Introduction

Energy sources

Energy is the capacity of a physical system to perform work. Energy exists in several forms such as heat, kinetic or mechanical energy, light, potential energy, electrical, or other forms. Energy is the ability to do work. Energy sources could be classified as Renewable and Non-renewable.

1. Renewable Energy
    i. Solar Energy
    ii. Wind Energy
    iii. Biomass and Biofuels
    iv. Water and geothermal
2. Non-Renewable energy
3. Related Resources

Need for non-conventional energy sources

The average rate of increase of oil production in the world is declining& a peak in production may be reached around 2015. There after the production will decline gradually & most of the oil reserves of the world are likely to be consumed by the end of the present century. The serious nature of this observation is apparent when one notes that oil provides about 30% of the world's need for energy from commercial sources & that oil is the fuel used in most of the world's transportation systems.

The production of natural gas is continuing to increase at a rate of about 4% every year. Unlike oil, there has been no significant slowdown in the rate of increase of production. Present indications are that a peak in gas production will come around 2025, about 10 years after the peak in oil production.

As oil & natural gas becomes scarcer, a great burden will fall on coal. It is likely that the production of coal will touch a maximum somewhere around 2050.

Finally, it should be noted that in addition to supplying energy, fossil fuels are used extensively as feed stock material for the manufacture of organic chemicals. As resources deplete, the need for using fossil fuels exclusively for such purposes may become greater.

India's production & reserves of commercial sources:

***Coal*:** Coal is the end product of a natural process of decomposition of vegetable matter buried in swamps & out of contact with oxygen for thousands of years. The word 'coal' denotes a wide variety of solid fuels. The varieties in approximate order of their formation are peat, lignite, bituminous & anthracite coal.

The rate of production of coal in India over the last 50 years is shown in fig (a). It can be seen that there has been an eleven-fold increase in production from 1951 to 2004 & that the average annual growth rate has been about 4.5%. In 2000, India's production was 300mt, which was about 6.7% of the world's production. India has fairly large reserves of coal

Fig.1. Annual production of coal in India [production rate (Mt/Year] v/s Year

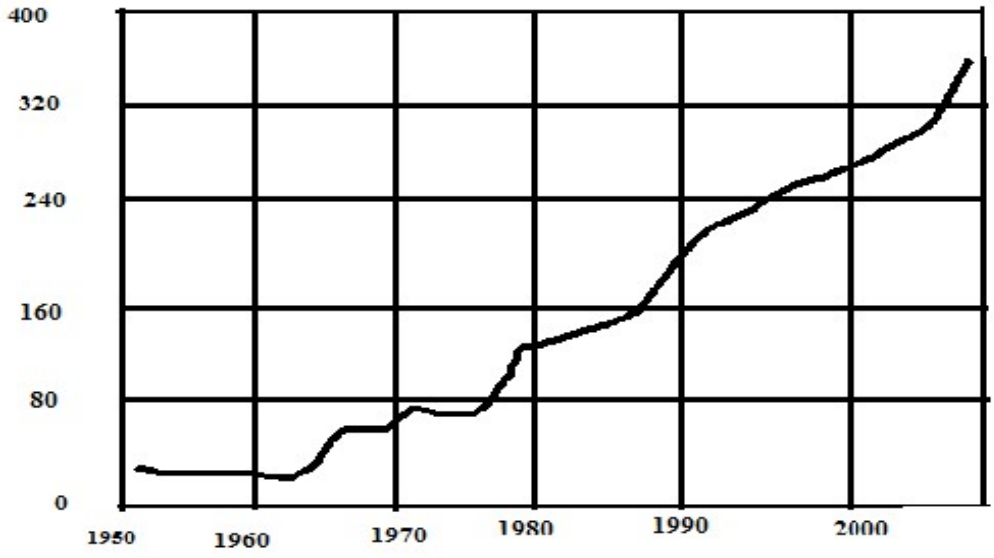


Table 1: Coal reserves in India (in Mt)

Year	Proved reserves	Indicated & inferred reserves	Total reserves (Resources)
1972	21360	59590	80950
1981	27912	87490	115402
1985	35030	120870	155900
1992	64800	129000	193800
2006	95866	157435	253301

***Oil*:** The below fig.2. Represents presents data on the annual consumption of petroleum products in India (curve 3) from 1951 onwards. It also shows the variation in the domestic production of crude oil (curve 1) & the import of crude (curve 2) over the years.

