Chapter 02: Decentralized electricity production

Lecture 03

II.7 Renewable energy sources

II.7.1 Solar energy

A- Definition

Solar energy originates from the sun, where nuclear fusion reactions produce vast amounts of radiant energy. This energy travels through space in the form of electromagnetic radiation.

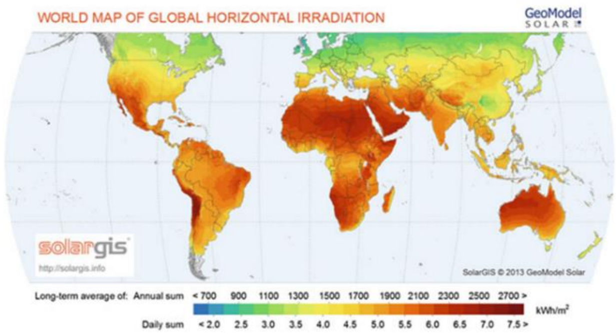

Figure.1 Global solar radiaion.

B- Solar radiation types

Solar radiation comes in various types based on its interactions with the Earth's atmosphere as follows:

- Direct Solar Radiation;
- Diffuse Solar Radiation;
- Reflected Solar Radiation;
- Global Solar Radiation.

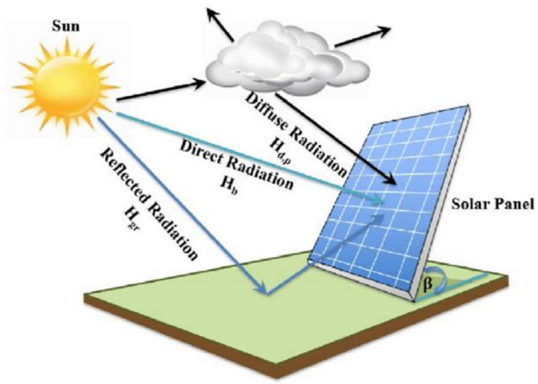

Figure.2 Solar radiation types.

C- Solar radiation measurements

Solar radiation is assessed through measured solar irradiance (instantaneous power per area) and solar insolation (energy per area over a specified time).

1- Solar irradiance:

Solar radiance, in kW/m², varies from 0 kW/m² at night to a maximum of about 1 kW/m² during the day. Measurements, taken with **pyranometers or pyrheliometers**.

Solar irradiance is used in more complex PV system performance calculations, assessing system performance at each point in the day.

2- Solar insolation:

representing total solar energy received over a specified time (often in kWh/(m² day)), is more commonly used in system design.

Solar insolation differs from solar irradiance as it averages instantaneous solar irradiance over a specific period.

Solar insolation data is applied in simpler PV system designs.

D- Solar thermal technology

- Example: Solar Water Heating Systems:

- Description: Solar water heaters use sunlight to heat water for domestic or industrial purposes. These systems typically consist of solar collectors, a heat transfer system, and a storage tank.

- Application in Decentralized Production: Solar water heating systems are commonly employed in homes, hotels, and industries to meet hot water demands.

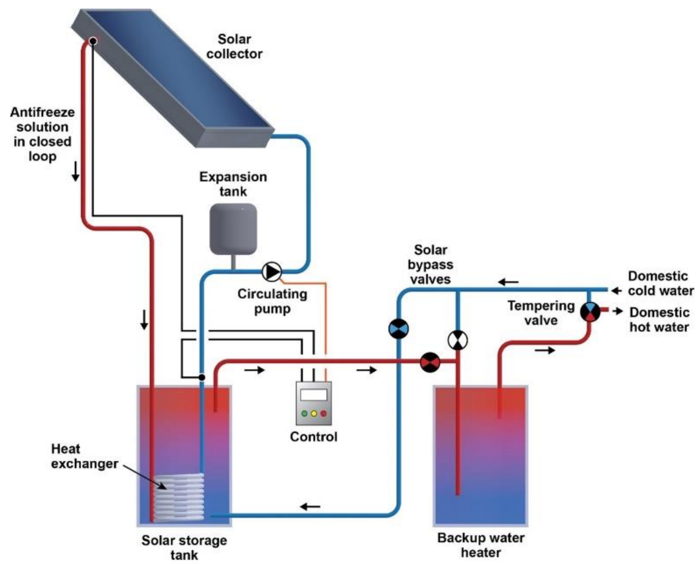

Figure.3 Water heating system.

E- Solar Photovoltaic (PV) technology

- Example: Photovoltaic (PV) Systems:

- Description: PV systems directly convert sunlight into electricity using semiconductor materials in solar cells. These systems are highly modular and can be installed on rooftops, in solar parks, or as part of small-scale, off-grid installations.

- Photovoltaic effect:

The photovoltaic effect is a process that converts light (photons) into electricity in photovoltaic cells, commonly known as solar cells.

- Used Atoms:

Silicon is a commonly used semiconductor material in photovoltaic cells. Silicon has four valence electrons, and it forms a crystal lattice structure. In the context of photovoltaics, silicon is often doped with specific atoms to create the necessary electrical characteristics.

