Solar Energy

- The sun is a sphere of intensely hot gaseous matter, having its core similar to thermo-nuclear fusion reaction. As a result, it emits continuously heat energy as a by- product when hydrogen atoms are converted to helium atoms. Sun like any other block body radiates this heat energy in all directions in the cosmosphere. The basic concept of nuclear fusion is to produce a heavier nucleus by fusing or combining two nuclei of lower mass. The core of the sun is a continuous nuclear fusion reaction, where four protons of Hydrogen are converted into one Helium nucleus. In fact, the total mass of this Helium nucleus is less than the mass of four Hydrogen protons. This means some amount of mass is lost in the reaction and is converted into Energy. To put it in a nut-shell, for every conversion of four protons of Hydrogen (total combined mass 4.0304) into one Helium Nucleus (mass is 4.0027) an amount of 0.0277 mass units of matter is lost in the form of heat energy. In fact, this is in accordance with the famous mass and heat energy relation expressed as E = mc2 of Einstein. Here E = Energy; m=mass & c = velocity of light. This is the energy sun radiates and sustains the fauna and flora on earth caused by various seasonal changes.

❑ The structure of the sun can be divided into three regions as

(a) Interior or core of sun

(b) Solar photosphere

(c) Solar atmosphere.

(a) Solar core is the fusion reactor from where 90% of the Sun’s energy is generated. This core alone constitutes 40% of the total mass of the sun. The pressure in this region will be in the order a billion atmosphere and temperature in the range of 8 x 106 to 40 x 106 k. The density is almost 100 times to that of water.

(b) Solar photosphere is the zone from which light and heat are emitted out of sun. This indicates that the → interior core of sun is separated by this photosphere by a zone where there should be a drop in the density to facilitate radiation. This portion is known as convective zone and it is estimated that about 60000 K drop in temperature with concurrent drop in density to a tune of 10–8 g/cm3 occur.

(c) This chromosphere is named due to its red colour, a gaseous field of 10,000 km in thickness. This zone alone contributes to the total energy emitted by sun a factor of 10–3.

Apart from these three zones, there is a zone generally visible during eclipses, as a whitish layer. This is known as Corona. This contains low density mass with highly ionized gaseous mixture.

Schematic Expression of Sun's Structure

As every one knows, earth rotates around sun in a elliptical orbit, which is nearly circular. As a result, the distance from Sun and earth varies only a maximum of 3% to the mean distance which is 150x106 km. The radiation reaching the earth surface has to pass through its atmosphere. As a result, quality of radiation may vary along with energy content when measures above the atmosphere and when compared with radiation measuring on the surface of the earth (at sea level this radiation energy at mid noon is 1 kw/m2). The radiation energy above the atmosphere is calculated as 1.353 kw/m2, which is generally referred as solar constant in outer space when earth is at mean distance from the sun. This indicates that, solar constant is higher than the energy received on earth which is due to the atmosphere and the behaviour of the light passing through the same.

❑ Behavior of Solar Energy Radiation in the Atmosphere:

Radiation from sun without undergoing any change in direction or so, that reaches the surface of the earth is known as **direct or beam** radiation. The distance travelled by this direct radiation in the atmosphere is equal to the mass of the atmospheric gaseous mass and is generally known as "air mass". Otherwise, to put it in a layman's language, the air mass is the ratio of the path of direct beam in the atmosphere to the beam traveled when sun is overhead to the observer. However, in the atmosphere, due to the presence of different gases, vapour, particles of matter/dust, etc., the direct beam upon reaching the atmosphere will change its direction due to the phenomena of absorption and scattering. In the atmosphere, the solar radiation undergoes absorption of short-wave ultra-violet rays by ozone layer and long-wave infra-red rays by carbon dioxide, vapour and others. Similarly, the above said substances also scatter the radiation in the atmosphere, a part of which finally reaches the earth. Hence, total terrestrial radiation means, the radiation received through beam and diffuse radiation due to scattering.

This total radiation falling on earth's surface will be around 5-7 kwh/m2 or + 6000 kcal/m2/day. India has a total land mass area measuring to 3.28 x 1011 square meters. At least if 1% of this radiation is utilized by employing solar devices with as little as with just 10% efficiency can yield us 492 x 109 kwhr / year of electricity. This clearly indicates the task before us to tap this energy for the betterment of public life needs innovation, commitment and to adopt the required life styles to suit the solar energy utilization. In fact, solar energy is clean, efficient and environment friendly, thus making the technologies also to fall the same suit, where human settlements enjoy the ever ending source of energy.

