Mysore College of Engineering and Management

Department of Mechanical Engineering

Renewable Energy Power Plant

MODULE 1:
SOURCES OF ENERGY, SOLAR RADIATION MEASUREMENTS

Energy- Capacity to do work.

• Most of the energy that we use is mainly derived from conventional energy sources.

• Due to the vast demand of energy, the rate of depletion of these resources has reached alarmingly low levels.

• This situation has directed us to seek alternate energy sources such as solar, wind, ocean, biomass, Hydel etc.

Energy Sources:

• The energy existing in the earth is known as CAPITAL energy.
• Energy that comes from outer space is called CELESTIAL or INCOME energy.

• The CAPITAL energy sources are mainly, fossil fuels, nuclear fuels and heat traps.

• CELESTIAL ENERGY SOURCES ARE- Electromagnetic, gravitational and particle energy from stars, planets, moon etc.

• ELECTROMAGNETIC ENERGY of the earth's sun is called DIRECT SOLAR ENERGY. This results in WIND, HYDEL, GEOTHERMAL, BIOFUEL, etc.

• GRAVITATIONAL ENERGY of earth's moon produces TIDAL ENERGY.

Renewable Sources of Energy:

Energy sources which are continuously produced in nature and are essentially inexhaustible are called renewable energy sources.

1. Direct solar energy
2. Wind energy
3. Tidal energy
4. Hydel energy
5. Ocean thermal energy
6. Bio energy
7. Geo thermal energy
8. Fuel wood
9. Fuel cells
10. Solid wastes

Non-renewable Energy Sources:

Energy sources which have been accumulated over the ages and not quickly replenishable when they are exhausted.

1. Fossil fuels.

2. Nuclear fuels.

3. Heat traps.

Differences between Renewable and Non Renewable Energy Sources

Factor	Renewable Energy Sources	Non Renewable Energy Sources
Exhaustibility/Inexhaustibility	Inexhaustible	Exhaustible
Availability	Abundantly and freely available	Not abundantly available
Replenishment	Replenished Naturally	Cannot be replenished
Environmental Friendliness	Environment friendly except in case of biomass	Not environment friendly
Cost Factor	Building Systems cost is high, running cost is low	Production cost is high
Nature of Availability	Intermittently available	Continuously available
Regional restriction and dependency factor	No regional restriction	Available in certain countries

Types of Fuels

The important fuels are as follows-
1) Solid fuels
2) Liquid fuels
3) Gaseous fuels

1) Solid fuels

➢ Coal is the major fuel used for thermal power plants to generate steam.
➢ Coal occurs in nature, which was formed by the decay of vegetable matters buried under the earth millions of years ago under pressure and heat.
➢ This phenomenon of transformation of vegetable matter into coal under earth's crust is known as Metamorphism.
➢ The type of coal available under the earth's surface depends upon the period of metamorphism and the type of vegetable matter buried, also the pressure and temperature conditions.
➢ The major constituents in coal moisture (5-40%), volatile matter (combustible & or incombustible substances about 50%) and ash (20-50%).
➢ The chemical substances in the coal are carbon, hydrogen, nitrogen, oxygen and sulphur.

➢ In the metamorphism phenomenon, the vegetable matters undergo the transformation from peat to anthracite coal, with intermediate forms of lignite and bituminous coal.

- ➢ Wood fuel can be used for cooking and heating, and occasionally for fueling steam engines and steam turbines that generate electricity. Wood may be used indoors in a furnace, stove, or fireplace, or outdoors in furnace, campfire, or bonfire.

2) Liquid fuels

➢ All types of liquid fuels used are derived from crude petroleum and its by-products.
➢ The **petroleum or crude oil** consists of 80-85% C, 10-15% hydrogen, and varying percentages of Sulphur, nitrogen, oxygen and compounds of vanadium.
➢ The crude oil is refined by fractional distillation process to obtain fuel oils, for industrial as well as for domestic purposes.
➢ The fractions from light oil to heavy oil are naphtha, gasoline, kerosene, diesel and finally heavy fuel oil.
➢ The heavy fuel oil is used for generation of steam.
➢ The use of liquid fuels in thermal power plants has many advantages over the use of solid fuels.

Some important advantages are as follows:

1. The storage and handling of liquid fuels is much easier than solid and gaseous fuels.
2. Excess air required for the complete combustion of liquid fuels is less, as compared to the solid fuels.
3. Fire control is easy and hence changes in load can be met easily and quickly.
4. There are no requirements of ash handling and disposal.
5. The system is very clean, and hence the labour required is relatively less compared to the operation with solid fuels.

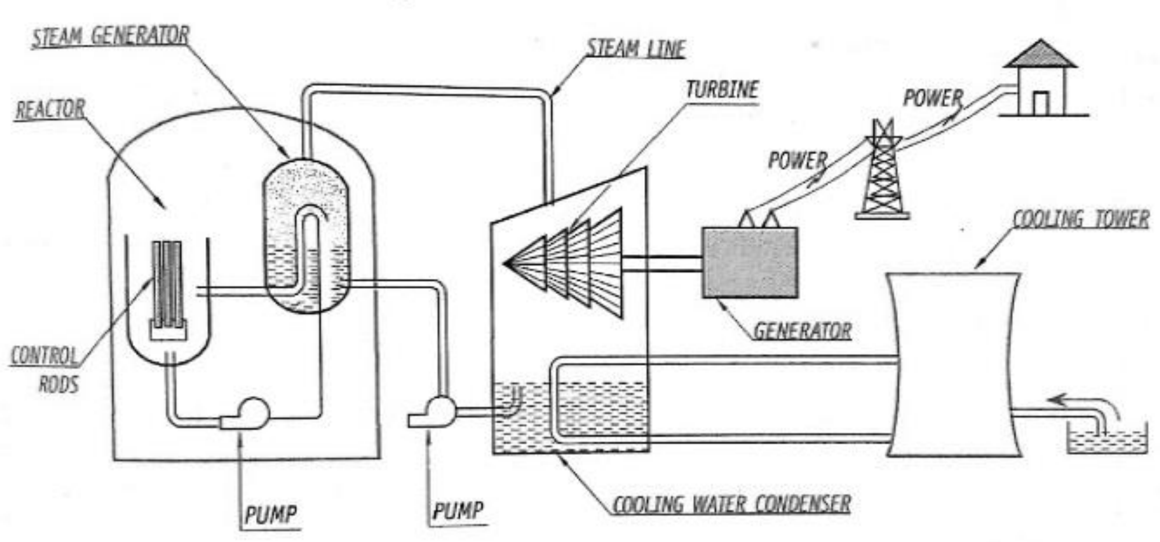
3) Gaseous Fuels

➢ For the generation of steam in gas fired thermal plants, either natural gas or manufactured gaseous fuels are used.
➢ However, manufactured gases are costlier than the natural gas.
➢ Generally, natural gas is used for power plants as it is available in abundance.
➢ The natural gas is generally obtained from gas wells and petroleum wells.
➢ The major constituent in natural gas is methane, about 60-65%, and also contains small amounts of other hydrocarbons such as ethane, naphthene and aromatics, carbon dioxide and nitrogen.
➢ The natural gas is transported from the source to the place of use through pipes, for distances to several hundred kilometers.
➢ The natural gas is colourless, odourless and non-toxic.
➢ Its calorific value ranges from 25,000 to 50,000 kJ/m3, in accordance with the percentage of methane in the gas.
➢ The artificial gases are producer gas, water gas coke-oven gas; and the Blast furnace gas.

