

# **Solar Energy and Radiation Terminologies**

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# Common Energy Terms

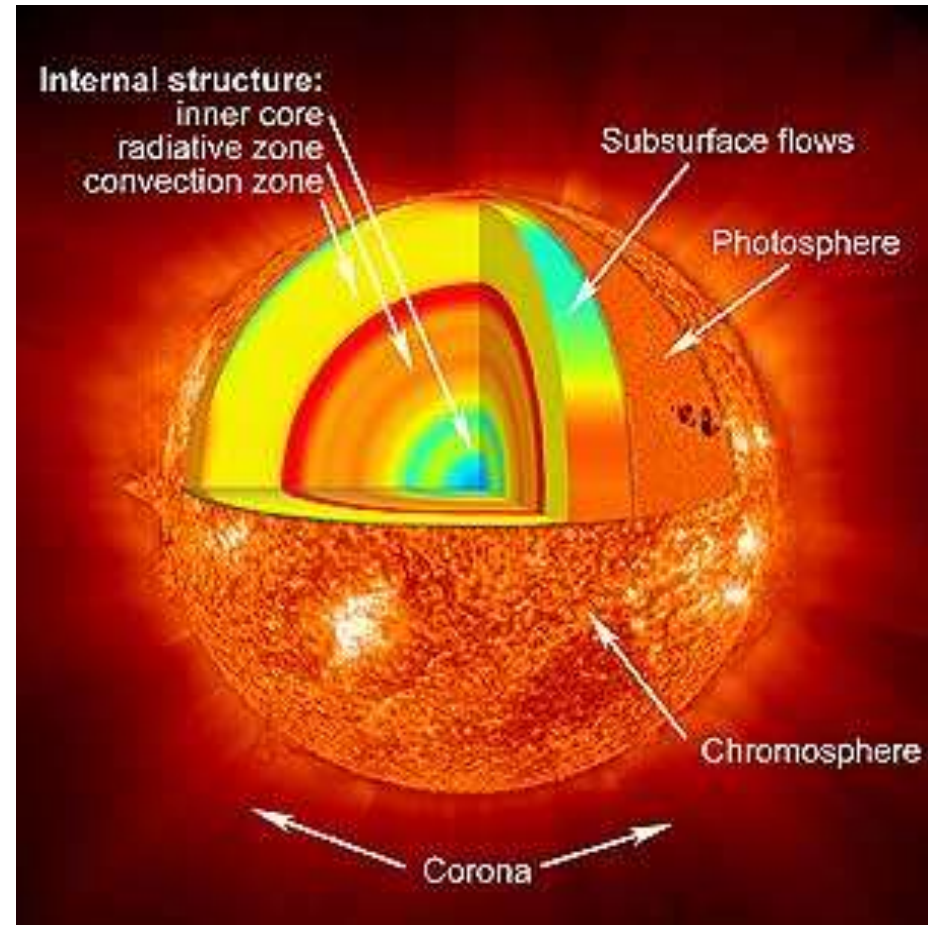
- ❖ **Energy:** Thermal, Mechanical, Electrical, Renewable Energy
- ❖ **What is Electricity?**
- ❖ **Current (Flow):** Ampere (A) = One coulomb of electrical charge ( $6.24 \times 10^{18}$  electrons) per second (C/s)
- ❖ **Voltage (Population):** Volts (V) = the difference of potential that would carry one ampere of current against one ohm resistance.
- ❖ **Power (Rating):** Watt (W) =  $V \times A = V \times C/s = \text{Joules/s}$
- ❖ kW, MW, kWh, MWh (Capacity of Plant MW or MWh?)
- ❖ PLF, kCal, Downtime, CUF, Outage
- ❖ Why W, J, V, A, M are capital?

