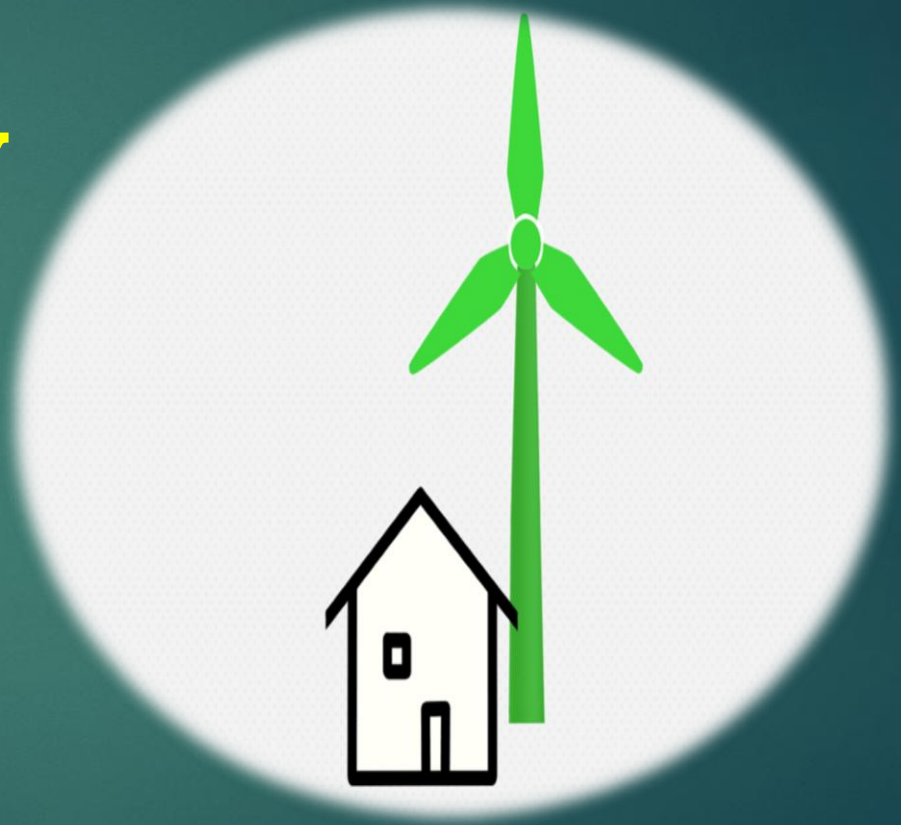
RENEWABLE ENERGY SOURCES AND APPLICATIONS
(Subject Code: 21MEO112T)

