Module-2:

SOLAR ENERGY

Syllabus:

Solar Radiation: Extra Terrestrial radiation, spectral distribution of extra terrestrial radiation, solar constant, solar radiation at the earth's surface, beam, diffuse and global radiation

Module2

Solar Power Plants: Measurement of Solar Radiation: Pyrometer, shading ring pyrheliometer, sunshine recorder, schematic diagrams and principle of working. **Solar Thermal Conversion:** Collection and storage, thermal collection devices. Fundamentals of solar energy and photovoltaic (PV) technology, Types of solar power plants: grid tied, off grid, and hybrid systems, Design considerations for solar power plants: site selection, orientation, and shading analysis, PV system components and their functionalities, Operation, maintenance, and performance monitoring of solar power plants

SOLAR ENERGY

- Solar energy is the radiant energy emitted by the sun, harnessed using various technologies to produce electricity, provide heating, and support other energy needs.
- This renewable and abundant energy source is captured primarily through solar photovoltaic (PV) cells, which convert sunlight directly into electricity, and solar thermal systems, to heat fluids or air for direct heating or to drive turbines for electricity generation.
- Solar energy offers numerous environmental and economic benefits, as it produces no greenhouse gases or air pollution during operation and reduces reliance on fossil fuels.

- Technologies for harnessing solar energy have evolved rapidly, making it more affordable and efficient.
- Solar power is a key factor in global efforts to combat climate change and transition to more sustainable energy sources.
- When this radiation strikes a solid or liquid, it is absorbed and transformed into heat energy.
- The heat energy is collected in fluid, generally water. This heat energy can be used in a solar heater or drier or can be used to run an engine.
- Flat plate collector or parabolic concentrated type collector is used to collect and concentrate the solar energy and increase the temperature of the working fluid.

BASIC PRINCIPLES OF SOLAR ENERGY

- The sun gives out 3.7×10^{20} MW of energy into space, out of which earth intercepts only 1.7×10^{11} MW.
- Solar radiation is reduced in intensity in the atmosphere by clouds, dust, haze and fog.
- The energy emitted by the sun in three minutes is equivalent to the world energy consumption during a year.
- Most of the energy we receive from the sun comes in the form of light, a short wave radiation.

Extra-Terrestrial Radiation (ETR)

Extra-terrestrial radiation refers to the solar energy received at the outer edge of the Earth's atmosphere before any interaction with atmospheric particles or gases. It represents the total solar radiation emitted by the Sun per unit area at the mean Earth-Sun distance. The intensity of this radiation is nearly constant and is known as the **solar constant**, which has an approximate value of **1361 W/m²**.

Since the Earth orbits the Sun in an elliptical path, the amount of extra-terrestrial radiation received varies slightly over the year. This variation is due to the changing Earth-Sun distance and is given by:

$$G_o = G_{sc} \times (1 + 0.033 \cos \times 360n/365)$$

Where:

- G_o = extra-terrestrial radiation on a horizontal surface (W/m²)
- G_{sc} = solar constant (1361 W/m²)
- n = day of the year (1 on January 1, 365 on December 31)

Spectral Distribution of Extra-Terrestrial Radiation

The Sun emits radiation across a broad spectrum, ranging from **ultraviolet (UV)** to **visible light** and **infrared (IR)** wavelengths. The distribution of this radiation follows **Planck's law**, which describes blackbody radiation, and the spectrum is approximately similar to that of a **black body at 5777 K**.

The spectral distribution of extra-terrestrial radiation consists of:

1. Ultraviolet Radiation (UV) (≤ 0.38 μm)

- About **8%** of the total solar radiation
- Includes extreme UV (X-rays) and near UV
- Largely absorbed by Earth's atmosphere (ozone layer)

2. Visible Light (0.38 - 0.78 μm)

- Contributes about **47%** of the total radiation
- This is the spectrum that is visible to the human eye
- Includes colors from violet (shorter wavelengths) to red (longer wavelengths

3. Infrared Radiation (IR) (≥ 0.78 μm)

- About **45%** of the total radiation
- Consists of near, mid, and far infrared
- Responsible for heat energy transfer from the Sun to Earth

The spectral distribution of extra-terrestrial radiation is **not uniform**, and most of the energy is concentrated in the **visible and near-infrared range**. This distribution plays a crucial role in climate studies, solar energy applications, and remote sensing.