➢ Generally, power plants fired with artificial gases are not found.
➢ The gaseous fuels have advantages similar to those of liquid fuels, except for the storage problems.
➢ The major disadvantage of power plant using natural gas is that it should be setup near the source; otherwise the transportation losses are too high.

Working principle of a nuclear power station

The schematic diagram of nuclear power station is shown in figure. A generating station in which nuclear energy is converted into electrical energy is known as nuclear power station. The main components of this station are nuclear reactor, heat exchanger or steam generator, steam or gas turbine, AC generator and exciter, and condenser.



Nuclear Energy Conversion

The reactor of a nuclear power plant is similar to the furnace in a steam power plant. The heat liberated in the reactor due to the nuclear fission of the fuel is taken up by the coolant circulating in the reactor. A hot coolant leaves the reactor at top and then flows through the tubes of heat exchanger and transfers its heat to the feed water on its way. The steam produced in the heat exchanger is passed through the turbine and after the work has done by the expansion of steam in the turbine, steam leaves the turbine and flows to the condenser. The mechanical or rotating energy developed by the turbine is transferred to the generator which in turn generates the electrical energy and supplies to the bus through a step-up transformer, a circuit breaker, and an isolator. Pumps are provided to maintain the flow of coolant, condensate, and feed water

Commercial and non commercial Energy sources:

Commercial Energy sources:

The commercial energy is the lifeline for industrial, agricultural, Transport and commercial development in the modern world. In the industrially well-developed countries, the commercial energy is also largely used for many household tasks. By far the most important forms of commercial energy re electricity, coal, lignite, refined petroleum products and natural gas that are available in the market for a price.

Non-Commercial Energy sources:
The traditional fuels like firewood, cattle dung and agro wastes that are gathered for use in rural households, and not bought at a price, are classified as non-commercial energy sources are often ignored in energy accounting. The other form of non-commercial energy includes renewable sources of energy like solar and wind as well as animal power. The solar energy is used for electricity generation, water heating, drying grain, fish and fruits. The wind energy finds use for electricity generation and water lifting. The animal power is largely used in villages for lifting water for irrigation
and crushing sugarcane, threshing and transportation.

World energy scenario:

The international Energy outlook 2004 projects strong growth for worldwide energy demand over the 24 year projection period from 2001 to 2025. Total world consumption of marketed energy is expected to expand by 54%, from 404 quadrillion Btu in 2001 to 623 quadrillion Btu in 2025. The major growth in energy demand is developing countries as two billion people lack access to affordable and reliable energy supplies. The world coal reserves are likely to last a little over 200 years but the oil and gas reserves areestimated at just 45 years and 65 years, respectively. Of the three major primary sources of energycoal, oil and gas, the coal consumption is heavily concentrated in the electricity generation sector. icity generation. The power generation accounts for virtually all the projected growth in coal consumption worldwide. One exception is China, where coal coal reserves and limited access to other sources of energy. Despite the rapid strides made in the development and adoption of new sources of energy, particularly renewable energy, petroleum remains the primary energy source all over the world. Since the first commercial exploitation of oil in Pennsylvania, USA, in 1859, the importance. In 1920, only 95 million tons of oil was produced annually around the world. This rose to 4 billion tones in 2003. The consumption of petroleum in the world, which started as a few tones per year about 140 years ago, has now reached to over 3000 million metric Tonnes (MMT) per year.

Global Primary energy consumption:
The global primary energy consumption at the end of 2003 was equivalent to 9741 million Tonnes of oil equivalent (MTOE). The primary energy consumption in some developed and developing countries is shown in table 1.5 and world primary energy consumption is projected up to year 2025
Energy consumption in developing countries:
Although 80% of living in the developed countries are attributable to high-energy consumption levels. Also, the rapid population growth in the developing countries has kept the per capita energy consumption low compared with that of highly industrialized countries. The world average energy consumption per person is equivalent to 2.2 Tonnes of coal. In industrialized

countries, people use four to five times more than the world average and nine times more than the average for the developing countries. An American uses 32 times more commercial energy than Indian.

(i) Coal:

More than 50 percent of Indian energy demand is met though coal. Power generation alone International Energy Annual 2002, the coal consumption in India is projected to increase from 369 million Tonnes in the year 2000 to 450 million Tonnes by the year 2010. production stands at around 290 million Tonnes per year. Presently the major coal production is concentrated in eight Indian States, namely: Andhra Pradesh, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, and West Bengal. Indian coal is typically of poor quality and such reserves were estimated at 84,396 million tones. This is almost 8.6% of the world reserves and it may last for about 230 years a coal reserves are expected to last only for 192 years at the current R/P ratio.

(ii) Lignite:

Lignite is the second stage of transformation of wood into coal. India is also one of the largest producers of lignite in the world. The total lignite reserves identified in India are 36,008 million tones and those about 85 percent are in Tamil Nadu.

The presence of lignite deposits in the Neyveli region was first revealed during well boring operations. The Government of India with the services of Powell Duffyrin Technical Services, London, developed a project report for an integrated project to mine and utilize the lignite available in the region. In order to exploit the deposits of Tamil Nadu Neyveli Lignite Corporation Limited was incorporated as a Central PSU in 1956.

iii) Oil:

India is one of the top ten oil guzzling nations in the world and will soon overtake Korea as total energy consumption. In sector wise petroleum product consumption transport sector alone accounts for 42% , industry 24% and domestic 24%.

51 to 112.56 MMT in 2002 03 and it is expected to reach 175 MMT in 2006 07 Future oil consumption is expected to grow rapidly to 3.2 million barrels / day by 2010, from 2 million barrels / day in 2002. India has oil reserves of about 504 billion barrels and the majority of them are located in the Bombay High, upper Assam, Cambay, and Krishna Godavari. Its annual crude oil production is peaked at about 32 million tones. By the end of the 10th plan period, the domestic production is likely to rise self-sufficiency in oil production has consistently declined from 60% in the 50s to 30% currently. Same is expected to go down further to 8% by 2020. Currently India import 70% of its crude needs, mainly from gulf nations. At the end of 2004, India l oil demand has to be met by imports.