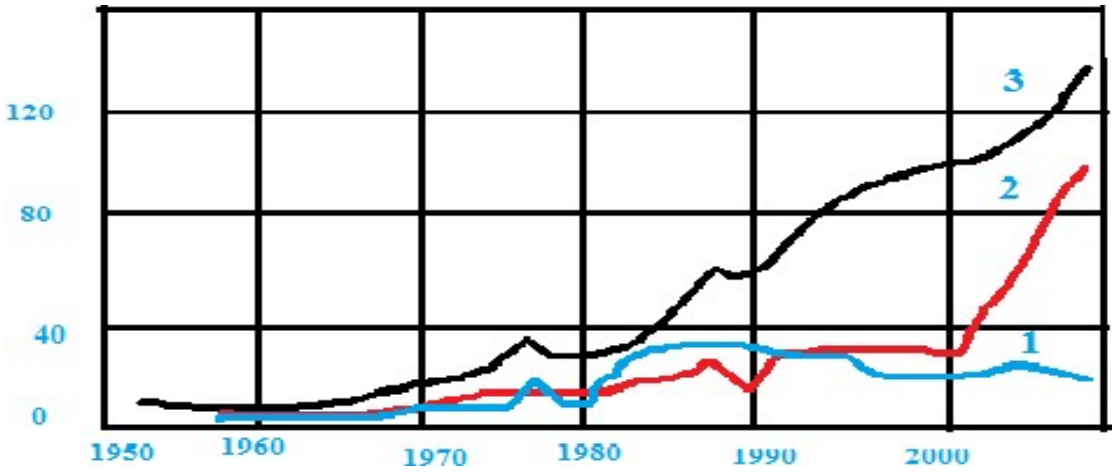


fig.2. Annual production, import & consumption of oil in India [Production Rate (Mt/Year) v/s Year]

Curve 1. Domestic production of crude, *Curve 2*. Import of crude, *Curve 3*. Consumption of products

Natural gas: presents data on the annual useful production of natural gas in India from 1969 onwards. In 1969, the production was only 0.516 billion m^3. It did not change much till 1973. However, subsequently the production increased rapidly. It was 8.913 billion m^3 in 1989, 13.5% from 1989 to 1997 & 3.1% from 1997 to 2005.

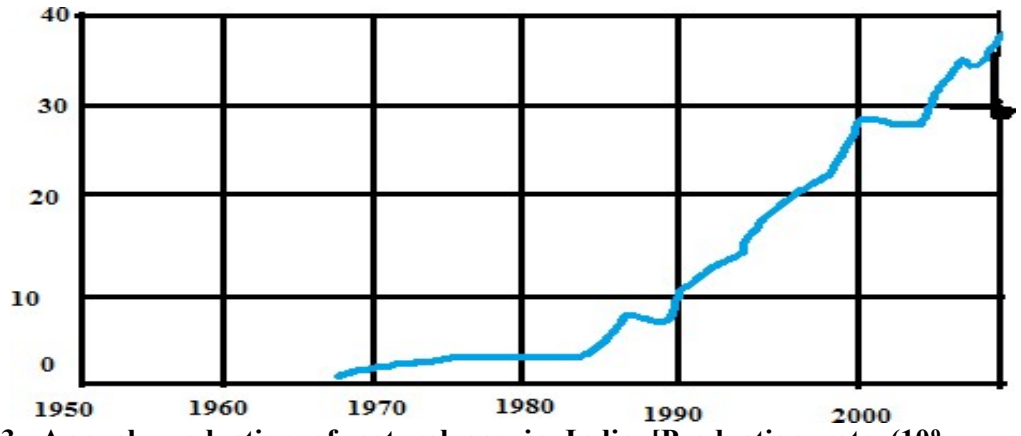


Fig.3. Annual production of natural gas in India [Production rate (10^9 m^3/Year) v/s Year]

Energy Alternatives

SOLAR ENERGY:

- Solar energy is a very large, inexhaustible source of energy. The power from the Sun intercepted by the earth is approximately **1.8x10^11 MW** which is many thousands of time larger than the present consumption rate on the earth of all commercial energy sources.
- Solar energy is received in the form of radiation, can be converted directly or indirectly into other forms of energy, such as heat & electricity. This energy is radiated by the Sun as electromagnetic waves of which 99% have wave lengths in the range of 0.2 to 4 micro meters.
- Solar energy reaching the top of the Earth's atmosphere consists about 8% U.V radiation, 46% of visible light, 46% Infrared radiation.

Merits of solar energy:

- It is an environmental clean source of energy
- It is free & available in adequate quantities in all most all parts of world where people live.

Demerits of solar energy:

- It is a dilute source of energy because even in hottest region the radiation flux is available only 1 KW/m2 & total radiation over a day is 7 KW/m2. These are low values from the point of view of technological utilization.
- It is required large collecting areas are required in many applications & these results increase of cost.

Solar applications:

Solar heating
Solar cooling
Solar pumping
Solar furnace
Solar production of hydrogen

Thermal Energy:

Thermal energy refers to the internal energy present in a system in a state of thermodynamic equilibrium by virtue of its temperature. The average transitional kinetic energy possessed by free particles in a system of free particles in thermodynamic equilibrium. This energy comes from the temperature of matter.
Thermal energy is the total energy of all the molecules in an object.

