

# Introduction to Solar Radiation

## Fundamentals of PV Engineering

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Motivation

Key concepts

Definitions

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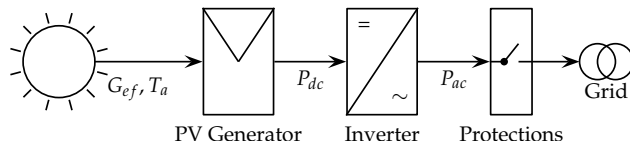
# Radiation and PV Systems

- ▶ The energy produced by a PV system depends mainly on the solar radiation incident on the PV generator.
- ▶ Consequently, the estimation of performance of a PV system in a location during a time period requires the knowledge of the available solar radiation.

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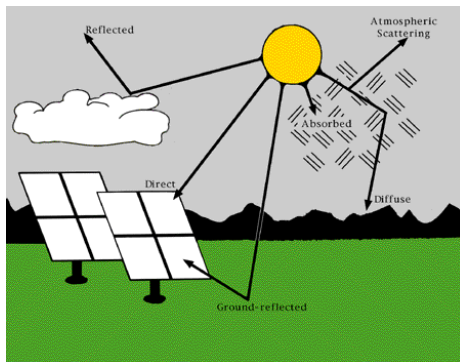
## Solar Radiation cannot be computed

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- ▶ Solar radiation reaching the earth surface is the result of **complex interactions with the atmosphere**.
- ▶ On-site measurements or satellite images are required for solar radiation estimation.

## Key concepts



# Inclination Angle

- ▶ PV generators have an **inclination angle higher than zero** to maximize the performance.
- ▶ The generator inclination angle depends on the latitude of the location and on the application\*.



\*Rule of thumb: latitude minus  $10^\circ$  for a Grid Connected PV System; latitude plus  $10^\circ$  for a Standalone PV System.

# Solar Radiation Databases

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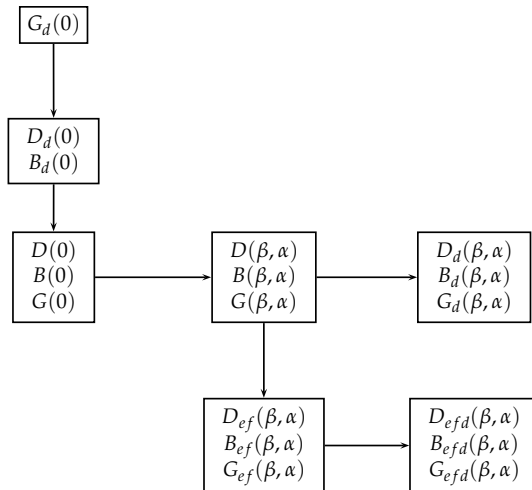
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- ▶ Therefore, it is unfeasible to maintain a database of incident solar radiation.
- ▶ Databases register solar radiation on the horizontal plane.
- ▶ Estimation of the solar irradiation **incident on the inclined plane** requires a transposition procedure.

# From Horizontal to Inclined





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# Irradiance and Irradiation

**Irradiance** solar radiation **power** received by a surface per unit area.

- ▶ Units:  $\text{W m}^{-2}$ ,  $\text{kW m}^{-2}$

**Irradiation** solar radiation **energy** received by a surface per unit area.

- ▶ Units:  $\text{Wh m}^{-2}$ ,  $\text{kWh m}^{-2}$
- ▶ Hourly irradiation, Daily irradiation, Monthly irradiation ...

# Extraterrestrial Solar Radiation

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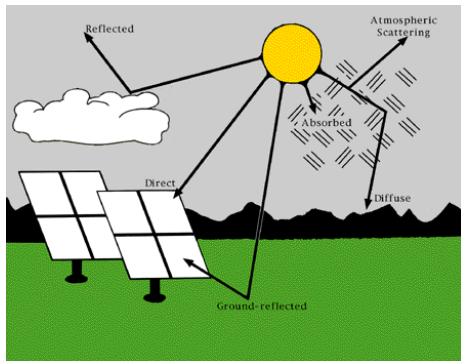
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- ▶  $B_0$ : Solar radiation energy/power at the top of the Earth's atmosphere on a surface perpendicular to the solar rays.
- ▶  $B_0 \simeq 1367 \text{ W m}^{-2}$  (Solar Constant)
- ▶  $B_0(0)$ , extraterrestrial irradiance on a horizontal plane, can be computed by analytical means.
  - ▶ Depends on the latitude, day of the year, hour of the day.

# Interaction with the Atmosphere

Due to the interaction with the atmosphere, the extraterrestrial radiation is absorbed, reflected and scattered.



# Diffuse, Beam, and Global

- ▶ Solar radiation reaching the Earth surface is named **global solar radiation**.
- ▶ It is the result of three components:
  - ▶ **Beam Radiation**: solar radiation traveling on a straight line from the sun to the receiving surface.
  - ▶ **Diffuse Radiation**: solar radiation scattered by the atmosphere. It is emitted from all directions of the sky.
  - ▶ **Albedo or Reflected Radiation**: solar radiation reflected by the ground.

$$G = B + D + R$$

# Horizontal, Incident, Effective

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- ▶  $G(0)$  **Radiation on a Horizontal Plane**
  - ▶ Measurements from ground stations, or satellite images.
- ▶  $G(\alpha, \beta)$  **Radiation incident on an Inclined Plane**
  - ▶ Transposition from radiation on the horizontal plane.
- ▶  $G_{ef}(\alpha, \beta)$  **Effective Radiation incident on a PV module**
  - ▶ Reflectance and transmittance of the PV module depend on the angle of incidence.
  - ▶ Dirt losses.