(iv) Natural Gas:

Natural gas is clean, environment friendly, and the most economical fuel in term of delivered price of energy. Compared to coal and other liquid hydrocarbons. Therefore, Indian Consumption of natural gas has raised faster any other fuel in recent years and today it accounts for about 8.9 percent of energy consumption in the country. In India, the current demand for natural gas about 96 million cubic meters per day (MCMD) as against availability of 67 MCMD. By 2007, the demand is expected to be around 200 MCMD. In 2002-03, the gas production was 86.56 MCMD, which in 2006-07 is likely to rise to 103.08.MCMD.It, is mainly based on the strength of more than doubling of production by private operators to 38.25 MCMD. The natural gas reserves in India are estimated at 660 billion cubic meters. Through currently natural gas accounts f compared to nearly 25% in the develop world, the share of gas is bound to increase to around 14% in by

CCGT plants using dual fuel naphtha or gas. But since naphtha is a relatively expensive fuel, CCGT plants will switch to gas if it is made available. Gas is also used as feedstock in fertilizer industry. Nearly 82 percent of annual gas production is consumed by power and fertilizer industries in India.

(v) LNG:

Liquefied natural gas (LNG) is a relatively recent phenomenon. Natural gas is cooled to extreme low temperatures to liquefy it and the liquid to transport in cryogenic ships to the destination. In liquid from the gas occupies just about one-six hundredth of its gaseous volume, but at the receiving end, the liquid has to be degasified through the process of heating. Thus LNG requires substantial infrastructure both at the shipping point and the destination which adds to its cost. Petro net LNG, terminal Dahej in Gujarat with an initial capacity of 5 million metric tons per annum (MMTPA), which amounts to 20 MCM/D. shell, transnational oil major, is in the process of setting up an LNG terminal at Hazira. The year 2004 could well go down as the start of a new era for the Indian petroleum sector. The first consignment of LNG the alternative fuel for gas, landed of Indian shores in January 2004. The gas -or- The marketing of the gas is being down by GAIL, Indian Oil Corporation and Bharat Petroleum Corporation in the ratio of 60:30:10, respectively. During the year, Petro net supplied 10 MCM/D LNG to consumers along the HBJ pipeline.

(vi) Electrical Energy:

As on March 31,2005,the all India electric power generating installed capacity under utilities was 1,18,419MW,consisting of 80,902MW of thermal(69%), 30,936MW of hydro(26%),2770MW of nuclear(2%) and 2488 MW of wind power (3%). During the year 2004-05, the gross generation was 587.3 billion units.

India is endowed with a vast and viable hydro potential for power generation of which only 15% has decreased and it presently stands at 25% as on May 31, 2004. It is assessed that exploitable hydro power potential at 60% load factor is 84,000MW. India currently has a peak demand shortage of around 14% and energy Deficit Of 8.4%. Keeping this view and to maintain a GDP growth of 8% to 10%, the Government of India has very prudently set a target of 215,804MW Power Generation capacity by March 2012.

Need for nonconventional energy source

1. Natural resources like wind, tides, solar, biomass, etc generate energy which is known as “Non-conventional resources“. These are pollution free and hence we can use these to produce a clean form of energy without any wastage.

2. These are mainly used for domestic purposes.
3. Usage of these sources of energy does not cause pollution and is eco-friendly.
4. Electricity generation
5. Water heating or cooling
6. Transporting
7. Rural
8. The major source of energy was fossil which is getting depleted at a higher rate and also there is a growing need to control pollution which has made us move to use non-conventional sources of energy.

As the consumption of energy grows, the population depends more and more on fossil fuels such as coal, oil and gas day by day. There is a need to secure the energy supply for future since the prices of gas and oil keep rising by each passing day. So we need to use more and more renewable sources of energy. For the effective exploitation of non-conventional sources, there has been an establishment of a separate department namely “Department of non-conventional sources of energy” by the government of India.

What is an energy alternative?

“Alternative energy” refers to energy from natural and renewable sources, such as solar or wind. It is presented as an alternative to conventional energy sources, which involve burning non-renewable fossil fuels like oil or coal.

Here are a few common sources of renewable energy:

- SOLAR ENERGY. Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. ...
- WIND ENERGY
- GEOTHERMAL ENERGY
- HYDROPOWER
  OCEAN ENERGY / Tidal Energy
- BIOENERGY.

INTRODUCTION

Solar energy is an important, clean, cheap and abundantly available renewable energy. It is received on Earth in cyclic, intermittent and dilute form with very low power density 0 to 1 kW/m2.Solar energy received on the ground level is affected by atmospheric clarity, degree of latitude, etc. For design purpose, the variation of available solar power, the optimum tilt angle of solar flat plate collectors, the location and orientation of the heliostats should be calculated.

In SI units, energy is expressed in Joule. Other units are angley and
Calorie where 1 angley = 1 Cal/cm2.day
1 Cal = 4.186 J

For solar energy calculations, the energy is measured as an hourly or monthly or yearly average and is expressed in terms of kJ/m2/day or kJ/m2/hour. Solar power is expressed in terms of W/m2 or kW/m2

ADVANTAGES

1. Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid.
2. Many everyday items such as calculators and other low power consuming devices can be powered by solar energy effectively.
3. It is estimated that the world's oil reserves will last for 30-40 years. On the other hand solar energy is infinite.
4. Solar energy is free although there is a cost in building of collectors and other equipment required to convert solar energy in to electricity or hot water

DISADVANTAGES

1. Solar energy can only be harnessed when it is daytime and sunny.
2. Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.
3. Solar power stations can be built but they do not match the power output of similar sized conventional power stations. They are also very expensive.
4. Large areas of land are required to capture the sun energy. Collectors are usually arranged together especially when electricity is to be produced and used in the same location.

Solar Radiation & Measurement:

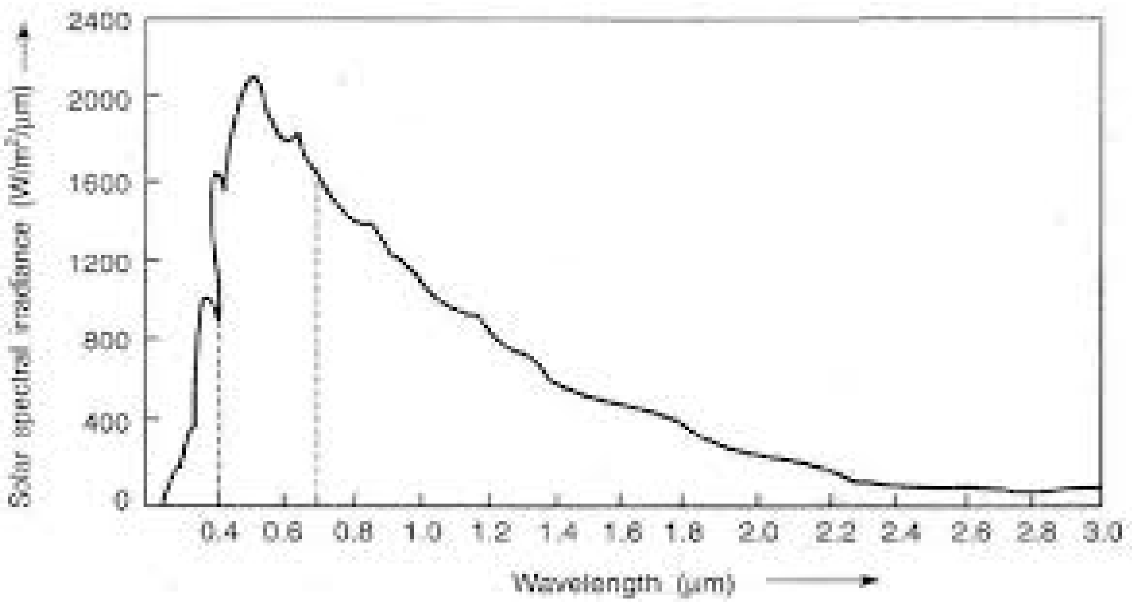
Radiation data for solar electric (photovoltaic) systems are often represented as kilowatt-hours per square meter (kWh/m^2). Direct estimates of solar energy may also be expressed as watts per square meter (W/m^2).