The thermal energy of an object depends on the 3 things:

1. The number of the molecules in the object
2. The temperature of the object (average molecular motion)

3. The arrangement of the object molecules (states of matter)

There are 3 modes of thermal energy
1.Conduction 2. Convection 3. radiation

Conduction: Heat is transferred from one molecule to another without the movement of matter.

Convection: Fluids (liquids & gases) transfer heat by convection, a process that causes mixing of the warmer regions with the cooler regions of liquid or gas.

The main difference between convection & conduction is that convection involves the movement of matter & conduction does not.
Radiation: it is the transfer of energy by electromagnetic waves.

ADVANTAGES:

- It is eco friendly
- Renewable sources
- No/less pollution
- By using this produce electricity
- Its help full for oil refining in Industry & home heating

DISADVANTAGES:

- Producing greenhouse gas
- Collecting of energy is a big problem, it requires sophisticated technology hence cost is more.

Applications:

- Steam engine
- Gasoline engine

Photovoltaic (PV) or Solar Cell:

It is a device that converts solar energy into electric current using the photoelectric effect. The first PV was introduced by Charles Frilt in the 1880's. In 1931 a German engg Dr.Bruno Lange developed PV by using Silver Solenoid in place of Copper oxide.

Photovoltaic power generation employs solar panels, composed of number of solar cells containing photovoltaic material. Photovoltaics are made up of semiconductors & it converts solar radiation into direct current electricity.

Photovoltaic system consists of

a) Solar cell array, b) load leveler, c) storage system, d) tracking system (where necessary

Working Principle:

PVs are made up of semiconductors that generate electricity when they absorb light. As photons are received, free electrical charges are generated that can be collected on contacts applied to the surface of the semiconductors. Because of solar cells are not heat engines, & therefore, do not need to operate at higher temperature, they are adapted to the weak energy flux of solar radiation, operating at room temperature.

Advantages:

- Compare to fossil fuels nuclear energy sources, very little research money has been invested in the development of solar cells.
- It gives long duration period(operation)
- Operating costs are extremely low compared to existing power technologies.

Applications:

- Space craft (silicon solar cell)
- It can be applicable to either small or large power plants
- These solar cells are used to operate irrigation pumps, navigational signals, highway emergency call systems, rail road crossing warnings & automatic metrological station.

WATER POWER (HYDRO POWER):

Power derived from the energy of falling water & running water, which may be harnessed for useful purposes. In ancient years hydro- power has been used for irrigation & the operation of various mechanical devices such as water mills, saw mills, textile mills, domestic lifts, power house & paint making.

How the generator works: A hydraulic turbine converts the energy of flowing water into mechanical energy. A hydro-electric generator converts this mechanical energy into electricity. The operation of generator is based on the principle discovered by Faraday. He found that when a magnet is moved past a conductor it causes electricity to flow.
In large generator electro magnets are made by circulating D.C through loops of wire wound around stacks of magnetic steel laminations. These are called field poles & are mounted on the perimeter of the rotor.

The rotor is attached to the turbine shaft & rotates at a fixed speed. When rotor turns, it causes the field poles (electromagnetic) to move past the conductors mounted in the stator. This is turn causes electricity to flow & a voltage to develop at the generation output terminals.

Classification of hydro power:

- Conventional hydroelectric, referring hydroelectric dams
- Run of the river hydroelectricity, which captures the kinetic

energy in rivers or streams without use of dams.

- Small hydro projects are 10 MW or less & often have no artificial reservoirs.
- Micro hydro projects a few KW to a few hundred KW isolated homes, villages or small industries
- The power available from falling water can be calculated from the flow rate & density of water, the height of fall & the local acceleration due to gravity.

$P=\eta\rho Qgh$

Where, P – Power in Watts
Η- dimension less efficiency of the turbine ρ –density of water in Kg/m^3
Q- Flow in m^3/sec
g- Acceleration due to gravity
h- Height difference between inlet & outlet

WIND ENERGY:

Energy of wind can be economically used for the generation of electricity.

Winds are caused from 2 main factors:

- Heating & cooling of the atmosphere which generates convection currents. Heating is caused by the absorption of solar energy on the Earth's surface & in the atmosphere.
- The rotation of the Earth with respect to atmosphere & its motion around the sun.

- The energy available in the wind over the Earth's surface is estimated to be 1.6×10^7 MW
- In India, high wind speeds are obtainable in coastal areas of Saurashtra, Western Rajasthan & some parts of Central India.
- Wind energy which is an indirect source of solar energy conversion can be utilized to run wind mill, which in turn drives a generator to produce electricity.
- The combination of wind turbine & generator is sometimes referred as an *AERO-GENERATOR*.
- A step-up transmission is usually required to match the relatively slow speed of the wind rotor to the higher speed of an electric generator.
- ta quoted by some scientists that for India wind speed value lies between 5 Km/hr to 15-20 Km/hr
- Wind forms are operating successfully & have already fed over 150 lakh units of electricity to the respective state grids.
- Wind speed increases with height.