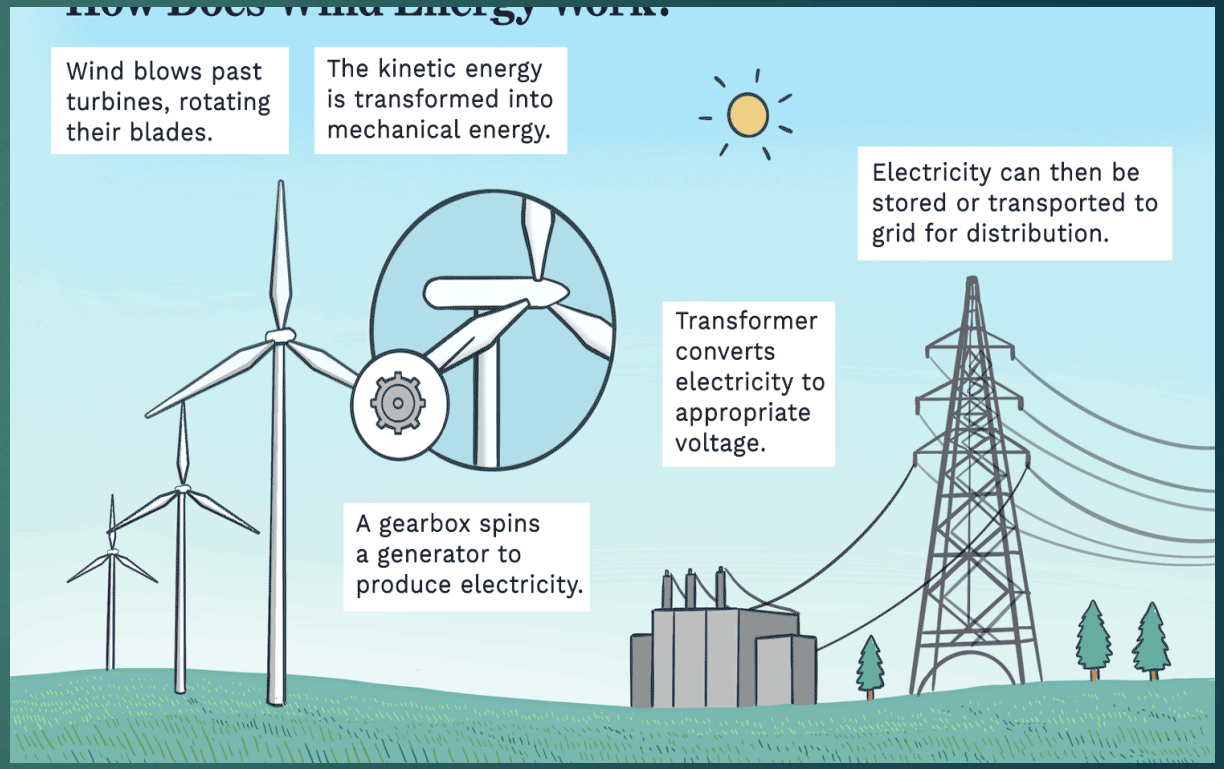
Unit-2
WIND Energy



Dr. Amit Kumar

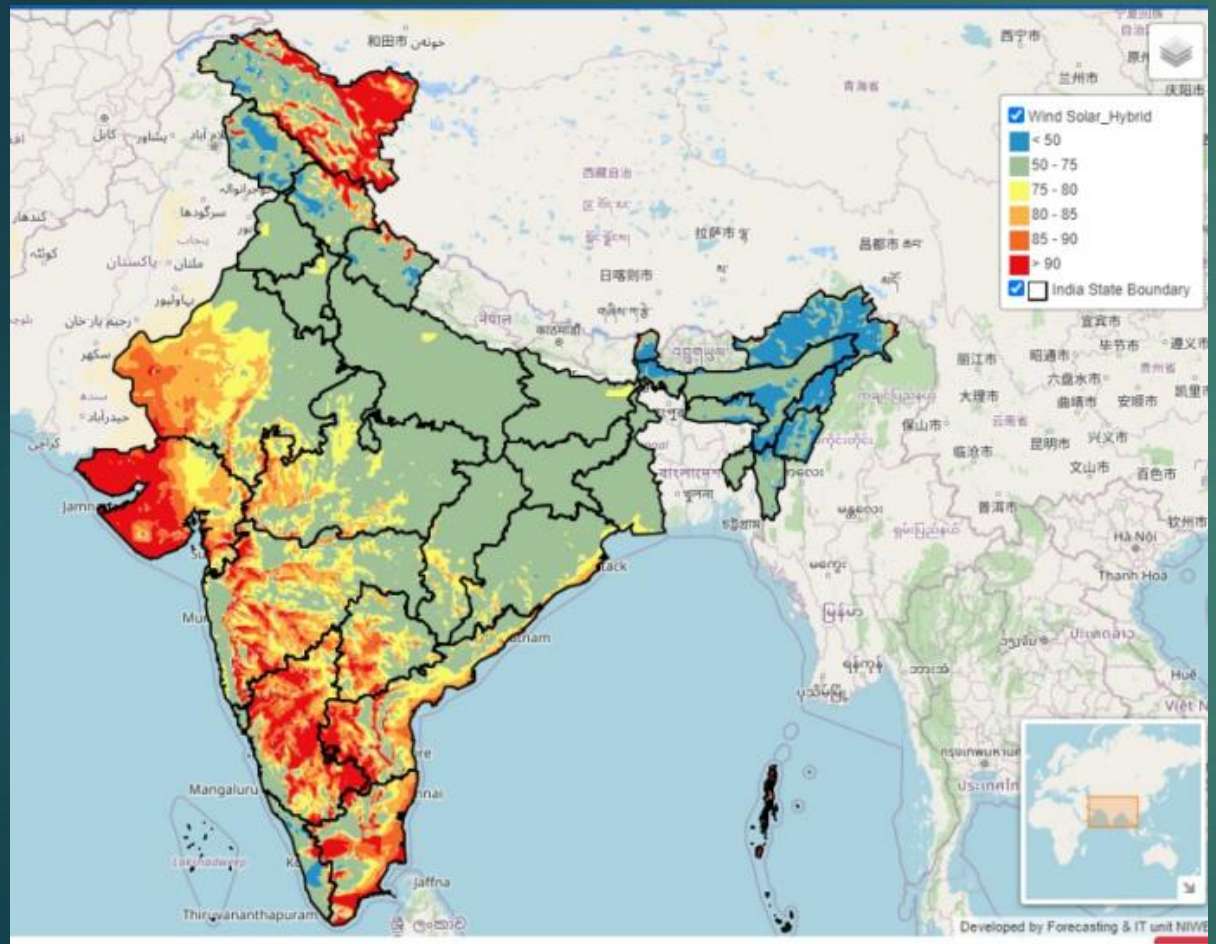
Introduction to Wind Energy

- Wind energy is a type of kinetic energy that is associated with natural wind or air flows in the earth's atmosphere.
- Wind turbines utilize kinetic energy from the natural wind to generate electricity.
- These wind turbines convert the wind energy into mechanical power, which is then converted to electric power to generate electricity.



Wind energy scenario in India and the world, Origin of wind, nature of wind, wind data measurement, Variation of Wind Speed with Height,