Extra-Terrestrial radiation

The incoming solar radiation to a horizontal surface above the atmosphere around the earth is called extraterrestrial radiation and is a function of latitude, season and hour of the day and can be calculated with the following parameters (Vaziri et al., 2008).

spectral distribution of extra-terrestrial radiation

A typical spectral distribution of extraterrestrial radiation is shown in Figure. The curve rises sharply with the wavelength and reaches the maximum value of 2074 W/m2-µm at a wavelength of 0.48 µm. It then decreases asymptotically to zero.



solar constant

The solar constant includes radiation over the entire electromagnetic spectrum. It is measured by satellite as being **1.361 kilowatts per square meter (kW/m^2)**

A solar constant is a measurement of the solar electromagnetic radiation available in a meter squared at Earth's distance from the sun. The solar constant is used to quantify the rate at which energy is received upon a unit surface such as a solar panel.

A solar constant is a measurement of the solar electromagnetic radiation available in a meter squared at Earth's distance from the sun. The solar constant is used to quantify the rate at which energy is received upon a unit surface such as a solar panel. In this context, the solar constant provides a total measurement of the sun's radiant energy as it is absorbed at a given point.

Solar constants are used in various atmospheric and geological sciences. Though called a constant, the solar constant is merely relatively constant. The relative constant does vary by 0.2% in a cycle that peaks once every eleven years. The first attempt at estimating the solar constant was made by Claude Pouillet in 1838 at 1.228 kW/m_2. The constant is rated at a solar minimum of 1.361 kW/m^2 and a solar maximum of 1.362.

The entire spectrum of electromagnetic radiation is included in the measurement of a solar constant and not just that of visible light. The best direct measurements of the solar constant are taken from satellites. The Stefan-Boltzman constant can also be used as a means to calculate a solar constant. In this context, the constant defines the power per unit area emitted by a black body as a function of its thermodynamic Temperature.

solar radiation at the earth's surface

The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation. The sum of the diffuse and direct solar radiation is called global solar radiation.

Atmospheric conditions can reduce direct beam adiation by 10% on clear, dry days and by 100% during thick, cloudy days.

In total approximately 70% of incoming radiation is absorbed by the atmosphere and the Earth's surface while around 30% is reflected back to space and does not heat the surface. The Earth radiates energy at wavelengths much longer than the Sun because it is colder.

Solar measuring instruments

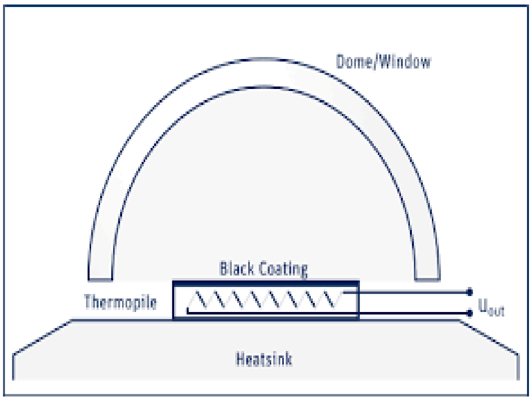
1. Pyranometer
2. Pyrheliometer
3. Sunshine Recorder
4. Actinometer
5. Bolometer

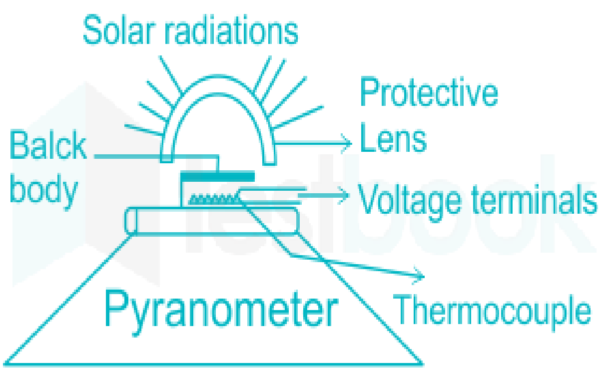
1. Pyranometer

A pyranometer is a sensor that measures solar irradiance over 180 degrees using a thermopile sensor with a black coating inside a glass dome. It measures diffuse sunlight. A pyrheliometer specifically measures direct beam sunlight using a thermopile sensor that tracks the sun inside an instrument with a window

Pyranometers operate based on the principle of thermopiles or photodiodes. When solar radiation strikes the sensor surface, it generates heat or produces an electric current proportional to the radiation intensity. This signal is then amplified and converted into irradiance units using calibration factors.

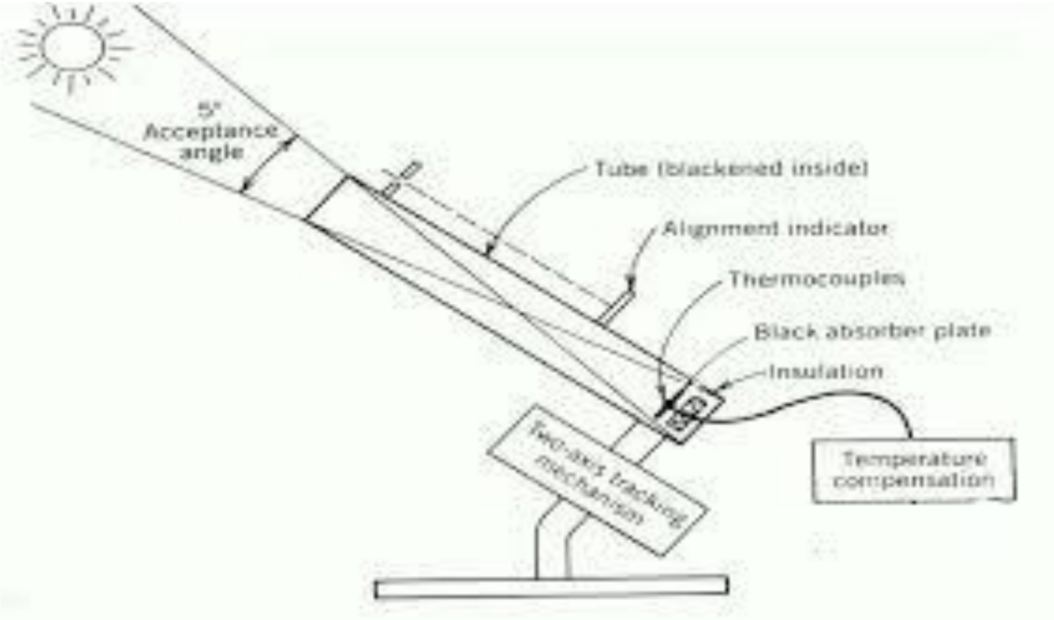
Pyranometers are devices that measure the amount of solar radiation, or sunlight that is received by a surface. They are commonly used in a variety of applications, including solar energy production, meteorology, agriculture, and global energy balance studies for the purpose of global climate change research.