BIO MASS:

- ✓ Bio-mass means organic matter.
- ✓ *The energy obtained from organic matter, derived from biological organisms (plants & animals)* is known as bio-mass energy.
- ✓ The average efficiency of photosynthesis conversion of solar energy into bio mass energy is estimated to be 0.5% - 1.0%.
- ✓ To use biomass energy, the initial biomass maybe transformed by chemical or biological processes to produce intermediate bio-fuels such as methane, producer gas, ethanol & charcoal etc.
- ✓ It is estimated that the biomass, which is 90% n tress, is equivalent to the proven current extractable fossil fuel reserves in the world. The dry matter mass of biological material cycling in biosphere is about 250 $\times 10^9$ tons/Y.
- ❖ Animals feed on plants, & plants grow through the photosynthesis process using solar energy. Thus, photosynthesis process is primarily responsible for the generation of bio mass energy.
- ❖ In simplest form the reaction is the process of photosynthesis in the presence of solar radiation, can be represented as follows.

$$H_2O + CO_2 \xrightarrow{\text{Solar energy}} CH_2O + O_2$$

ADVANTAGES:

1] It is renewable source.
2] The energy storage is an in-built feature of it.
3] It is an indigenous source requiring little or no foreign exchange.
4] The forestry & agricultural industries that supply feed stocks also provide substantial economic development opportunities in rural areas.
5] The pollutant emissions from combustion of biomass are usually lower than fossil fuels.

DISADVANTAGES:

1] It is dispersed & land intensive source.

2] Low energy density

3] Labor intensive & the cost of collecting large quantities for commercial applications are significant.

TIDAL ENERGY:

The tides in the sea are the result of the universal gravitational effect of heavenly bodies like SUN & MOON on the Earth.

- *Periodic rise & fall of the water level of sea* is called TIDE.
- These tides can be used to produce electrical power which is known as tidal power.
- When the water is above the mean sea level called ***flood tide***.
- When the water is below the mean sea level called ***ebb tide.***

Basic principle of tidal power:

Tides are produced mainly by the gravitational attraction to the moon & the sun on the water of solid earth & the oceans. About 70% of the tide producing force due to the moon & 30% to the sun. The moon is thus the major factor in the tide formation.

Surface water is pulled away from the earth on the side facing the moon & at the same time the solid earth is pulled away from the water on the opposite side. Thus, high tides occur in these two areas with low tides at intermediate points.

As the earth rotates, the position of a given area relative to the moon changes, & so also do the tides.

The difference between high & low water level is called the range of the tide.

Limitations of tidal energy:

- Economic recovery of energy from tides is feasible only at those sites where energy is concentrated in the form of tidal range of about 5m or more, & geography provide a favourable site for economic construction of tidal plant, thus it is site specific.
- Due to mis-match of lunar driven period of 12 hrs 25 min & human (solar) period of 24 hrs, the optimum tidal power generation is not in phase with demand,
- Changing tidal range in 2 weeks period produces changing power,
- The turbines are required to operate at variable head.
- Requirement of large water volume flow at low head necessitates parallel operation of many times & Tidal plant disrupts marine life at the location & can cause potential harm to ecology.

WAVES ENERGY:

- *Waves are caused by the transfer of energy from surface winds to sea*. The rate of energy transfer depends upon the wind speed & the distance over which interacts with water.
- The energy flux in waves is more than that available from solar, wind & other renewable sources. The power in the waves is proportional to the square if its

amplitude & to the period of its motion. The energy stored is dissipated through friction at shore & turbulence at rates depending on characteristics of wave & water depth.

- Wave energy in open oceans is likely to be inaccessible. The resource potential near coastlines is estimated as in excess of 20, 00,000MW. Wave power is usually expressed in KW/m, repressing the rate at which energy is transferred across a line of 1 m length parallel to the wave front.

ADVANTAGES:

- The availability of large energy fluxes
- Productivity of wave conditions over periods of days,

DIFFICULTIES:

- Irregularity of wave patterns in amplitude, phase & direction, which makes it difficult to extract power efficiently.
- The power extraction system is exposed to occasional extreme stormy conditions.
- Peak power of deep-water waves is available in open sea, where is difficult to construct, operate & maintain a system & transmit power to the store,
- The slow & irregular motion of wave is required to be coupled to be electrical generator requiring high & constant speed motion.