Wind energy potential in India



Wind-Solar Potential Map in NIWE web portal

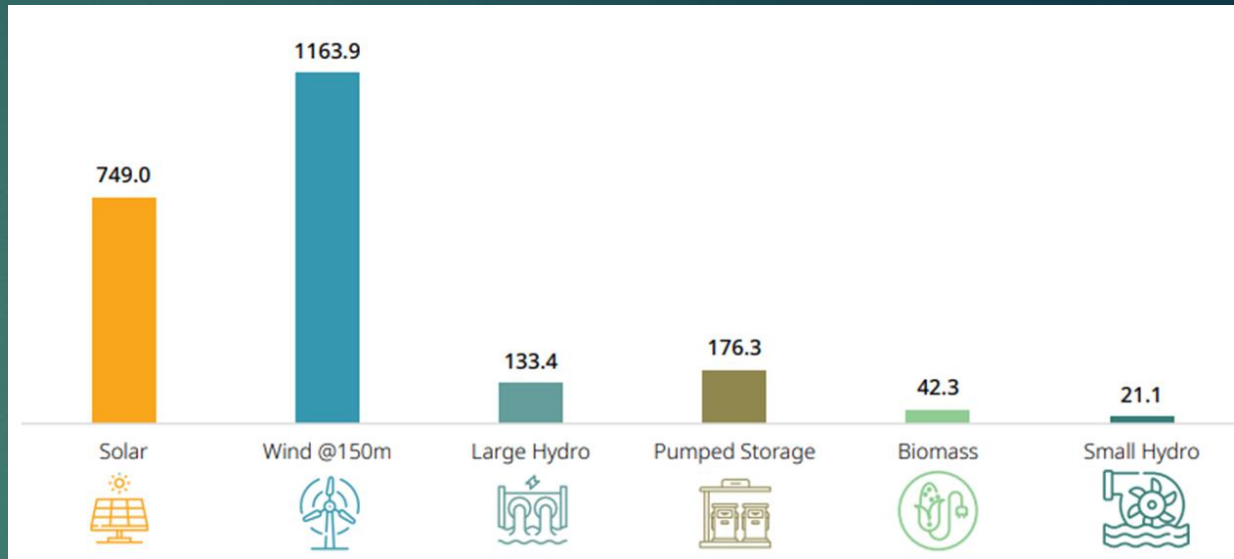
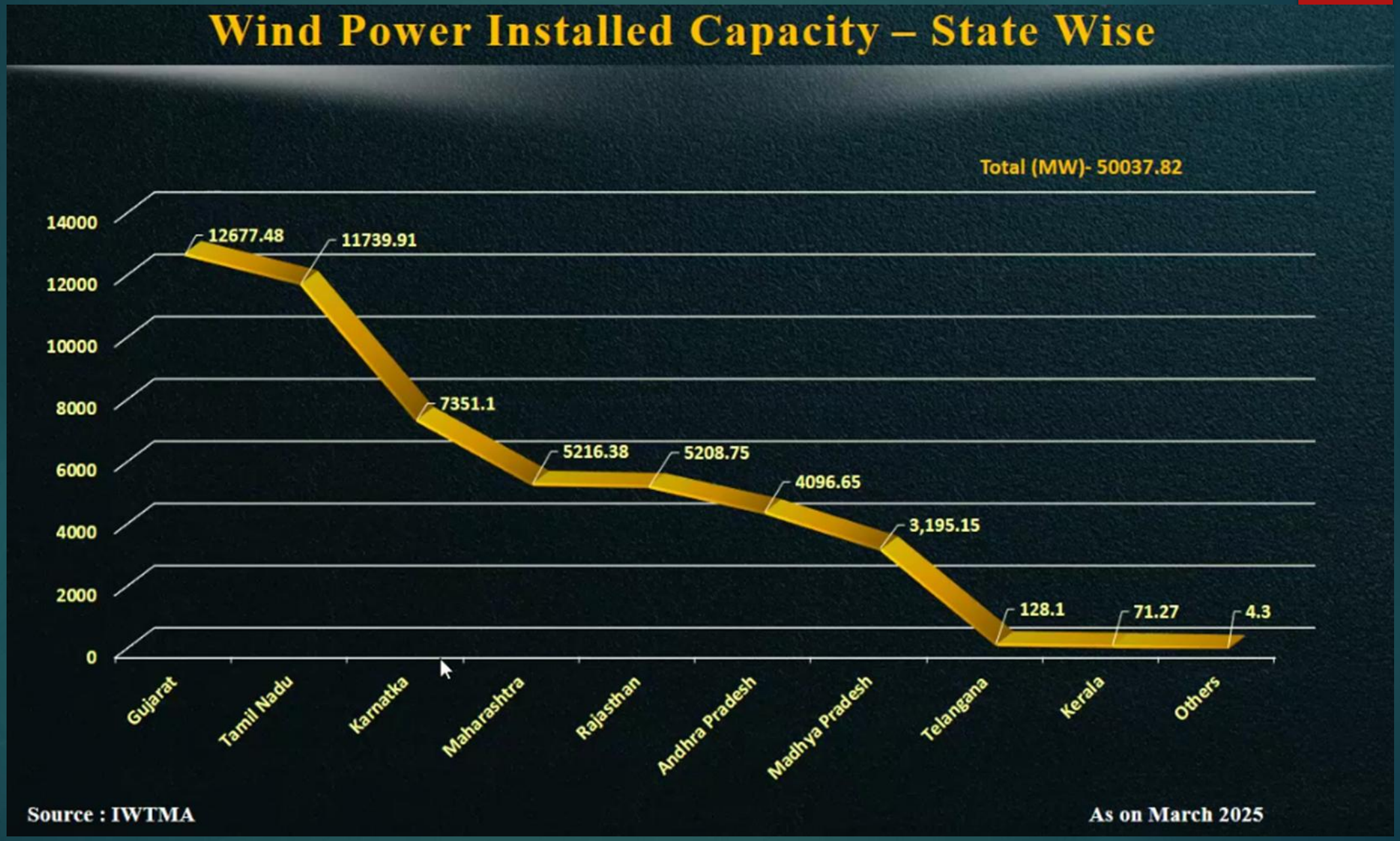


Figure 25: *Resource potential for various renewable energy sources (in GW)*

Source: (ICED, 2024)

A recent study by the National Institute of Wind Energy (NIWE) indicates that India's wind potential, at 150 meters above ground level, is approximately 1164 GW.

