RENEWABLE ENERGY

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About the Tutorial

Renewable energy is a term used to refer to forms of energy that are naturally obtained from the environment and from sources that can be replenished naturally. These include solar energy, wind energy, geothermal energy, hydropower, and biomass.

This tutorial explains the basic concepts of each form of renewable energy and the efficiency of each form.

Audience

This tutorial is meant for all those readers who want to learn the basic concepts of renewable energy, its sources, production, and utilization.

Prerequisites

It is a very basic introductory tutorial. Any student who wants to gather knowledge on Renewable Energy and its sources can go through the tutorial.

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1. Renewable Energy – Introduction

Renewable energy is a term used to refer to forms of energy that are naturally obtained from the environment and from sources that can be replenished naturally. These include solar energy, wind energy, geothermal energy, hydropower, and biomass.

The term renewable energy should not be confused with alternative energy, which describes sources of energy outside the regular forms like gasoline that are considered more environment-friendly or less harmful.

Advantages of Renewable Energy

Advantages of using renewable sources of energy are-

- Less maintenance cost as most sources entail few or no moving parts, hence, less mechanical damages.
- They are economical and can cut costs spent on fossil fuel.
- They emit little or no waste in the environment.
- Renewable energy sources do not deplete. Therefore, these have a better prospect for the future.

Sources of Solar Energy

This tutorial explains five major sources of renewable energy. Each source will be reviewed briefly, although detailed discussion will be provided in the subsequent chapters.

- **Solar energy:** Energy from the Sun is referred to as solar energy. Solar energy could be used as either active solar or passive solar. Active solar is directly consumed in activities such as drying clothes and warming of air. Technology has provided a number of ways to utilize this abundant resource.
- **Geothermal energy:** This refers to heat energy stored under the ground for millions of years through the earth formation. It utilizes a rich storage of unutilized thermal energy that exists under the earth's crust.
- **Hydro-power:** This is a major renewable energy source used all over the world today to produce electricity.
- **Wind energy:** In ancient times, wind energy was used to move ships by impacting on the sails.
- **Biomass energy:** In energy generation, it refers to waste plants that are utilized to generate energy by combustion.

Part 1: Solar Energy

2. Solar Energy – Introduction

Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat.

Solar technology can be broadly classified as-

- **Active Solar:** Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Active solar is directly consumed in activities such as drying clothes and warming of air.

- **Passive Solar:** Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Conversion of Solar Energy

The solar energy is the energy obtained by capturing heat and light from the Sun. The method of obtaining electricity from sunlight is referred to as the Photovoltaic method. This is achieved using a semiconductor material.

The other form of obtaining solar energy is through thermal technologies, which give two forms of energy tapping methods.

- The first is solar concentration, which focuses solar energy to drive thermal turbines.

- The second method is heating and cooling systems used in solar water heating and air conditioning respectively.

The process of converting solar energy into electricity so as to utilize its energy in day-to-day activities is given below-

- Absorption of energy carrying particles in Sun's rays called photons.

- Photovoltaic conversion, inside the solar cells.

- Combination of current from several cells. This step is necessary since a single cell has a voltage of less than 0.5 V.

- Conversion of the resultant DC to AC.

In the next chapter, we will learn the Photovoltaic method of converting solar energy into electricity.

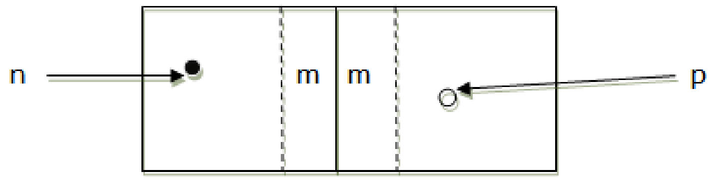
3. Solar Energy – Photovoltaic Effect

It is essential that we have some basic knowledge of PN Junctions before moving on to learn the concept of Photovoltaic Effect.

The PN Junction

The PN Junction was invented by Russell of Bell laboratories in the USA. It refers to a junction between two semiconductors, that is, P-Type and N-type. Russell discovered that the two semiconductors have an interesting behavior at the junction that causes conduction in one direction only.

A P-type semiconductor has holes (absence of electron) as majority charge carriers. An N-type semiconductor has electrons as majority charge carriers.



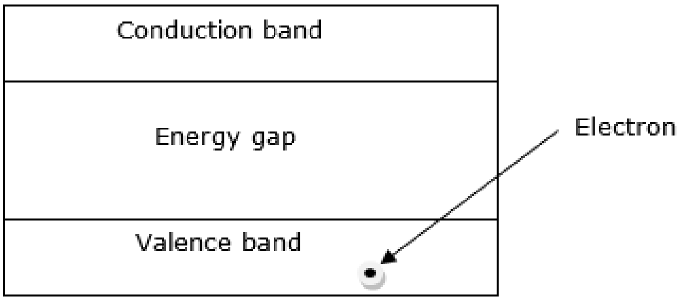
In the diagram given above, at the junction:

- Extra charges diffuse across to the opposite junctions such that the positive on the p-side gain negative charges and neutralize them.
- Similarly, the negatives at the N-side gain positive charges and neutralize them.
- This forms a margin (m) at either side where extra charge are depleted to make this region neutral and at a state of equilibrium. This region is referred to as a **depletion layer** and no charge from either side crosses.
- The depletion layer offers a potential barrier and thus requires external voltage to overcome it. This process is called **biasing.**
- To conduct, in **forward biasing**, the applied voltage should pump electrons (negative) from n-junction towards the p-side of the junction. Continuous flow of current guarantees a constant movement of electrons to fill holes, hence conduction across the depletion layer.
- Reversing the applied voltage, in a process called **reverse biasing**, causes holes and electrons to drift apart, increasing the depletion layer.
- An external load is connected to a solar cell with positive terminal connected to the N- side wafers and the negative terminal to the P- side wafers. A potential difference is created by **photovoltaic** effect.

The current obtained by electrons displaced by photons is not sufficient to give significant potential difference. The current is therefore contained to cause further collisions and release more electrons.

Photovoltaic Effect

A solar cell utilizes the concept of a p-n junction in capturing the solar energy. The following figure shows the fermi level of a semiconductor.



For a semiconductor to conduct, electrons must cross the energy gap from the valence band to the conduction band. These electrons require some energy to dislodge and move across the valence gap. In solar cells, photons emitted from the Sun provide the required energy to overcome the gap.

A photon incident on the surface could be absorbed, reflected, or transmitted. If it is reflected or transmitted, it does not help dislodge an electron and is thus wasted. Therefore, a photon must be absorbed to provide the energy required to dislodge and move electrons across the valence gap.

If E_{ph} is the energy of a photon and E_G is the threshold energy to cross the energy gap, then the possible outcomes, when photon hits the surface of a semiconductor are-

- **$E_{ph} < E_G$:** In this case, the photon does not attain the threshold and will just pass through.
- **$E_{ph} = E_G$:** The photon has the exact threshold to dislodge an electron and create a hole electron pair.
- **$E_{ph} < E_G$:** The photon energy surpasses the threshold. This creates an electron-hole pair, though it is a waste, since the electron moves back down the energy gap.

Absorption of solar radiation

In most cases, absorption coefficient of the semiconductor is used to determine the efficiency of absorbing energy from Sun. Low coefficient means poor absorption. Therefore, how far a photon goes is a factor of both absorption coefficient (α) and wavelength of the radiation (λ).

$$\alpha = \frac{4\pi k}{\lambda}$$

Where, k is the extinction coefficient.