GEOTHERMAL ENERGY:

- Geothermal energy is energy coming out of the molten interior (in the form of heat) of the earth towards the surface. Volcanoes, Geysers, Hot springs & boiling mud pots are visible evidence of the great reservoirs of heat that lies within the earth.
- Most Geothermal energy produces low grade heat at about 50-70˚c which can be used directly for thermal applications.
- Occasionally, geothermal heat is available at temperature about 90˚c & so electrical power production from turbines can be contemplated.
- Because of non-homogeneous in the earth crust, there are numerous local hot spots just below the surface where the temperature is in fact much higher than the average value expected. Ground water comes into contact with the hot rocks in some of those locations & as a result, dry steam wet & hot water or hot water alone is formed. A well drilled to these locations

causes the steam/water to emerge at the surface where its energy can be utilised either for generating electricity or for space heating.

ADVANTAGES:

- It is reliable source of energy
- It is available 24 hours/day
- It is available is independent of weather
- It has an inherent storage future, so no extra storage facility is required
- Geo thermal plants require little land area.

DISADVANTAGES:

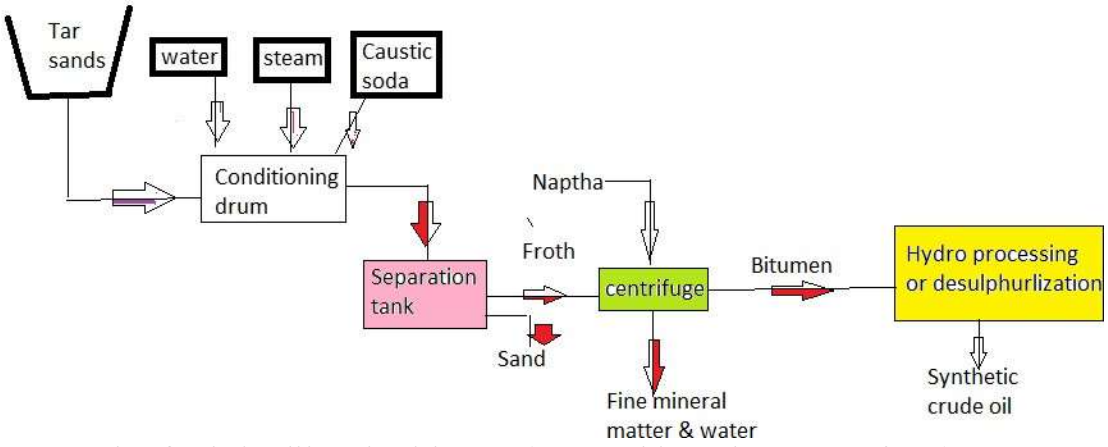
- Generally, energy is available as low-grade heat
- Continuous extraction of heated ground water may lead to subsidence [setting or slumping of land]
- Geo thermal fluid also brings with it the dissolved gases & solute [as high as 25 Kg/m^3] which leads to air & land pollution.
- Drilling operation leads to noise pollution.

Applications:

1] Direct heat use, 2] Electric power generation.

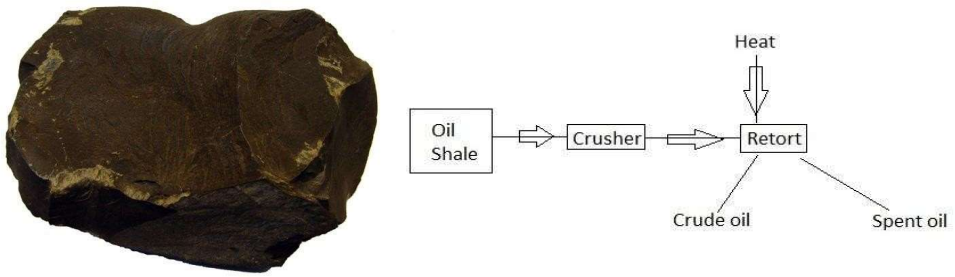
TAR SANDS:

- Tar sand or oil sands is an expression used to describe porous sandstone deposits impregnated with heavy viscous oils called *bitumen or simply deposits of heavy oils*.
- The above schematic diagram indicating the processes involved in producing synthetic crude oil from tar sands made up of sand stone deposits containing bitumen.
- The sands obtained from surface mining are first passed through a conditioning drum where water, steam & *caustic soda* are added & *slurry* is formed. The slurry passes into a separation tank where the coarse sand settles at the bottom & a froth of bitumen, water & fine mineral matter forms on the top.



- The froth is diluted with *naptha* & subjected to *centrifugal action*. As a result, fine mineral matter & water is removed. After this, the naptha is recovered & recycled, & the bitumen obtained is subjected to hydro processing & desulphurization to produce synthetic crude oil.

OIL SHALE:



Oil shale [a sedimentary rock] refers to a finely textured rock mixed with a *solid organic material* called *kerogen*. When crushed, it can be burnt directly [like coal] & has a heating value ranging from 2000 to 17,000 KJ/Kg. It

is used in this manner for generating electricity & supplying heat.

Alternatively, the oil shale can be converted to oil. This is done by heating crushed oil shale to about 500 ˚c in the absence of air. Under the conditions, *pyrolysis* occurs & the kerogen is converted to oil.