Wind Power Installed Capacity – State Wise



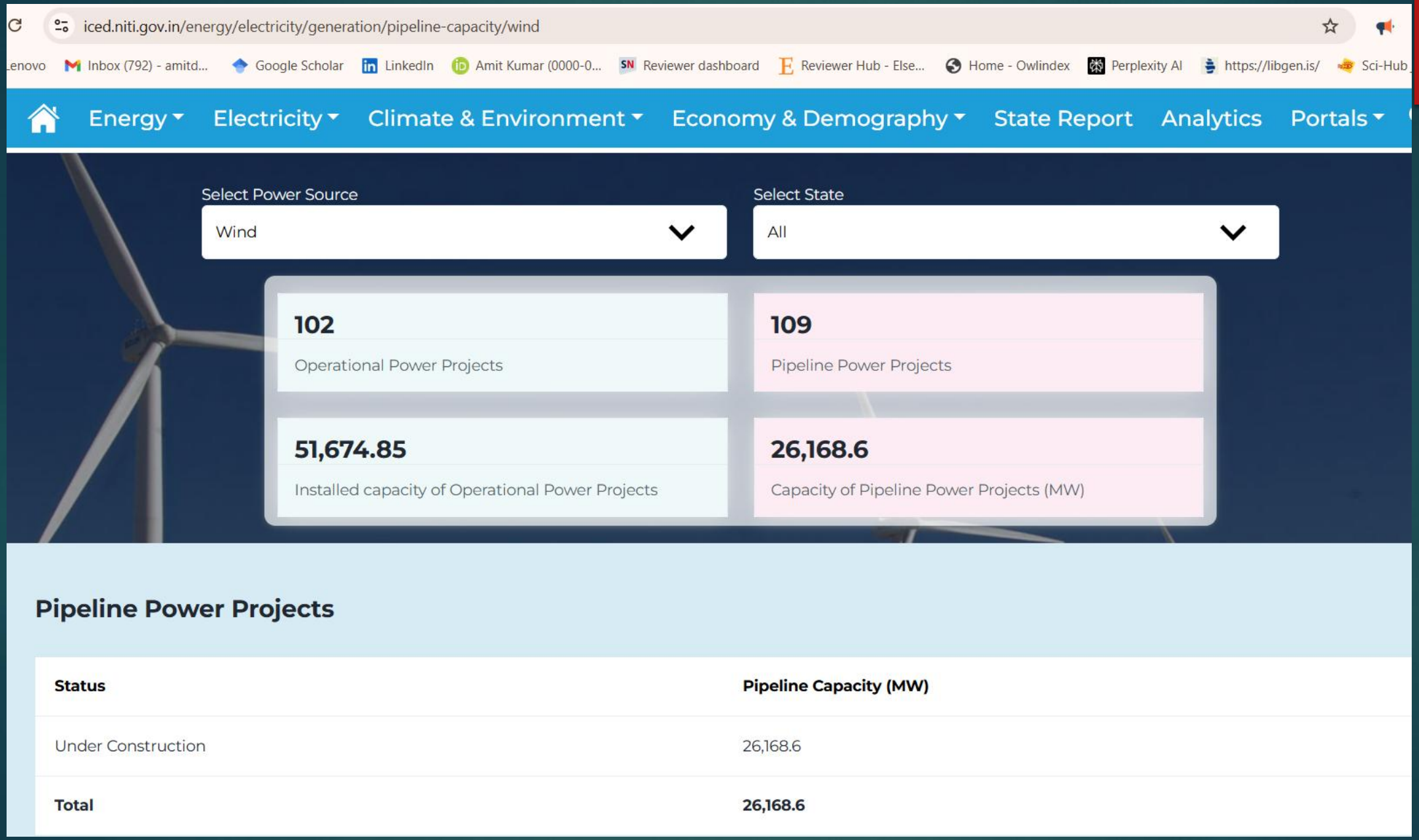
Source : IWTMA

As on March 2025

Largest wind farms in India

Wind Farm	Producer	State	Current Capacity (MW)
Muppandal windfarm	Multiple Owners	Tamil Nadu	1500
Jaisalmer Wind Park	Suzlon Energy	Rajasthan	1600
Brahmanvel windfarm	Parakh Agro Industries	Maharashtra	528
Dhalgaon windfarm	Gadre Marine Exports	Maharashtra	278
Chakala windfarm	Suzlon Energy	Maharashtra	217
Vankusawade Wind Park	Suzlon Energy	Maharashtra	210