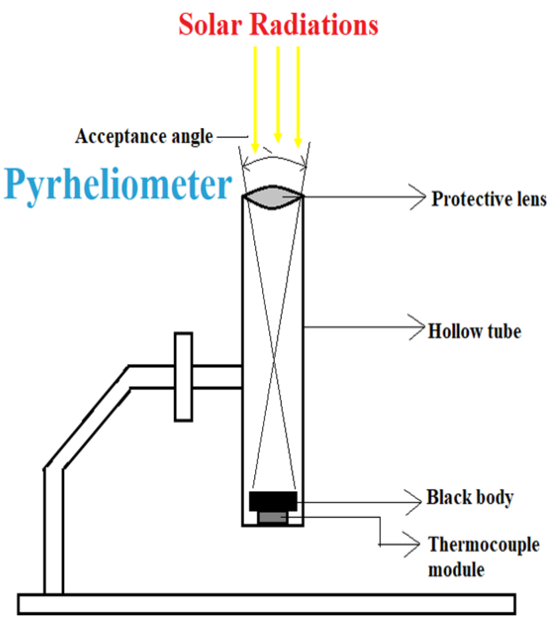




2. Pyrheliometer

A Pyrheliometer is an instrument that can measure direct beam solar irradiance. Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded. The signal voltage is converted via a formula to measure watts per square metre. The power consumption is quite low. It can work with a wide range of voltages. It is rigid and stable. Since it solely measures direct radiation, it is commonly employed in solar tracking systems.

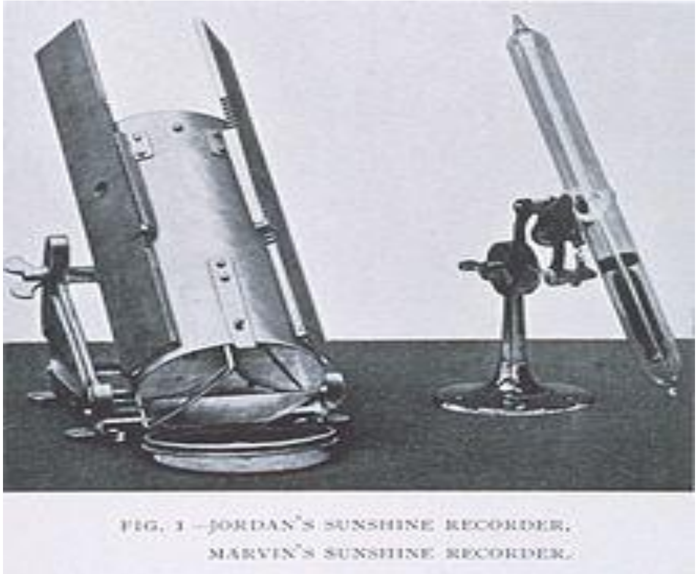




3. Sunshine Recorder

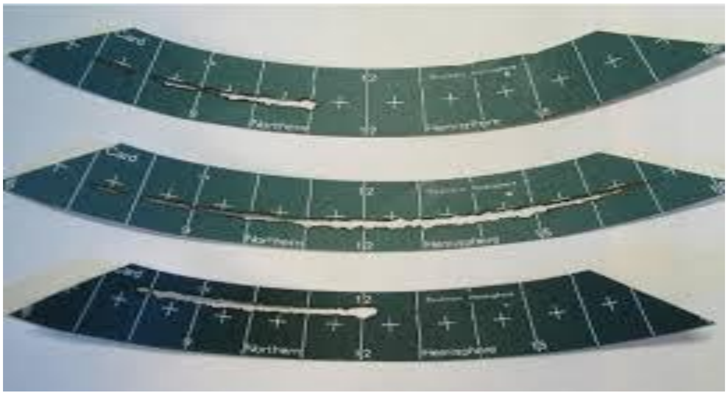
A **sunshine recorder** is a device that records the amount of sunshine at a given location or region at any time. The results provide information about the weather and climate as well as the temperature of a geographical area. This information is useful in meteorology, science, agriculture, tourism,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



A Jordan sunshine recorder (left). The other instrument is a Marvin sunshine recorder.

Older recorders required a human observer to interpret the results; recorded results might differ among observers. Modern sunshine recorders use electronics and computers for precise data that do not depend on a human interpreter. Newer recorders can also measure the global and diffuse radiation.

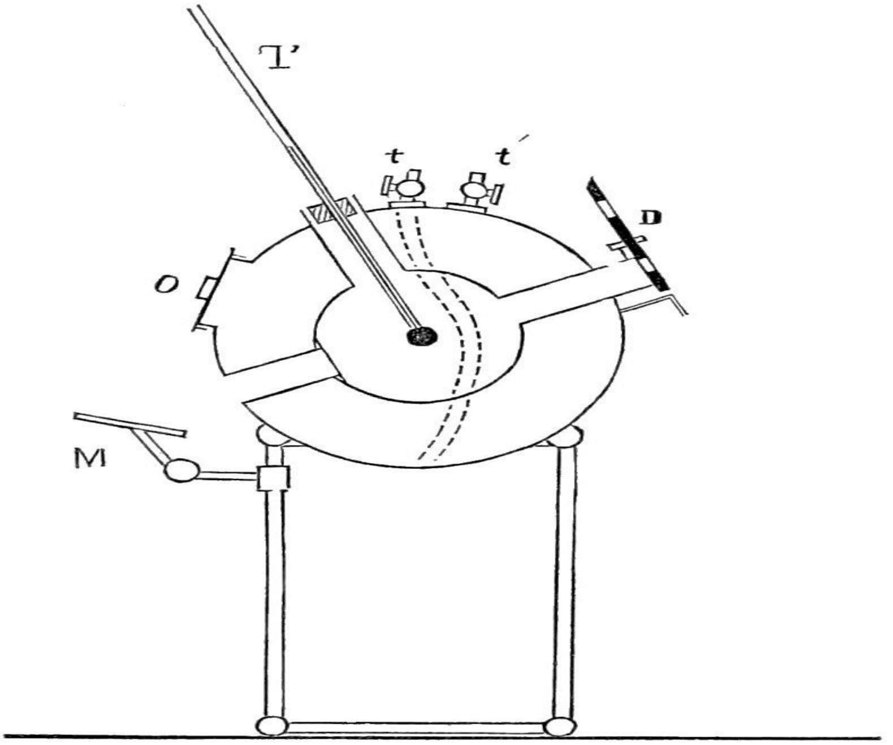


Sunshine is measured using either Campbell-Stokes sunshine recorders or modern sunshine sensors. A pyranometer is used for measuring global radiation.

4. Actinometer

An **actinometer** is an instrument that can measure the heating power of radiation. Actinometers are used in meteorology to measure solar radiation as pyranometers, pyrheliometers and net radiometers.