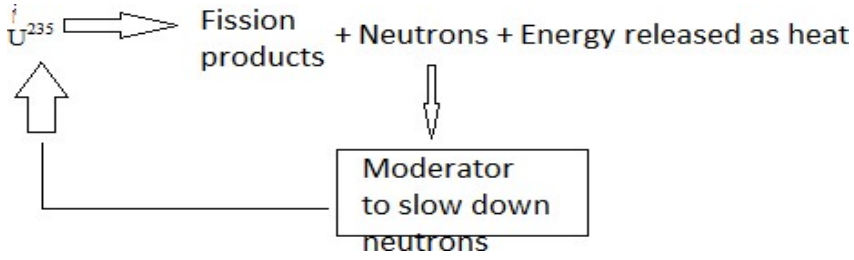
Demerits:

1] The use of oil shale is the environmental degradation associated with surface mining & with the disposal of large amounts of sand & spent shale rock which remains after the crude oil is obtained.
2] A large amount of energy is consumed in producing oil from these sources.

NUCLEAR POWER:

Under the nuclear option, the 2 alternatives under study are, 1] the breeder reactor, 2] nuclear fusion

The breeder reactor: In order to understand the working of a breeder reactor, it is necessary to understand the fission reactions. Naturally occurring uranium contains 3 isotopes, U^{234}, U^{235} & U^{238}. The relative % of these isotopes is U^{234} – 0.006%, U^{235}- 0.711% & U^{238} -99.283% of these isotopes, only U^{235} undergoes spontaneous fission when subjected to bombardment by slow neutrons. It is in fact that only naturally occurring fissile material.



The break-up of U^{235} when subjected neutrons & the release of a large amount of energy as heat [8.2×10^7 KJ/gm of U^{235}]. The neutrons are slowed down by a moderator, & used to bombard the U^{235} nucleus again, there by setting up a controlled chain reaction. Although U^{238} is not a fissile material, it is a fertile material, i.e., it can be converted by neutron bombardment into a fissile material, plutonium-239. Similarly, naturally-occurring thorium-232 is also a fertile material. It can be converted into U^{233} which is a fissile material.

It will be seen that the neutrons generated by the fission reaction serve two purposes. They help in converting a fertile material to a fissile material & also sustain the fission reaction for the fissile material formed. The above reactions are called *breeder reactions* if they produce more fissile material than they consume & the nuclear reactor in which they are caused to occur is called a *breeder reactor*.

Breeding is achieved by having both fissile & fertile materials in the reactor core under conditions which provide enough neutrons to propagate chain reactions in the fissile material as well as to convert more fertile material into fissile material than was originally present.

Solar Radiation

Solar Radiation Outside The Earth's Surface:

Sun is a large sphere of very hot gases; the heat being generated by various kinds of fusion reactions. Its diameter is $1.39X10^6$km, while that of the earth is $1.27X10^4$ km. It subtends an angle of 32minutes at the earth's surface. This is because it is also at large distance. Thus, the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its centre to its edge. However, for engineering calculations. It is customary to assume that the brightness all over the solar disc uniform.

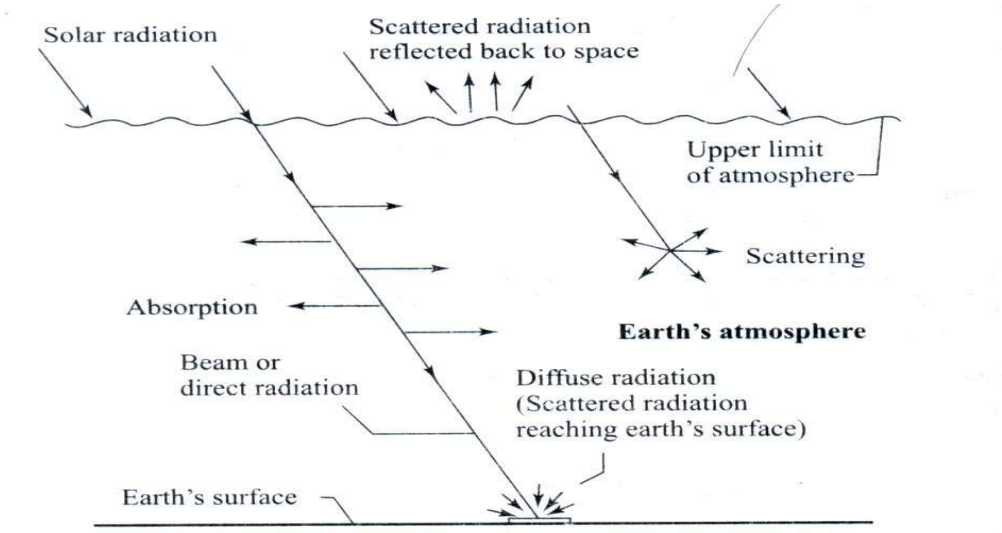
Solar Constant (Isc):

It is the rate at which energy is received from the sun on a unit area perpendicular to the rays of the sun, at the mean distance of the earth from the sun. Based on the measurements made up to 1970 a standard value of 1353 W/m^2 was adopted in 1971. However, based on subsequent measurements, a revised value of 1367 W/m^2 has been recommended.