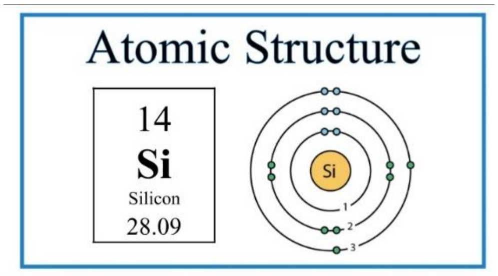

Figure.4 Silicon atomic structure.

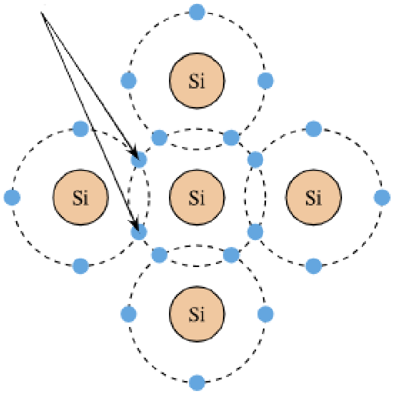

Figure.5 Silicon particles.

The photovoltaic cell typically consists of an **N-type** (negatively doped) and a **P-type** (positively doped) semiconductor material, forming a PN junction.

In the **N-type** material, an atom such as **phosphorus** is introduced as a dopant, providing extra electrons.

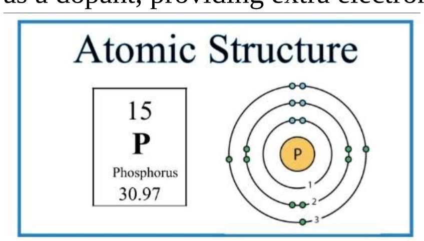

Figure.6 Phosphorus atomic structure.

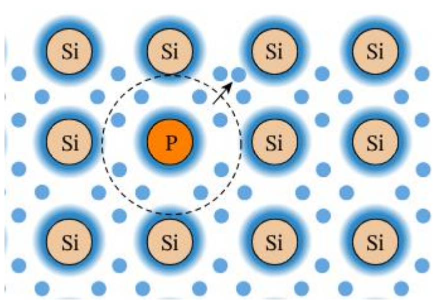

Figure.7 N-type particles.

In the **P-type** material, an atom such as **boron** (Group III element) is introduced as a dopant, creating holes or vacancies for electrons.

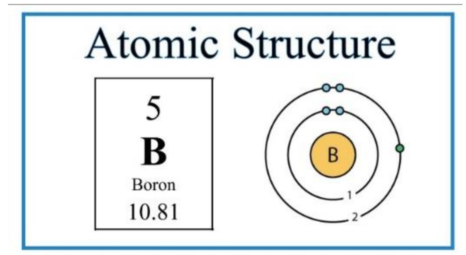

Figure.8 Boron atomic structure.

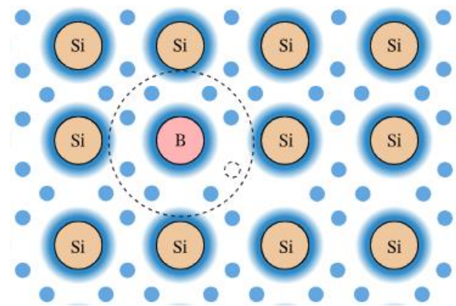

Figure.9 P-type particles.

- Depletion Layer Formation:

The junction between the N-type and P-type materials forms a depletion layer where charge carriers (electrons and holes) are depleted due to diffusion and recombination processes.

- Recombination and Ion Formation:

When photons (light particles) strike the semiconductor material, they can generate electron-hole pairs through the absorption of energy.

Electrons excited by the absorbed photons move to the conduction band, creating free electrons. This process is known as electron-hole pair generation.

- Electric Field and Charge Separation:

The recombination process creates an electric field within the depletion layer, separating charges and creating a potential difference. The electric field prevents further diffusion of electrons from the N-type to the P-type and holes from the P-type to the N-type. When an external circuit is connected to the photovoltaic cell, the separated charges create a current as they flow through the circuit, producing electrical power.

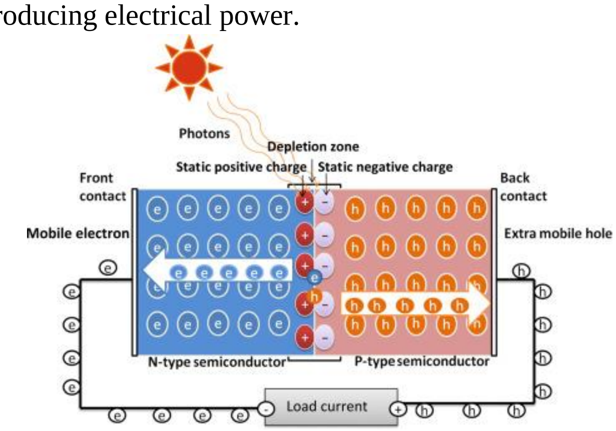

Figure.10 Illustration of PV effect.