# **Basics of Solar Energy**

# The Sun

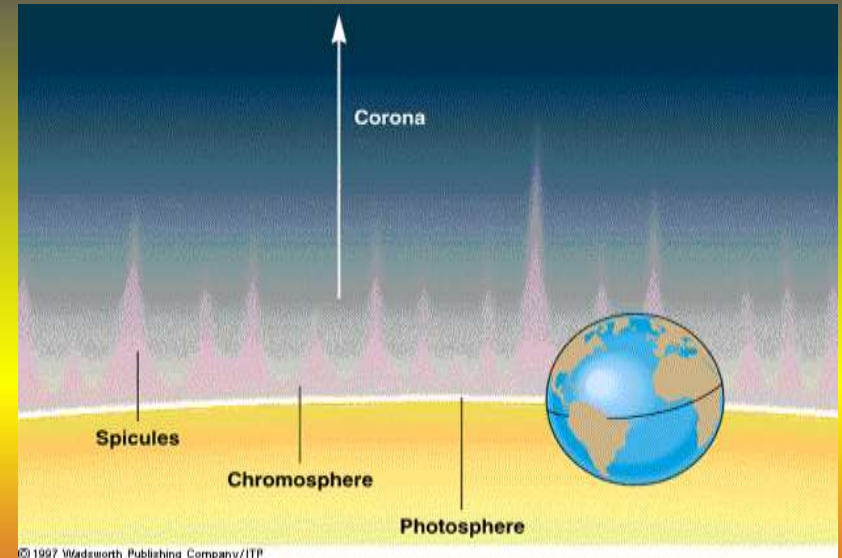
## Two Regions

- Inner layers i.e. **interior** is a sphere with radius  $R = 7 \times 10^8$  miles
  - **Inner Core**
  - **Radiative Zone and**
  - **Convection Zone**
- Outer layers i.e. **atmosphere** (from innermost to outermost)
  - **Photosphere**
  - **Chromosphere**
  - **Corona**



# The Sun: Outer Layers

- **The photosphere:**
  - 300 km thick
  - 6,000 Degree C
  - Covered by granulation
  - Visible wavelengths
- **The chromosphere:**
  - 2000 km thick
  - 10,000 Degree C
  - Ultraviolet wavelengths
  - Seen only during eclipse



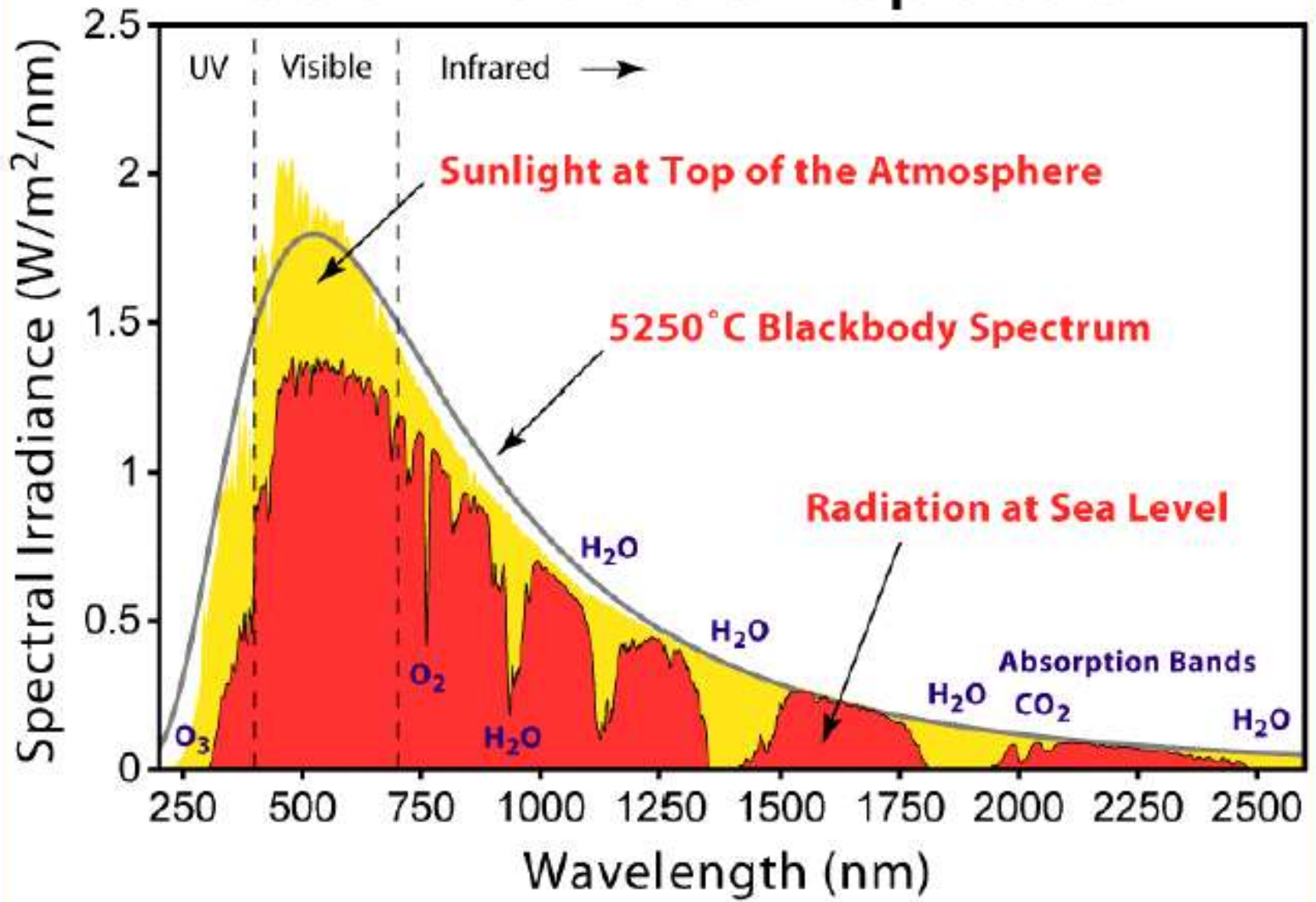
- **The corona:**
  - Outermost layer
  - Extends millions Kms
  - 5,00,000 degrees C
  - Seen only during eclipse

