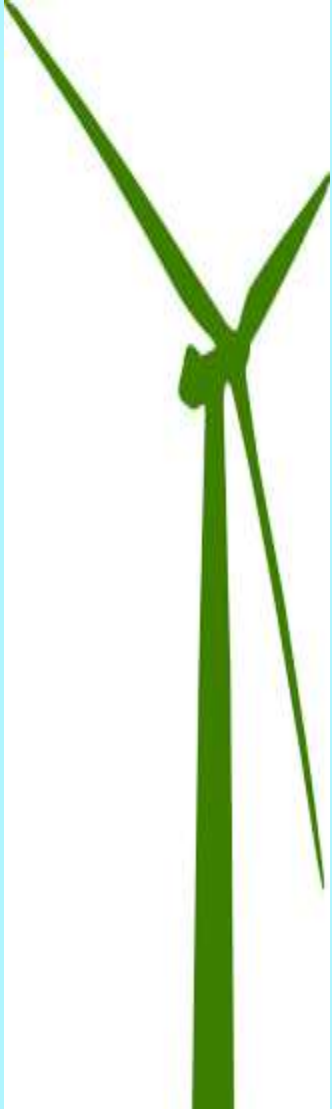


Wind Energy Advantages



- 1) Wind Energy is an inexhaustible source of energy and is virtually a limitless resource.
- 2) Energy is generated without polluting environment.
- 3) This source of energy has tremendous potential to generate energy on large scale.
- 4) Like solar energy and hydropower, wind power taps a natural physical resource.
- 5) Windmill generators don't emit any emissions that can lead to acid rain or greenhouse effect.
- 6) Wind Energy can be used directly as mechanical energy.
- 7) In remote areas, wind turbines can be used as great resource to generate energy.

Wind Energy Advantages

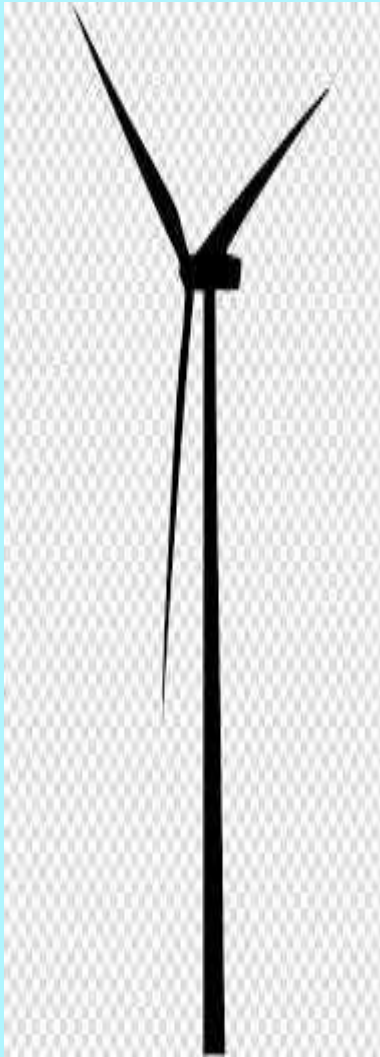


8) In combination with Solar Energy they can be used to provide reliable as well as steady supply of electricity.

9) Land around wind turbines can be used for other uses, e.g. Farming.

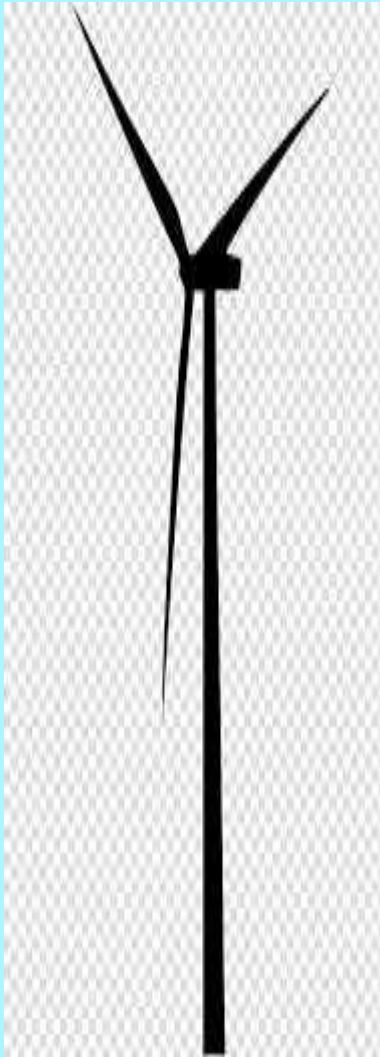
To generate electricity on a large scale, a number of windmills are set up over a large area, called a wind energy farm. Such areas need a wind speed min. of 15kmph.

Wind Energy Disadvantages



- 1) Wind energy requires expensive storage during peak production time.
- 2) It is unreliable energy source as winds are uncertain and unpredictable.
- 3) There is visual and aesthetic impact on region
- 4) Requires large open areas for setting up wind farms.
- 5) Noise pollution problem is usually associated with wind mills.
- 6) Wind energy can be harnessed only in those areas where wind is strong enough and weather is windy for most parts of the year.

Wind Energy Disadvantages



- 7) Usually places, where wind power set-up is situated, are away from the places where demand of electricity is there. Transmission from such places increases cost of electricity.
- 8) The average efficiency of wind turbine is very less as compared to fossil fuel power plants. We might require many wind turbines to produce similar impact.
- 9) It can be a threat to wildlife. Birds do get killed or injured when they fly into turbines.
- 10) Maintenance cost of wind turbines is high as they have mechanical parts which undergo wear and tear over the time.

Thank You