An actinometer is a chemical system or physical device which determines the number of photons in a beam integrally or per unit time. This name is commonly applied to devices used in the ultraviolet and visible wavelength ranges. For example, solutions of iron(III) oxalate can be used as a chemical actinometer, while bolometers, thermopiles, and photodiodes are physical devices giving a reading that can be correlated to the number of photons detected

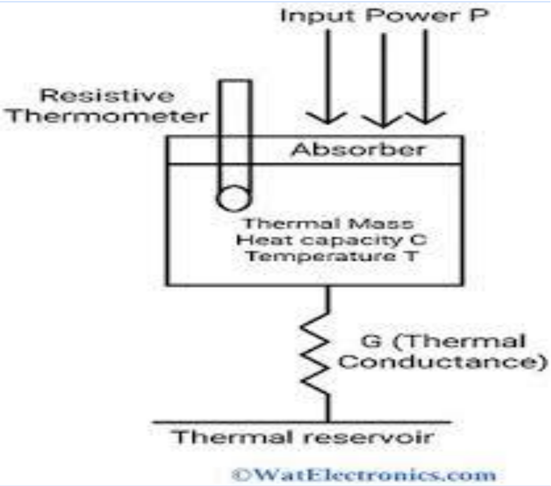


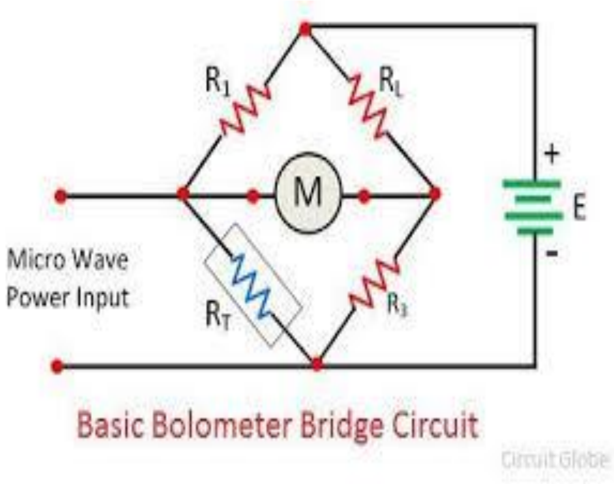
5. Bolometer

A bolometer is a device that measures radiation by measuring the temperature of an object which is warmed by absorption of the radiation.

A bolometer consists of an absorptive element, such as a thin layer of metal, connected to a thermal reservoir (a body of constant temperature) through a thermal link. The result is that any radiation impinging on the absorptive element raises its temperature above that of the reservoir – the greater the absorbed power, the higher the temperature. The intrinsic thermal time constant, which sets the speed of the detector, is equal to the ratio of the heat capacity of the absorptive element to the thermal conductance between the absorptive element and the reservoir.[3] The temperature change can be measured directly with an attached resistive thermometer, or the resistance of the absorptive element itself can be used as a thermometer. Metal bolometers usually work without cooling. They are produced from thin foils or metal films. Today, most bolometers use semiconductor or superconductor absorptive elements rather than metals. These devices can be operated at cryogenic temperatures, enabling significantly greater sensitivity.

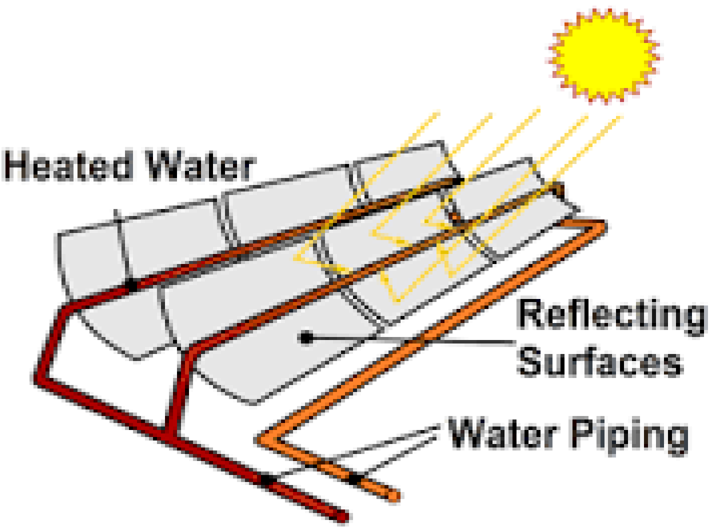
Bolometers are directly sensitive to the energy left inside the absorber. For this reason they can be used not only for ionizing particles and photons, but also for non-ionizing particles, any sort of radiation, and even to search for unknown forms of mass or energy (like dark matter); this lack of discrimination can also be a shortcoming. The most sensitive bolometers are very slow to reset (i.e., return to thermal equilibrium with the environment). On the other hand, compared to more conventional particle detectors, they are extremely efficient in energy resolution and in sensitivity. They are also known as thermal detectors.





Solar Collector.

A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use. The solar collector works on the green house effect principle; solar radiation incident upon the transparent surface of the solar collector is transmitted through though this surface.



MODULE 2

solar radiation geometry, solar thermal system, solar photovoltaic system

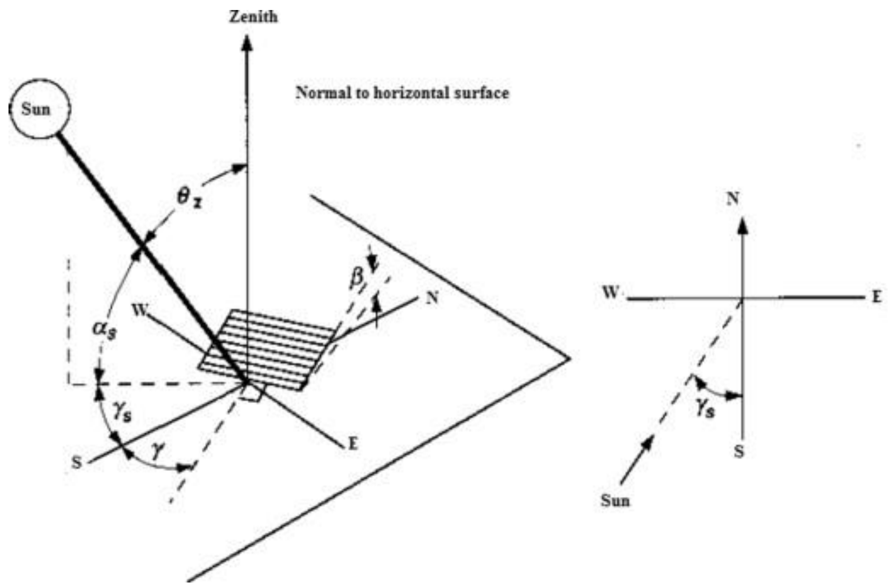
Solar flux on a plane surface

Angle of Declination: - Declination is the angle between the magnetic and geographic meridian, or the angle between magnetic north and true north in the horizontal plane.
At most places on the Earth's surface, the compass doesn't point exactly toward geographic north. The deviation of the compass from true north is an angle called "declination" (or "magnetic declination").