# Characteristics of the Sun

- **Mass (kg):  $1.989 \times 10^{30}$**
- **Diameter (km):  $1.39 \times 10^6$**
- **Mean density (gm/cm<sup>3</sup>): 1.410**
- **Mean surface temperature (°C): 6,000**
- **Age (billion years): 4.5**

- **Approximate wavelength ranges:**
  - **Ultraviolet : 200 - 400 nm**
  - **Visible : 400 - 800 nm**
  - **Near-Infrared : 800 - 4000 nm**
  - **Infrared : 4000 - 10000 nm**
- **Approximately 99% : 300 to 3000 nm**
- **Approximately 45% : 400 to 800 nm**

# Solar Radiation Spectrum



# Radiation Types

- **The Sun Emits energy:**
  - **Electromagnetic radiation**
  - **At an extremely large and relatively constant rate**
- **Utilization: Heat, Light & UV**
- **Outer space:  $1367.7 \text{ W/m}^2$**
- **On earth surface:  $1000 \text{ W/m}^2$**
- **Direct radiation**
- **Diffuse radiation**
- **Global radiation: Direct + Diffuse**



# Solar Radiation Measurements

- **Global horizontal irradiance (GHI):  
Pyranometer**
- **Total:**
- **Direct + Diffuse**
- **Useful for PV**



# Solar Radiation Measurements



- **Direct Normal Irradiance (DNI):  
Pyrheliometer**
- **Direct on perpendicular surface**
- **Useful for Reflectors, CSP**

