Wind energy is obtained from the kinetic energy of moving air and is converted into electrical energy using wind turbines. The available wind power depends on air density, wind speed, and the swept area of the turbine.

**Derive an expression for the power available in the wind for conversion by a wind turbine. Also, derive the expression for wind power density.**

To derive the expression of wind power available for conversion in a wind turbine system, consider the kinetic energy of moving air.

#### Kinetic Energy of Air

The kinetic energy (K.E.) of a mass of air (m) moving with velocity (v) is:

$$K.E. = \frac{1}{2} m v^2$$

#### Mass Flow Rate

The mass of air passing through the swept area (A) is:

$$m = \rho \times V$$

For continuous airflow, the mass flow rate is:

$$\dot{m} = \frac{dm}{dt} = \rho A v$$

Where:
$\rho$ = Air density ($\approx 1.225$ kg/m³)
$A$ = Swept area of rotor ($A = \pi R^2$)
$v$ = Wind velocity

#### Wind Power Expression $(P_w)$

Power is the rate of change of energy:

$$P_w = \frac{1}{2} \dot{m} v^2$$

Substituting ($\dot{m} = \rho A v$):

$$P_w = \frac{1}{2} (\rho A v) v^2$$

$$Pw=12\rho Av3P_w = \frac{1}{2} \rho A v^3$$

## Wind Power Density (Pd)\left(P_d\right)

Wind power density is defined as power per unit area:

$$Pd=PwAP_d = \frac{P_w}{A}$$

Substituting ($P_w$):

$$Pd=12\rho v3P_d = \frac{1}{2} \rho v^3$$