Source : IWPA



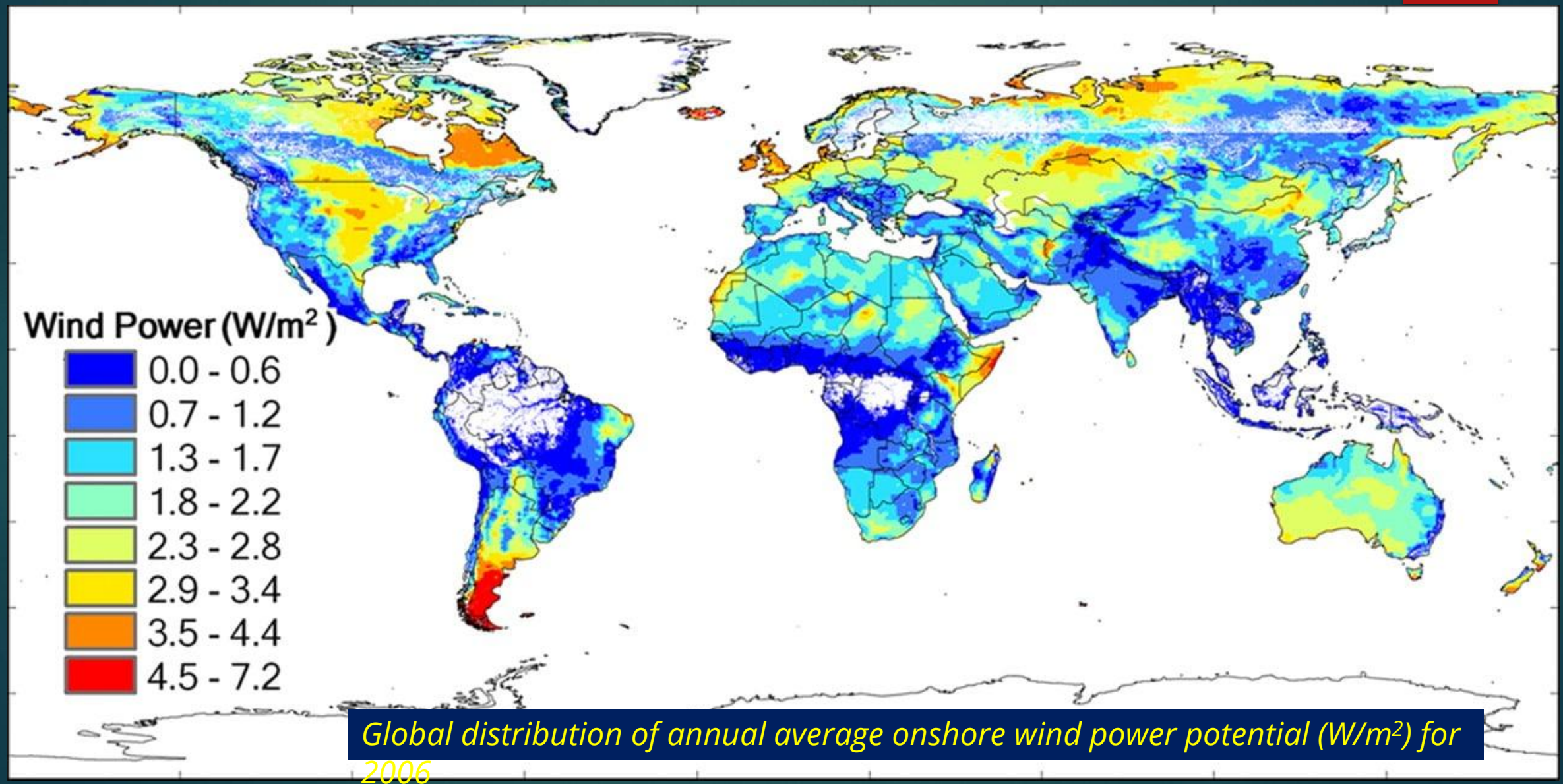
Pipeline Power Projects

Status	Pipeline Capacity (MW)
Under Construction	26,168.6
Total	**26,168.6**

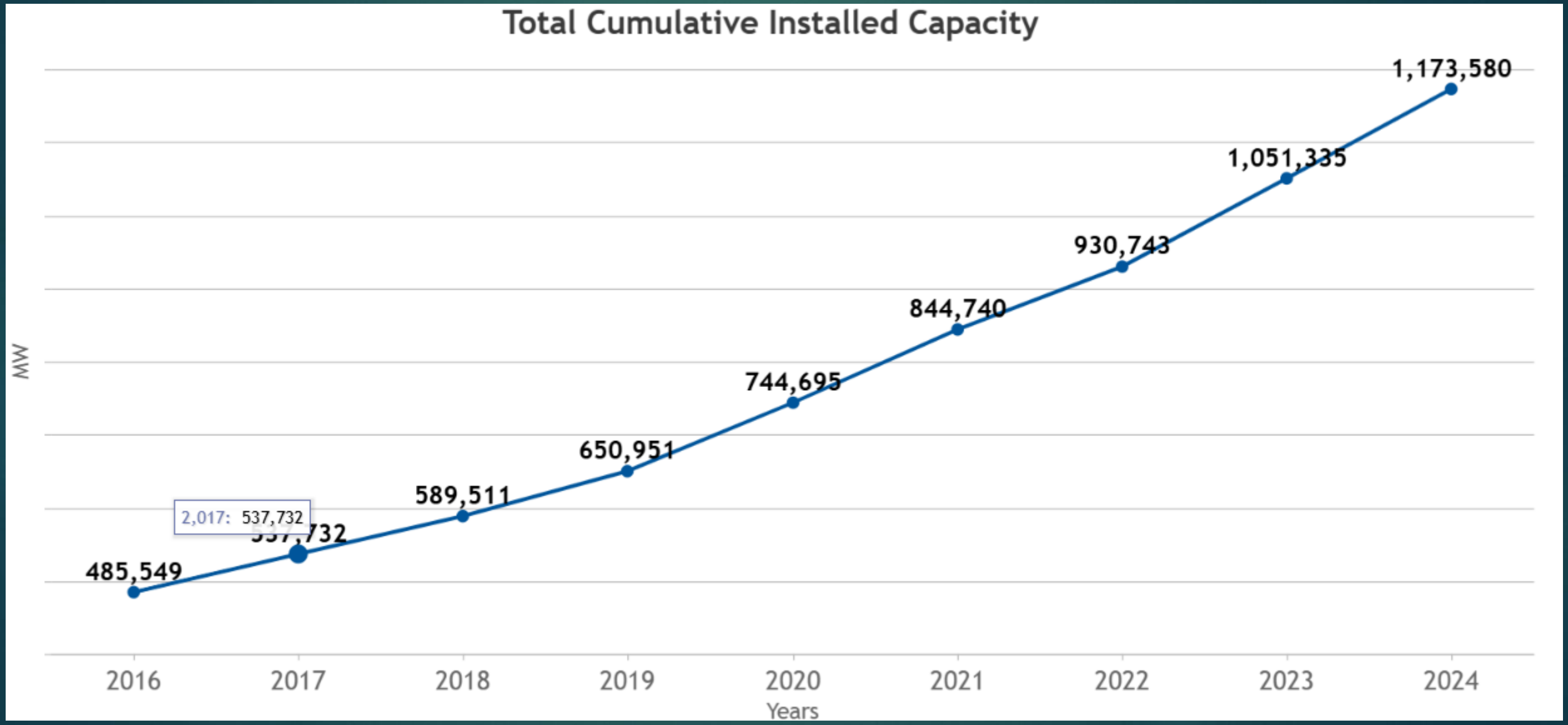
Wind Power scenario in India (2025)

- **Installed Capacity: 50 GW → 4th largest in the world**
- **Geographic Spread:** Mainly in **Southern, Western & Northwestern states**
- **Potential at 120m above the local ground level:**
  - **132 GW** (≥32% CUF)
- **Land Use:** Wind farms occupy only **~2%** of area → rest usable for agriculture
- **Grid Support:** Capable of **fast frequency response**

Wind energy potential in World



Global distribution of annual average onshore wind power potential (W/m²) for 2006


Total Cumulative Installed Capacity
MW
485,549
537,732
589,511
650,951
744,695
844,740
930,743
1,051,335
1,173,580
2,017: 537,732
2016
2017
2018
2019
2020
2021
2022
2023
2024
Years

Global Wind Power Scenario (2025)

- **>10% of global electricity** demand now met by wind (more than nuclear power).
- **30+ countries** have wind share **above 10%**.
- **11 countries** generate **>20% electricity** from wind.
- **7 leaders (>30%)**:
  - DK Denmark (>50%)
  - DE Germany
  - GB UK
  - PT Portugal
  - NL Netherlands
  - IE Ireland
  - UY Uruguay

- **Future Potential**:
  - Global target: **40–50% wind share** (WWEA scenario).
  - Key driver of **electrification in transport & heating/cooling**.
  - Wind power → fuels **cars, homes, industries**.