# Solar Radiation Measurements

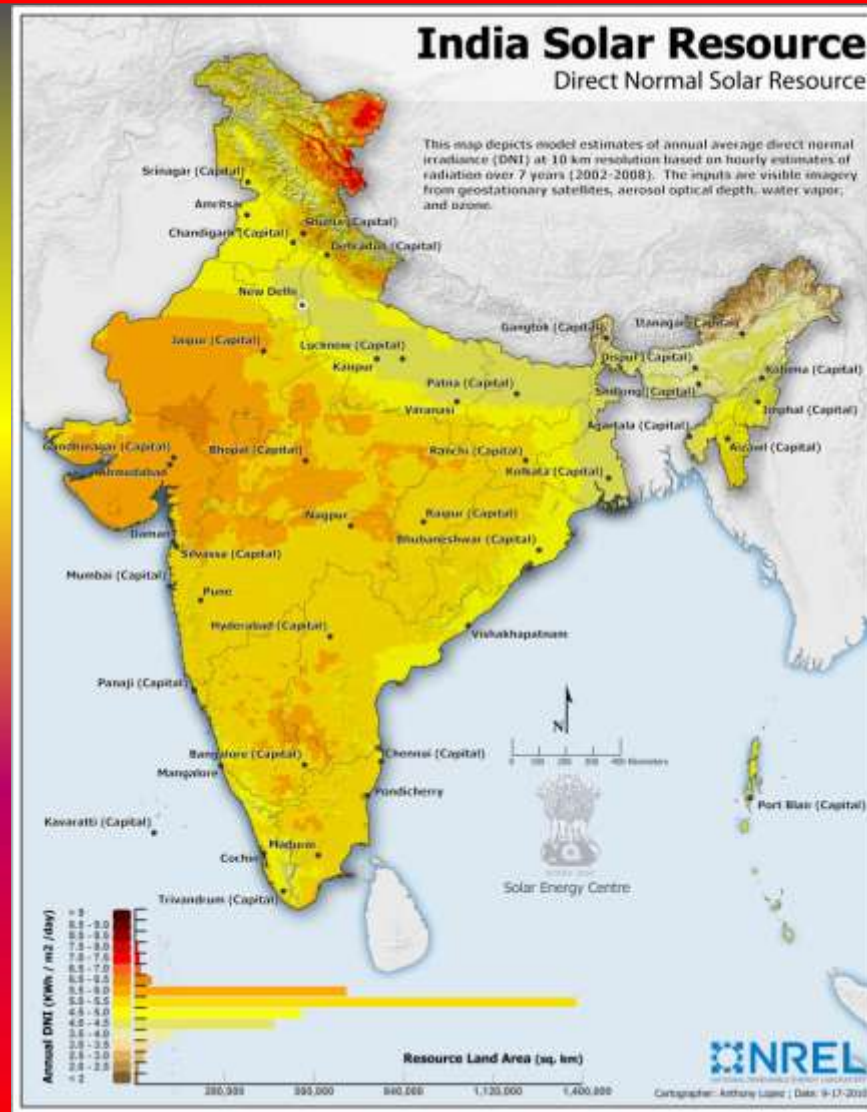
- **Solar insolation** - Total amount of solar energy received at a particular location during a specified time period
- **Unit:** kWh/m<sup>2</sup>/day
- **Power project :**
  - CSP min. 1800 kWh/m<sup>2</sup>/yr (Reported)
  - SPV min. 1500 kWh/m<sup>2</sup>/yr (Suggested)
- **Micro-grid:** No standard
- **Actual ground data:** Not always available
- **Derived data:** NASA, METONORM, GeoModel

# Solar Radiation Map: GHI



**Ideal: > 1500 kWh/m<sup>2</sup>/yr, Maharashtra: > 2000 kWh/m<sup>2</sup>/yr (Good)**

# Solar Radiation Map: DNI



**Ideal: > 1800 kWh/m<sup>2</sup>/yr, Maharashtra: > 1900 kWh/m<sup>2</sup>/yr (Avg.)**

# **Solar Radiation Terminologies**

# Solar Radiation Terminologies

- **Radiant energy:** Energy emitted in the form of electromagnetic radiation. Measured in joules (J)
- **Radiant flux:** Rate of flow of radiant energy w. r. t. time (Watt)
- **Insolation:** The actual amount of sunlight falling on a specific geographical location (**incident solar radiation**)
- **Irradiance (E):** Radiant energy incident on a surface per unit area per unit time (Watt/m<sup>2</sup>), (J/m<sup>2</sup>/sec) more popular kWh/m<sup>2</sup>/day

# Solar Radiation Terminologies

## Direct solar radiation:

- Reaches the Earth's surface without being diffused, direct beam
- Atmospheric conditions reduce:
  - 10% on clear, dry days
  - 100% during thick, cloudy days
- Measured by **Pyrheliometer**