The declination angle, denoted by δ, varies seasonally due to the tilt of the Earth on its axis of rotation and the rotation of the Earth around the sun. If the Earth were not tilted on its axis of rotation, the declination would always be 0°. However, the Earth is tilted by 23.45° and the declination angle varies plus or minus this amount. Only at the spring and fall equinoxes is the declination angle equal to 0°. The rotation of the Earth around the sun and the change in the declination angle is shown in the animation below.

The surface azimuth

The surface azimuth angle γ is the deviation of the projection on a horizontal plane of the normal to the surface from the local meridian. The slope, β, referred also to the surface inclination, is the angle between the plane of the surface in question and the horizontal; $0° \leq \beta \leq 180$.



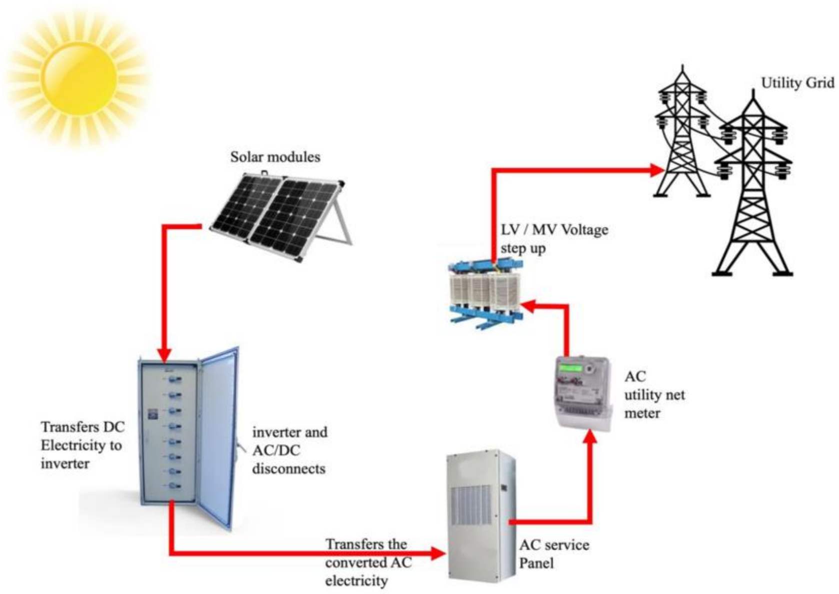
In land navigation, azimuth is usually denoted alpha, α, and defined as a horizontal angle measured clockwise from a north base line or meridian. Azimuth has also been more generally defined as a horizontal angle measured clockwise from any fixed reference plane or easily established base direction line.

Hour angle definition

In astronomy and celestial navigation, the **hour angle** is the dihedral angle between the meridian plane (containing Earth's axis and the zenith) and the hour circle (containing Earth's axis and a given point of interest).

It may be given in degrees, time, or rotations depending on the application. The angle may be expressed as negative east of the meridian plane and positive west of the meridian plane, or as positive westward from 0° to 360°. The angle may be measured in degrees or in time, with $24^h = 360°$ exactly.
The hour angle is the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour with morning being negative and afternoon being positive. For example, at 10:30 a.m. local apparent time the hour angle is −22.5° (15° per hour times 1.5 hours before noon).

Solar Power Plant



Solar radiation is radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. The spectrum of **solar radiation** is close to that of a black body with a temperature of about 5800 K. About half of the **radiation** is in the visible short-wave part of the electromagnetic spectrum.

Solar Constant

This is the amount of energy received in unit time on a unit perpendicular to the suns direction at the mean distance of the earth from the sun. The surface of the earth receives about 1014 kW of solar energy from the sun. One square meter of the land exposed to direct sun-light receives an energy equivalent of about 1 kW of power. The radiant solar energy falling on the earth surface is directly converted into thermal energy. The surfaces on which the solar rays fall are called collectors.
There are two types of collectors:
(a) Flat plate collectors (b) Focusing collectors.

Liquid Flat Plate Collectors

It has the following components:

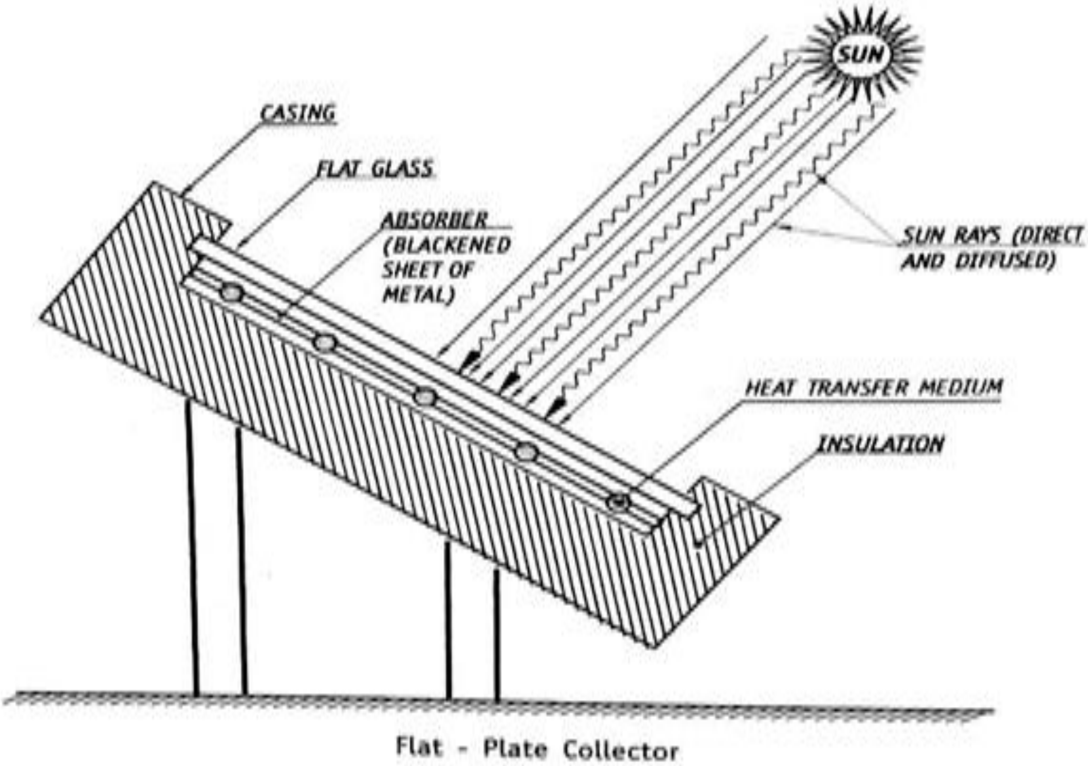
(a) Absorbing plate
• Made of Copper, Aluminium or steel.

• It is coated with material to enhance the absorption of solar radiation.

• From the absorbing plates heat is transferred to tubes which carry either water or air.