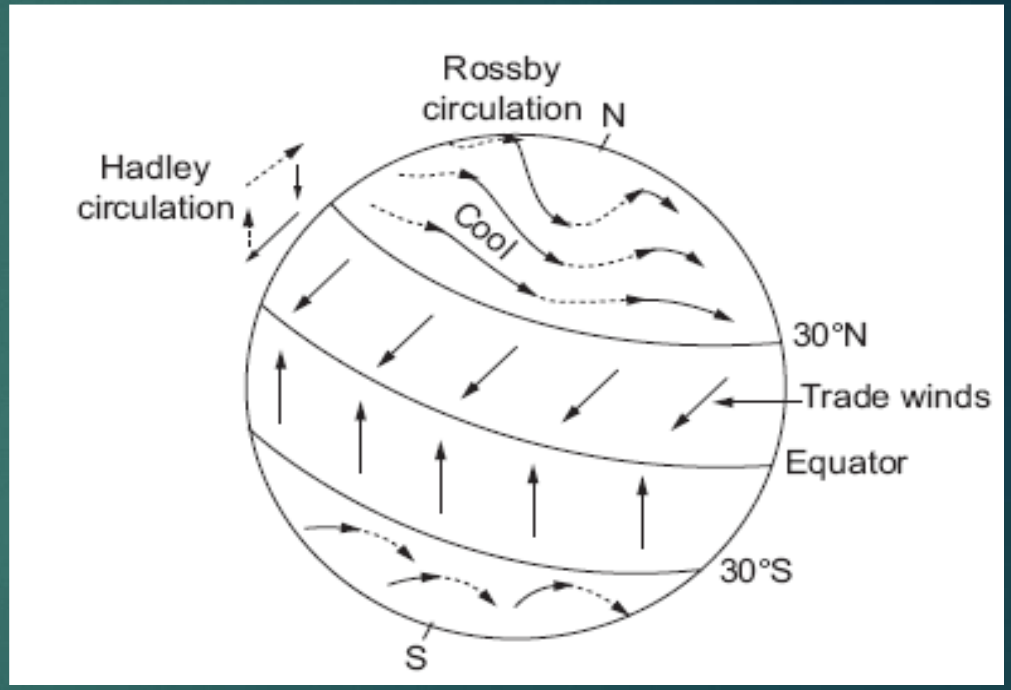
ORIGIN OF WINDS

Global Wind Patterns

The Earth's rotation and the unequal heating of its surface create three main global wind belts: the trade winds, the prevailing westerlies, and the polar easterlies.

The trade winds blow from the east towards the equator, while the prevailing westerlies blow from the west in the mid-latitudes.

The polar easterlies blow from the polar regions towards the mid-latitudes.



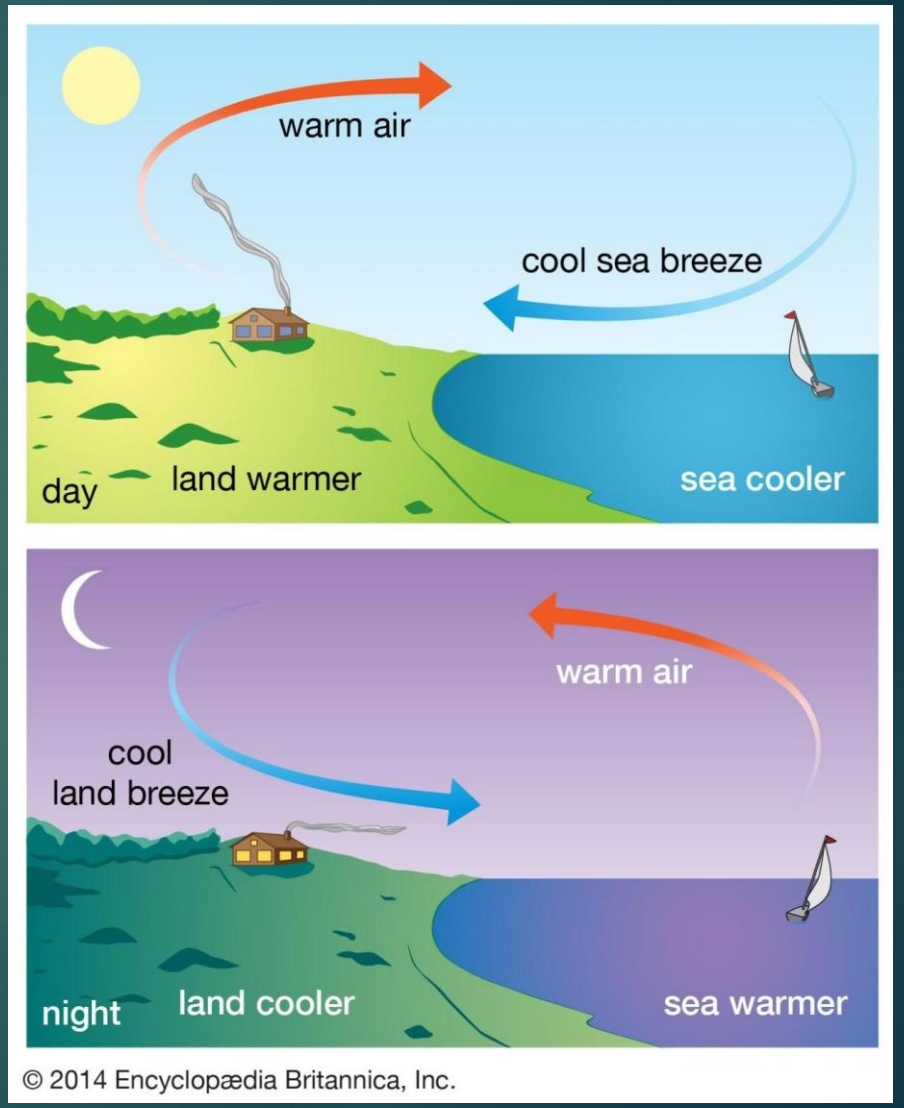
Global circulation of wind

Local Wind Systems

Local wind systems are influenced by topography, land, and sea breezes, and temperature variations.