# Solar Radiation Terminologies

## Diffuse solar radiation:

- Radiation scattered and reflected by:
  - Air molecules (Rayleigh scattering),
  - Water vapour (Mia Scattering),
  - Clouds, dust, pollutants,
  - Forest fires and volcanoes

# Solar Radiation Terminologies

## Global Radiation:

- The sum of the diffuse and direct solar radiation
- Measured by **pyranometer**
- The measured global horizontal solar irradiance is

$$I_{gh} = I_{bn} \cos \theta_c + I_{dh}$$

Where,

- $I_{bn}$  - irradiance coming directly from the sun's disk, measured normal to the rays and
- $I_{dh}$  - diffuse radiation falling on a horizontal surface
- $\theta_c$  - Solar zenith angle at the mid-time between sunrise and solar noon for the monthly average day

# Solar Radiation Terminologies

## Terrestrial radiation

- Long wave radiation emitted by the earth surface back into the atmosphere
- Most of it is absorbed by the water vapour in the atmosphere, while less than 10 % is radiated directly into space.

## Extra-terrestrial radiation

- Solar radiation outside of the earth's atmosphere
- The top of the atmosphere - 40 km from the earth's surface.

## Clearness index:

- Ratio of global horizontal solar radiation to the extraterrestrial horizontal solar radiation

$$K_T = H_{th} / H_{oh}$$

# Earth Sun Angles

## Solar altitude angle (h):

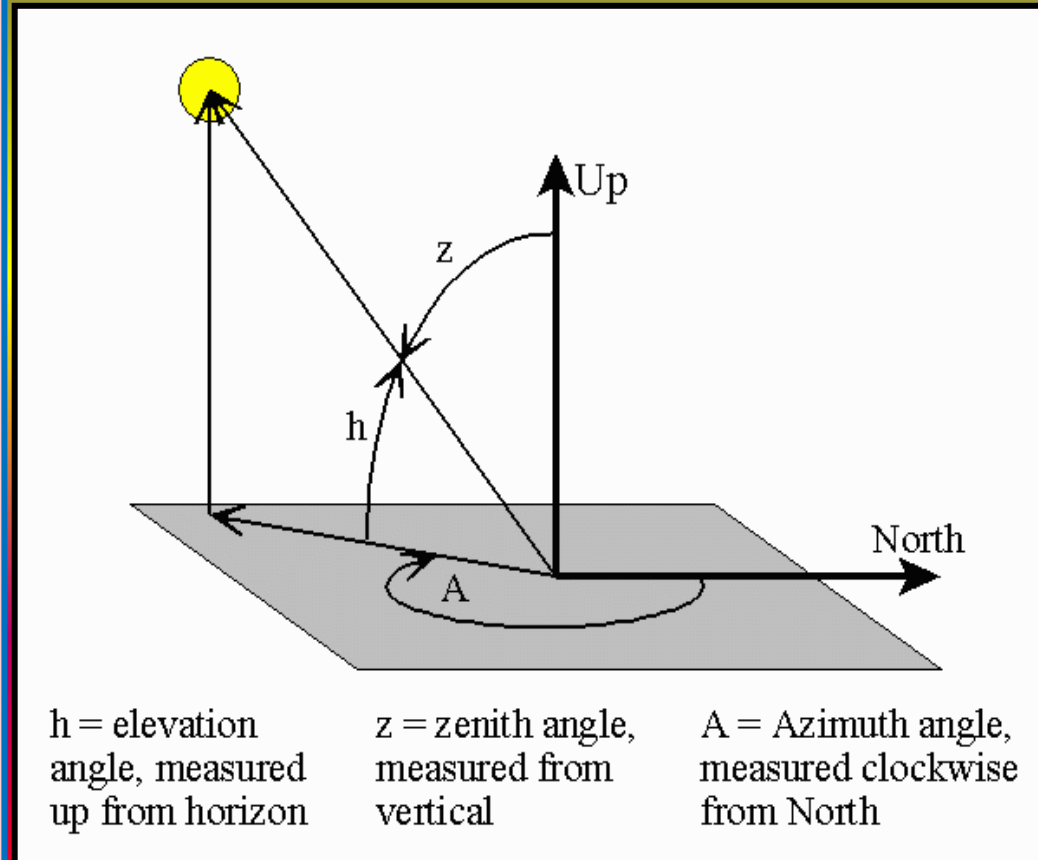
Angle between the radiation from the sun and its projection on horizontal plane.