The earth revolves around the sun in an elliptical orbit having a very small eccentricity and the sun at the foci. Consequently, the distance between earth and sun varies a little through the year. Because of this variation, the extra-terrestrial flux also varies.

Solar Radiation Received at the Earth's surface:

Solar radiation received at the earth's surface is in the attenuated form because it is subjected to the mechanisms of absorption and scattering as it passes through the earth's atmosphere (Figure below).



Absorption occurs primarily because of the presence of ozone and water vapour in the atmosphere and lesser extent due to other gases (like CO_2, NO_2, CO, O_2 and CH_4) and particulate matter. It results in an increase in the internal energy of the atmosphere. On the other hand, scattering occurs due to all gaseous molecules as well as particulate matter in the atmosphere. The scattered radiation is redistributed in all directions, some going back to the space and some reaching the earth's surface.

Solar radiation received at the earth's surface without change of direction i.e, in line with the sun is called *direct radiation* or *beam radiation*. The radiation received at the earth's surface from all parts of sky's hemisphere (after being subjected to scattering in the atmosphere) is called *diffuse radiation*. The sum of beam radiation and diffuse radiation is called as *total* or *global radiation*.

Beam Radiation:

TILTFACTOR (r_b): The ratio of beam radiation flux falling on the tilted surface to that of horizontal surface is called the *TILT FACTOR* for beam radiation.

For case of tilted surface facing due south γ=0

$$\cos\theta = \sin\delta \sin(\phi - \beta) + \cos\delta \cos\omega \cos(\phi - \beta)$$

while for a horizontal surface

$$\cos\theta_z = \sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega$$

Hence $$r_b = \frac{\cos\theta}{\cos\theta_z} = \frac{\sin\delta \sin(\phi - \beta) + \cos\delta \cos\omega \cos(\phi - \beta)}{\sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega}$$

Diffuse Radiation:

TILT FACTOR (rd): The ratio of diffuse radiation flux falling on the tilted surface to that of horizontal surface is called the *TILT FACTOR* for diffuse radiation

Its value depends on the distribution of diffuse radiation over the sky and the portion of the sky dome seen by the tilted surface.

Assuming that the sky is an isotropic source of diffuse radiation, for a tilted surface with slope β, we have

$$r_d = \frac{1 + \cos\beta}{2}$$

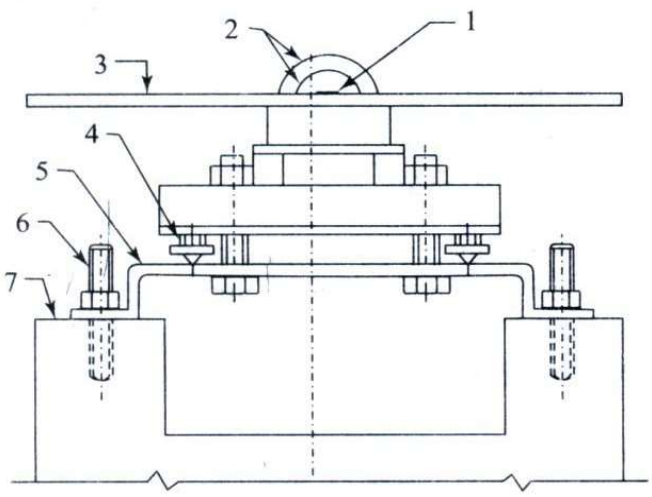
(1+ cosβ)/2 is the shape factor for a tilted surface w.r.t. sky

For Total radiation, let H_b=Hourly beam radiation and H_d=Hourly diffuse radiation

Instruments used for measuring solar radiation:

Pyranometer:

A pyranometer is an instrument which measure's either global or diffuse radiation falling on a horizontal surface over a hemispherical field of view. A sketch of one type of pyranometer as installed for measuring global radiation is shown in the following figure.