Land and sea breezes occur due to the different heating rates of land and water.

Mountain and valley breezes are caused by the temperature difference between the slopes and the valley floor.



NATURE OF WINDS

The Beaufort scale, a wind speed classification, gives a description of the effect of the wind. It was initially designed for sailors and described the sea state, but has been modified to include wind effects on land. It is a useful guide to wind speed. The description of wind based on Beaufort number is given in Table:

Beaufort number	Wind speed		Observable effects	Wind Description
	m/s	km/h		
0	0.0–0.4	0.0–1.6	Smoke rises vertically	Calm
1	0.4–1.8	1.6–6	Smoke drifts but vanes unaffected	Light
2	1.8–3.6	6–13	Leaves move slightly but vanes unaffected	Light
3	3.6–5.8	13–21	Leaves in motion, flags begin to extend	Light
4	5.8–8.5	21–31	Small branches move, dust raised, pages of book loosen	Moderate
5	8.5–11	31–40	Small trees sway, wind noticeable	Fresh
6	11–14	40–51	Large branches sway, telephone lines whistle	Strong
7	14–17	51–63	Whole tree in motion	Strong
8	17–21	63–76	Twigs break off, walking difficult	Gale
9	21–25	76–88	Slight structural (e.g. chimneys) damage	Gale
10	25–29	88–103	Trees uprooted, much structural damage	Strong gale
11	29–34	103–121	Widespread damage	Strong gale
12	>34	>121	Disastrous conditions, countryside devastated, only occurs in tropical cyclones	Hurricane

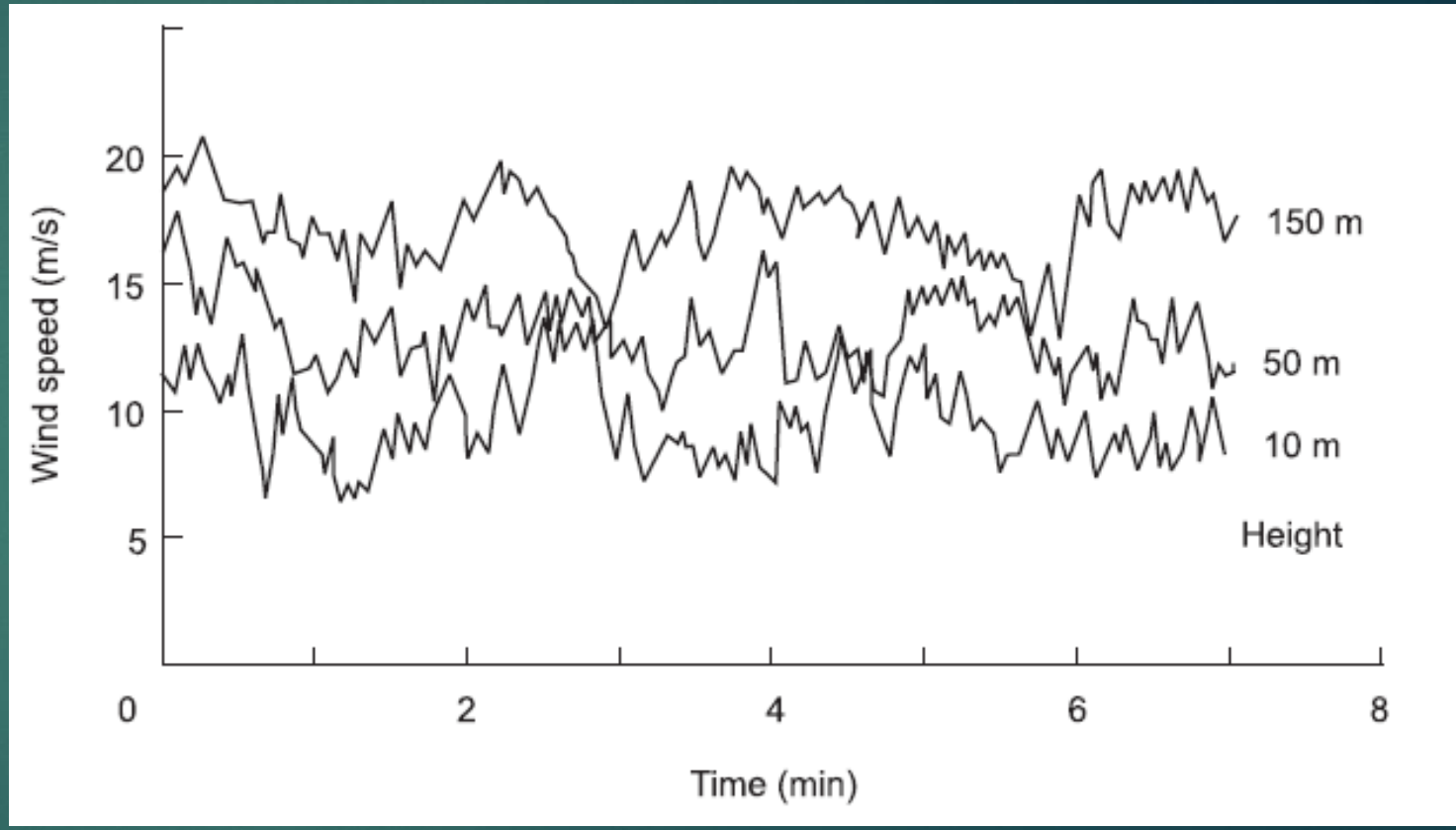
WIND DATA measurement

The wind speed recorded at three heights, 10 m, 50 m and 150 m during strong winds. These records demonstrate the main characteristics of the flow in the region near ground. Main conclusions may be drawn as:

(i) Wind speed increases with height.