## Zenith angle (z):

Angle between the radiation from the sun and line perpendicular to the horizontal plane

## Solar azimuth angle (A):

Angle, measured clockwise on the horizontal plane, from the north-pointing coordinate axis to the projection of the sun's central ray



# Air mass

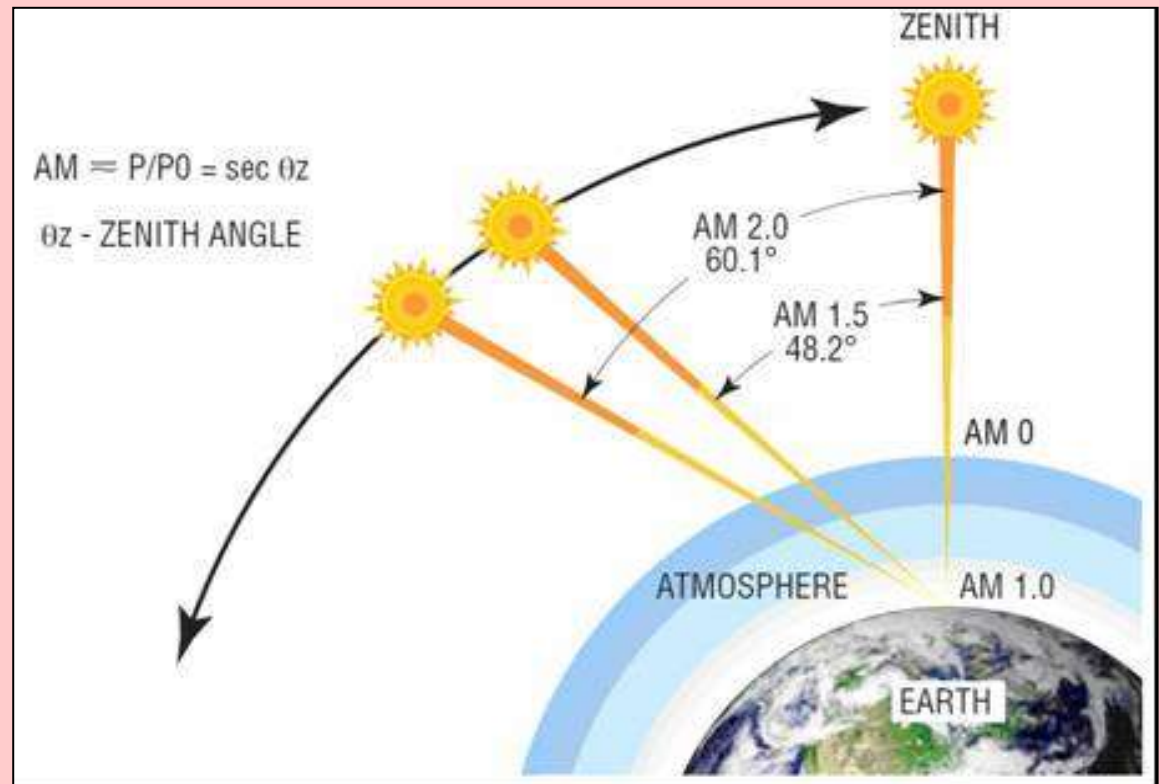
Ratio of the distance that solar radiation travels through the earth's atmosphere (path length), to the distance (path length) it would travel if the sun were directly overhead.

