"Photovoltaics" → def: a method of converting solar radiation into DC electricity using semiconductors (or other materials) that exhibit the photovoltaic effect.

1) World Energy Sources
a. So called "Fossil Fuels" - coal, oil, natural gas
   * Oil may be "slowly" renewable: carbonates into subduction zones
b. Nuclear
c. Geothermal
d. Solar
   1. Indirect solar: bio-fuels, wind, wave, hydro/hydroelectric
   2. Direct solar: thermal, photovoltaics

2) Energy from the Sun
a. Solar "Power" reaching the Earth's outer atmosphere:
   \[ \sim 10^{17} \text{ W} = 10^8 \text{ GW} \]

   → Solar Constant → solar power reaching the Earth's atmosphere:
   \[ = 1366 \text{ W/m}^2 = 1.366 \text{ kW/m}^2 \]
   \[ \sim 30\% \text{ is lost passing through the atmosphere} \]
   → yields an insolation at Earth's surface of about 1000 W/m²
   → Defined at sea level on a clear day
   → The accepted standard for "strong sunshine"
b. Annual Mean Insolation

- Earth is a sphere with a circular solar footprint
- \( A = \pi R^2 \), \( R \equiv \text{Earth's radius} \)
- Earth is approx. a sphere: \( SA = 4\pi R^2 \), that spins
- annual mean insolation above the atmosphere is approximately \( = 1366/4 = 342 \text{ W/m}^2 \)
- However, it is shared very unequally

\[
\begin{array}{c}
\text{Over Equator} \\
\sim 90^\circ \\
\text{Earth}
\end{array}
\]

\[
\begin{array}{c}
\text{Near Poles} \\
\Theta \rightarrow \theta \ll 90^\circ \\
\text{Earth}
\end{array}
\]

1. Atmospheric Losses \( \sim 30\% \)
- absorption by atmospheric gases (wavelength dependent)
- scattering by dust and other molecules
- clouds

* Vary with local climates

Ex. Avg. insolation at Earth's surface:
- Sahara Desert \( \sim 300 \text{ W/m}^2 \)
- Near Poles \( \sim 80 \text{ W/m}^2 \)

2. If we know avg. insolation, use 8760 hrs to determine total energy received over 1 year

Ex: London/Berlin \( \rightarrow \) avg. insolation \( = 120 \text{ W/m}^2 = 1050 \text{ kWh/m}^2 \)
Sydney Aus. \( \rightarrow \) " \( = 200 \text{ W/m}^2 = 1750 \text{ kWh/m}^2 \)

Note: averaged over night/day, summer/winter

\( \therefore \) use with caution
May vary considerably from year to year

More data (from another book, different units: MJ/m²-day

Montgomery, AL: Dec: 8.16, June: 22.38

Phoenix, AZ: Dec: 10.58, June: 31.09

NY, NY: Dec: 4.58, June: 19.41