Even though it is in exhaustible source of useful energy, the major drawback to the extensive application of solar energy are.

1. Intermittent and variable manner in which it arrives at the earths surface
2. Large area required to collect the energy at useful rate.

❑ Principles Behind Solar Heat Energy Utilization :

Solar radiation from Sun's surface is subjected to three basic phenomena called Conduction; Radiation and Convection: when the heat of the said electromagnetic waves is to be transferred to other substances. Solar energy devices are designed based on these three principles of heat transfer. As a result, the devices on which the sun rays are trapped also radiate a portion of the energy based on the characteristics of its surface area or so. While designing solar energy devices, all these issues are to be taken in to consideration.

A. Radiation: By and large, heat/energy transfer is in the space or through a medium by means of Electromagnetic waves. This means, if two bodies are separated by a distance, and when temperature difference exists, the body with higher temperature radiates the energy towards the lower side through a medium or space. A perfect radiator (black body) emits its radiant energy from its surface at the rate q as expressed by

q = As T4

Where,

- A = Area of the body
- T = Absolute temperature OK
- s = is constant equal to 56.7 x 10-9w/m2.k4 (This is also known as Stefan Boltzmann's constant)

Exactly the sun is doing this job by radiating the energy through space to earth. Hence the energy radiated in this fashion is known as “Radiant Heat”. The intensity of radiant heat is directly proportional to absolute temperature of the body that eminates the energy. In the case of our solar devices, a major portion of the energy received from sun is absorbed by the surface/solar collector. This characteristic incident radiation absorbed is known as “Absorbivity”. The energy reflected back is known as “Reflectivity” (reflectivity of a substance depends on its characteristics surface, wavelength and direction of the radiation) and the portion being allowed to be transmitted is “Transmissivity”. Transmissivity is a function of wave length and the angle of incidence of the incoming radiation. That means, a surface with ‘0” transmissivity is known as opaque since both absorbivity and reflectivity are equal to the total incidence radiation. If transmissivity is more or less equal to total radiation, indicates that the surface or material is totally transparent or partial or so on based on its degree of transmissivity. If I denotes the total incident radiation per unit time per unit area of a surface, and Ia, Ir and It represent respectively the amount of radiation absorbed; reflected and transmitted; then relationship can be expressed as:

This indicates that $Ia + Ir + It = I$

B. Conduction: This heat transfer mainly relates to the transfer of heat in solid substances from one place to the other place due to the existence of temperature difference. In solar thermal energy utilization the conduction of heat and transfer are very important since we use solid metallic and non-metallic substances.

The basic conduction equation is:

Where,

q = the rate of heat transfer (conduction)

K_x = is the characteristics thermal conductivity of the material used in direction x

A = the area covered in the direction of heat flow

σT = the temperature gradient (difference in the direction of flow)

C. Convection: In moving substances, the molecules of the fluid (water, air, etc) either gain or loose the energy due to radiation or conduction. However, this gain or loss of energy is carried by the flow of fluids from one place to the other. This phenomena is known as convection. The rate of heat transfer by convection qc between a surface and a fluid can be calculated from the relation;

$$qc = hc .A (Ts – Tf)$$

Where,

A = Base area of heat transfer by convection is m2

T s = Surface temperature OC

T f = Fluid temperature OC

h c = is convection heat transfer coefficient kCal/hr/m2 OC

The solar energy can be utilized directly and indirectly in different ways which has been listed below

- **<u>The direct way of using solar energy are</u>**
  (i) Solar thermal technology through solar collectors
  (ii) Photo voltaic energy conversion technology
  (iii) Solar hydrogen gas production technology.

- **<u>The indirect way of using solar energy are</u>**
  (i) Wind energy through wind mills
  (ii) Biomass through energy plantation
  (iii) Biogas through Biogas plants
  (iv) Tidal wave energy.

❑ Applications of Solar energy:

1. Heating and Cooling of buildings
2. Solar water and air heating
3. Salt production by evaporation of seawater
4. Solar distillation
5. Solar drying of agricultural products
6. Solar cookers
7. Solar water pumping
8. Solar refrigeration
9. Electricity generation through Photo voltaic cells
10. Solar furnaces
11. Industrial process heat
12. Solar thermal power generation