## Different Spectrum:

- AM 0 - Outside atmosphere
- AM 1 - At the zenith
- AM 1.5 - At 48°
- AM 2 - At 60°

## Standard Spectrum:

- AM 1.5
- 25 °C
- 1,000 W/m<sup>2</sup>
- For solar cell efficiency



# Solar Technology Options

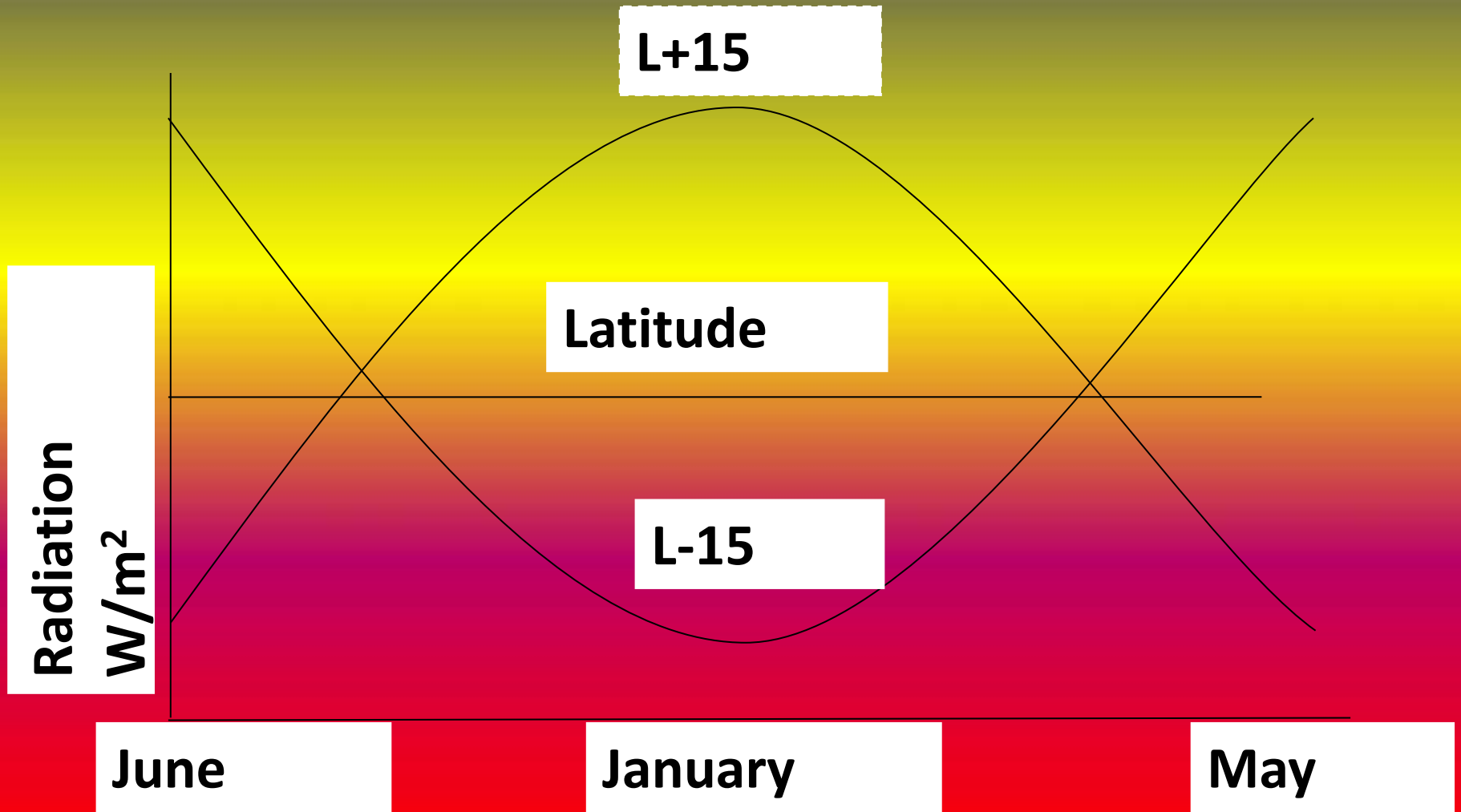
## Solar Photovoltaic Electricity Generation

- Convert sunlight falling on PV cell into D.C. electricity
- Solar Thermal Direct Application
  - Water/ air heating
  - Process steam generation

## Solar Thermal Electricity Generation

- Solar energy is focused through mirrors to heat working fluid
- Heated working fluid produce steam
- Drive a turbine-generator to produce electricity

# Winter or Summer Optimization



# THANK YOU

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