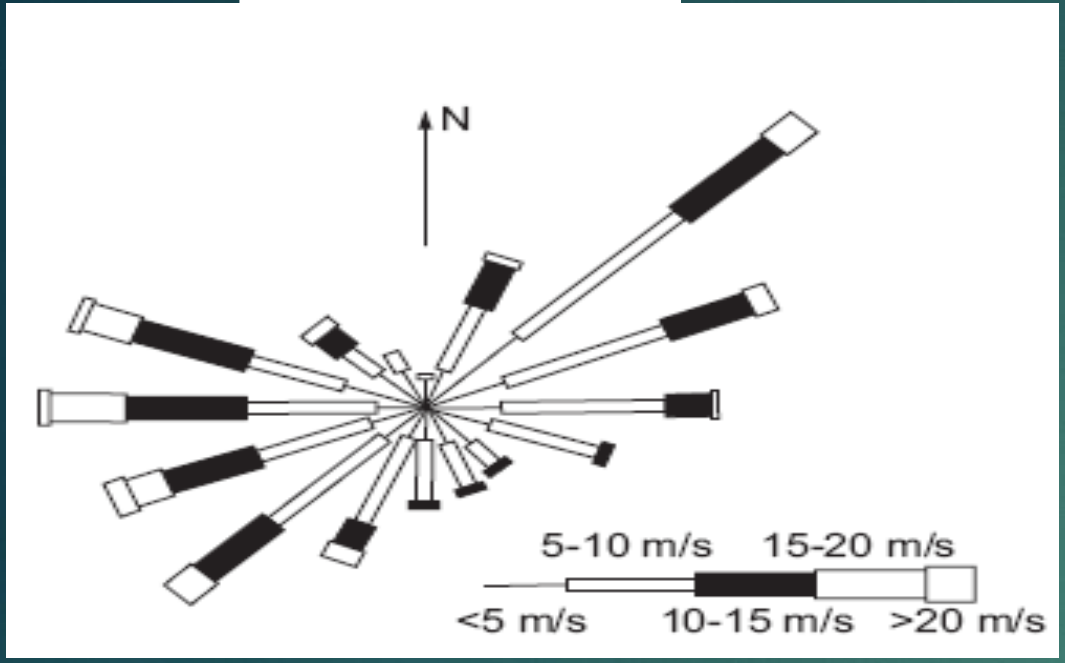
(ii) Wind speed is fluctuating with time, i.e. turbulences are present at the site.

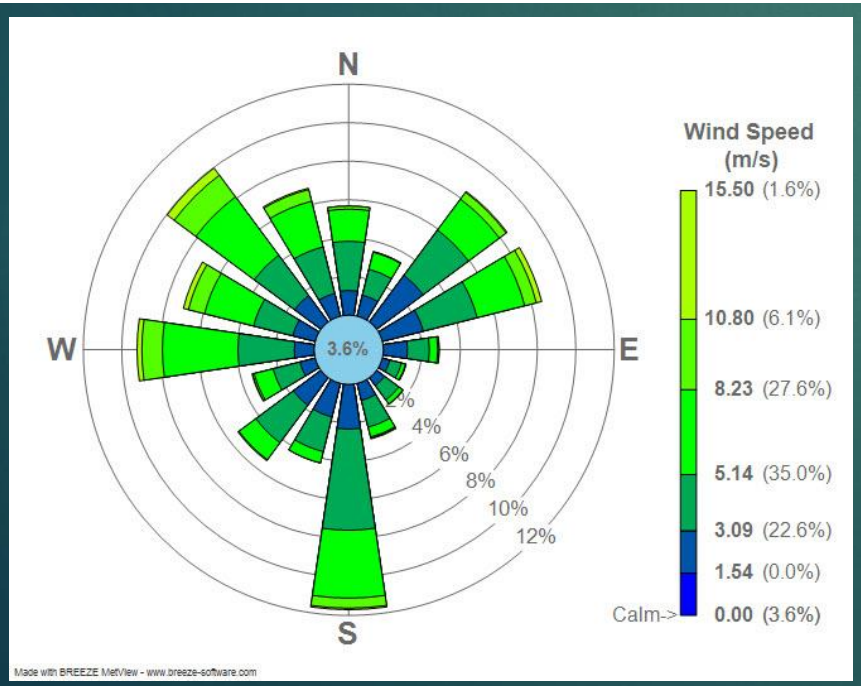
(iii) The turbulence is spread over a broad range of frequencies.



Wind speed recording

A typical wind rose





- For the purpose of energy studies, mean wind speed is used, which is generally based on different averaging periods from 10 min to 1 h in different countries. An elegant method of describing average wind speed, duration and direction on a single graph. It is known as wind rose.
- It depicts the compass bearing from which the wind comes (all 16 directions) along with average wind speed and duration in a year. The lengths of bars represent the percentage of duration.

Instrument for wind measurement

- Wind speed
  - Anemometers: they rotate with the wind and, hence, can give a measure of the wind speed at a given **height**. Problem with ice/dust that can lodge in the bearing.
  - LIDAR/SODAR: use the Doppler effect to measure wind speeds:
    - Need not be put at a given height.
    - No problem with ice or dust.
    - But more costly and less reliable.
- Wind direction: wind vane.

For detailed wind data and potential maps, consult the National Institute of Wind Energy (NIWE) website, which provides detailed wind potential at various heights and state-wise data for India, including offshore potential.

The Ministry of New and Renewable Energy (MNRE) also provides data and insights into India's wind energy sector, highlighting areas with high wind potential and the state of installations.

Variation of Wind Speed With Height

$$u_z = V \ln\left(\frac{z-d}{z_o}\right)$$

As seen in the diagram, near the line of local obstructions the average wind speed does not follow Eq. (i.e. the dotted line) but deviates from it and becomes highly erratic. It is very important then to place the wind turbine well above the height of local obstructions so that the turbine disk receives a strong uniform wind flux across its area without erratic fluctuations.

$$u_z = u_H\left(\frac{z}{H}\right)^{\alpha}$$

where u_H is mean wind speed at reference height H (usually 10 m), a depends on surface roughness and the range of height being covered