(b) Transparent covers
• Sheets of solar radiation transmitting materials placed above the absorbing plate.
• They allow solar energy to reach the absorbing plate while reducing convection, conduction and re-radiation heat losses.

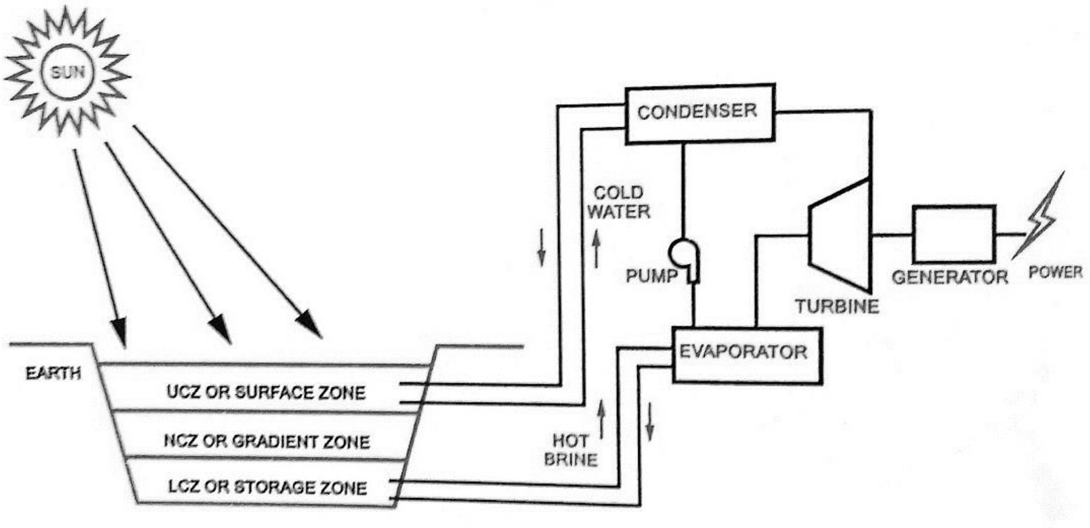
(c) Insulation
• It minimizes and protects the absorbing plate from heat losses.



Flat - Plate Collector

Working
A flat plate collector works by converting solar radiation into thermal energy. The dark coating on the plate absorbs the incoming sunlight and heats up the plate. The fluid in the pipes flows through the plate and picks up the heat from the plate. A black absorbing surface (absorber) inside the flat plate collectors absorbs solar radiation and transfers the energy to water flowing through it. FPCs are suitable for low-medium temperature applications including domestic hot water, heating, preheating and combined systems. In buildings FPC can be used both as a direct system or an indirect system. In the first case, cold water in a storage tank is pumped and heated directly through the collector.

Solar Pond Technology



Solar Pond

• A salinity gradient solar pond is an integral collection and storage device of solar energy.
• By virtue of having built-in thermal energy storage, it can be used irrespective of time and season.
• In an ordinary pond or lake, when the sun's rays heat up the water this heated water, being lighter, rises to the surface and loses its heat to the atmosphere.
• The net result is that the pond water remains at nearly atmospheric temperature.
• The solar pond technology inhibits this phenomenon by dissolving salt into the bottom layer of this pond, making it too heavy to rise to the surface, even when hot.
• The salt concentration increases with depth, thereby forming a salinity gradient.
• The sunlight which reaches the bottom of the pond remains entrapped there.
• The useful thermal energy is then withdrawn from the solar pond in the form of hot brine.
The pre-requisites for establishing solar ponds are: a large tract of land (it could be barren), a lot of sun shine, and cheaply available salt (such as Sodium Chloride) or bittern.
• Generally, there are three main layers. The top layer is cold and has relatively little salt content.
• The bottom layer is hot -- up to 100°C (212°F) -- and is very salty.
• Separating these two layers is the important gradient zone.

Photovoltaic Cell

Solar energy can be directly converted to electrical energy by means of photovoltaic effect. Photovoltaic effect is defined as the generation of an electromotive force (EMF) as a result of the absorption of ionizing radiation. Devices which convert sunlight to electricity are known as solar cells or photovoltaic cells. Solar cells are semiconductors, commonly used are barrier type iron-selenium cells.

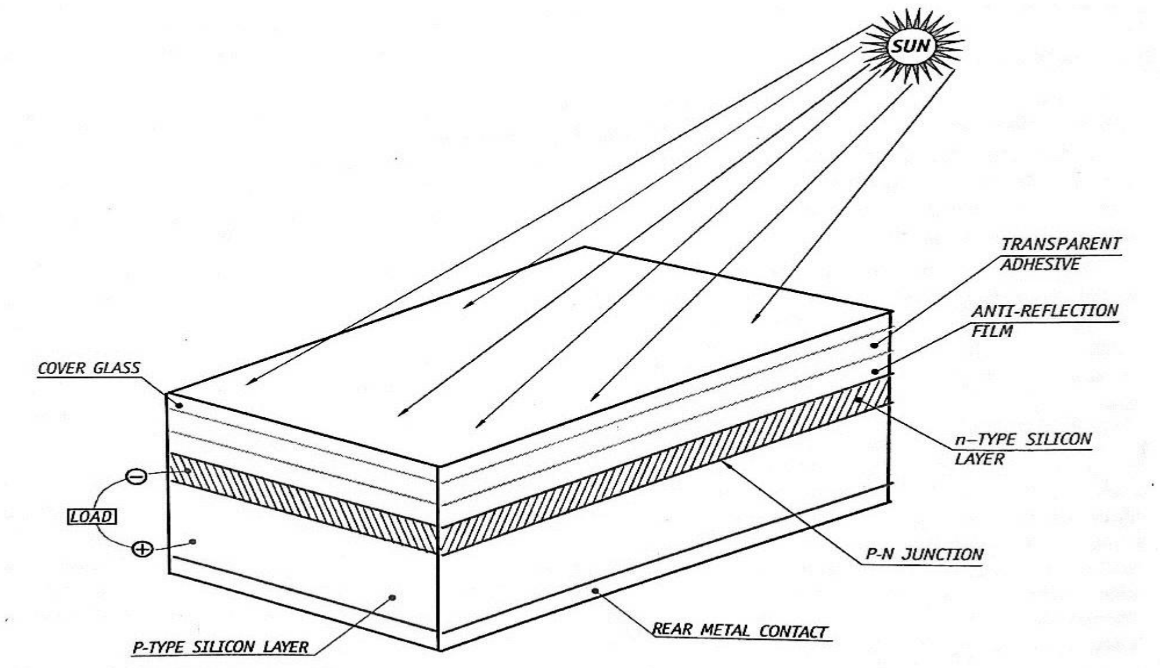
• Iron-selenium cells consist of a metal electrode on which a layer of selenium is deposited.

• On the top of this a barrier layer is formed which is coated with a very thin layer of gold.

• The layer of gold serves as a translucent electrode through which light can impinge on the layer below.

• Under the influence of sunlight, a negative charge will build up on the gold electrode and a positive charge on the bottom electrode.

This difference in charge will produce voltage in proportion to the suns radiant energy incident on it.



Solar Cell