1.Black surface, 2. Glass domes ,

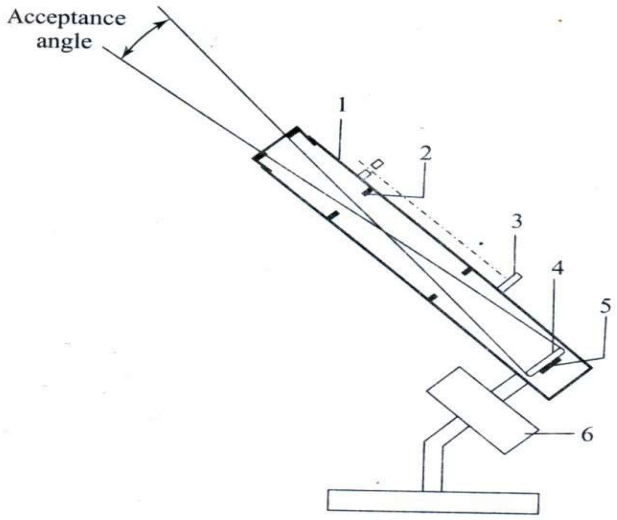
3. Guard plate 4. Leveling screws,

5.mounting plate, 6. Grouted bolts,

Pyranometer consists of a black surface which heats up when exposed to solar radiation. Its temperature increases until the rate of heat gain by solar radiation equals the rate of heat loss by convection, conduction and radiation. The hot junctions of thermopile are attached to the black surface, while the cold junctions are located under a guard plate so that they do not receive the radiation directly. As a result, an emf is generated. This emf which is usually in the range of 0 t0 10mv can be read, recorded or integrated over a period of time and is a measure of global radiation.

The pyranometer can also be used for measurement of diffuse radiation. This is done by mounting it at the centre of a semi-circular shading ring. The shading ring is fixed in such a way that it's plane is parallel to the plane of path of sun's daily movement across the sky and it shades the thermopile element and two glass domes of pyranometer at all the times from direct sun shine. Consequently, the pyranometer measures only the diffuse radiation received from the sky.

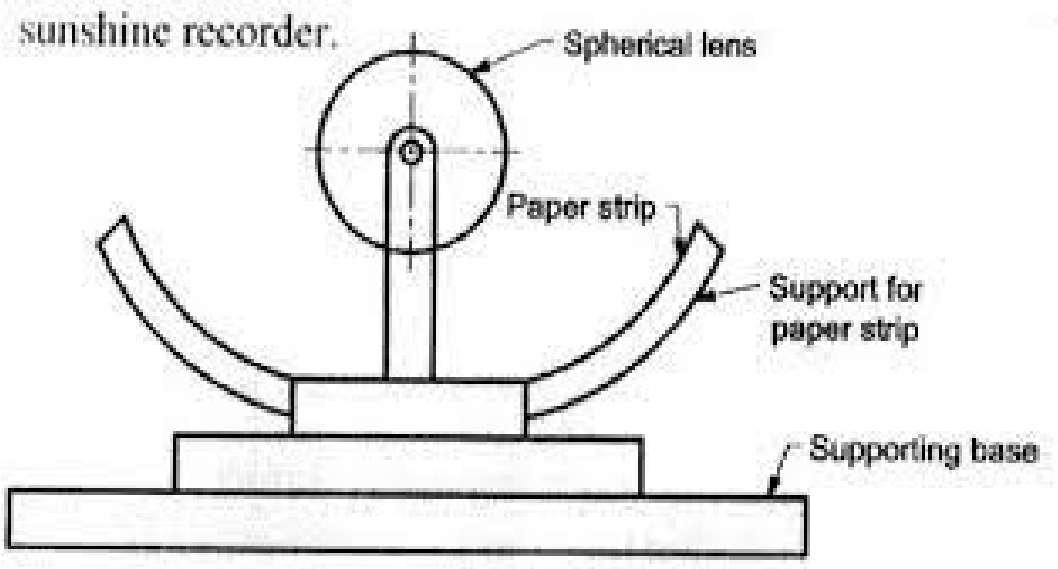
Pyrheliometer:



1. tube blackened on inside surface,
2. baffle, 3. Alignment indicator,
4. Black absorber plate
5. thermopile junctions
6. two-axis tracking mechanism

This is an instrument which measures beam radiation falling on a surface normal to the sun's rays. In contrast to a pyranometer, the black absorber plate (with hot junctions of a thermopile attached to it) is located at the base of a collimating tube. The tube is aligned with the direction of the sun's rays with the help of a two-axis tracking mechanism and alignment indicator. Thus, the black plate receives only beam radiation and a small amount of diffuse radiation falling within the acceptance angle of the instrument.

Sun shine recorder



A **sunshine recorder** is a device that records the amount of sunshine at a given location or region at any time. The results provide information about the weather and climate as well as the temperature of a geographical area. This information is useful in meteorology, science, agriculture, tourism, and other fields. It has also been called a heliograph.

There are two basic types of sunshine recorders. One type uses the sun itself as a time-scale for the sunshine readings. The other type uses some form of clock for the time scale

Working principle This recorder consists essentially of a glass sphere of 96 mm diameter mounted concentrically in a section of a spherical metal bowl, the diameter of which is such that the sun`s rays are focused sharply on a card held in the grooves, in the bowl. Three overlapping pairs of grooves are provided in the bowl to taken up cards suitable for the different seasons of the year.

The sphere is made of uniform and well annealed colorless glass and is carefully ground and polished with great precision.