SOLAR RADIATION

•The Solar radiation energy is also sub-divided into beam radiation or Direct radiation and Diffused radiation.

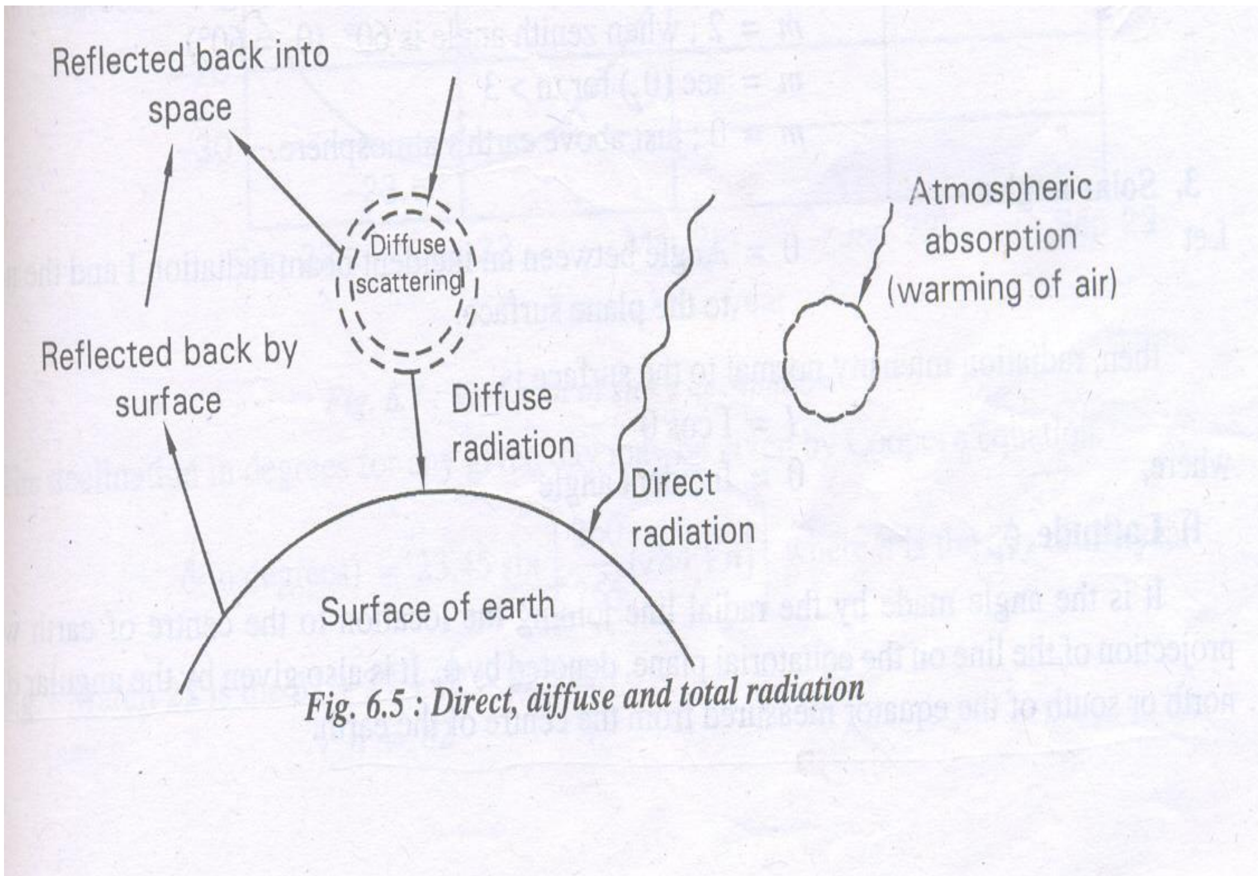
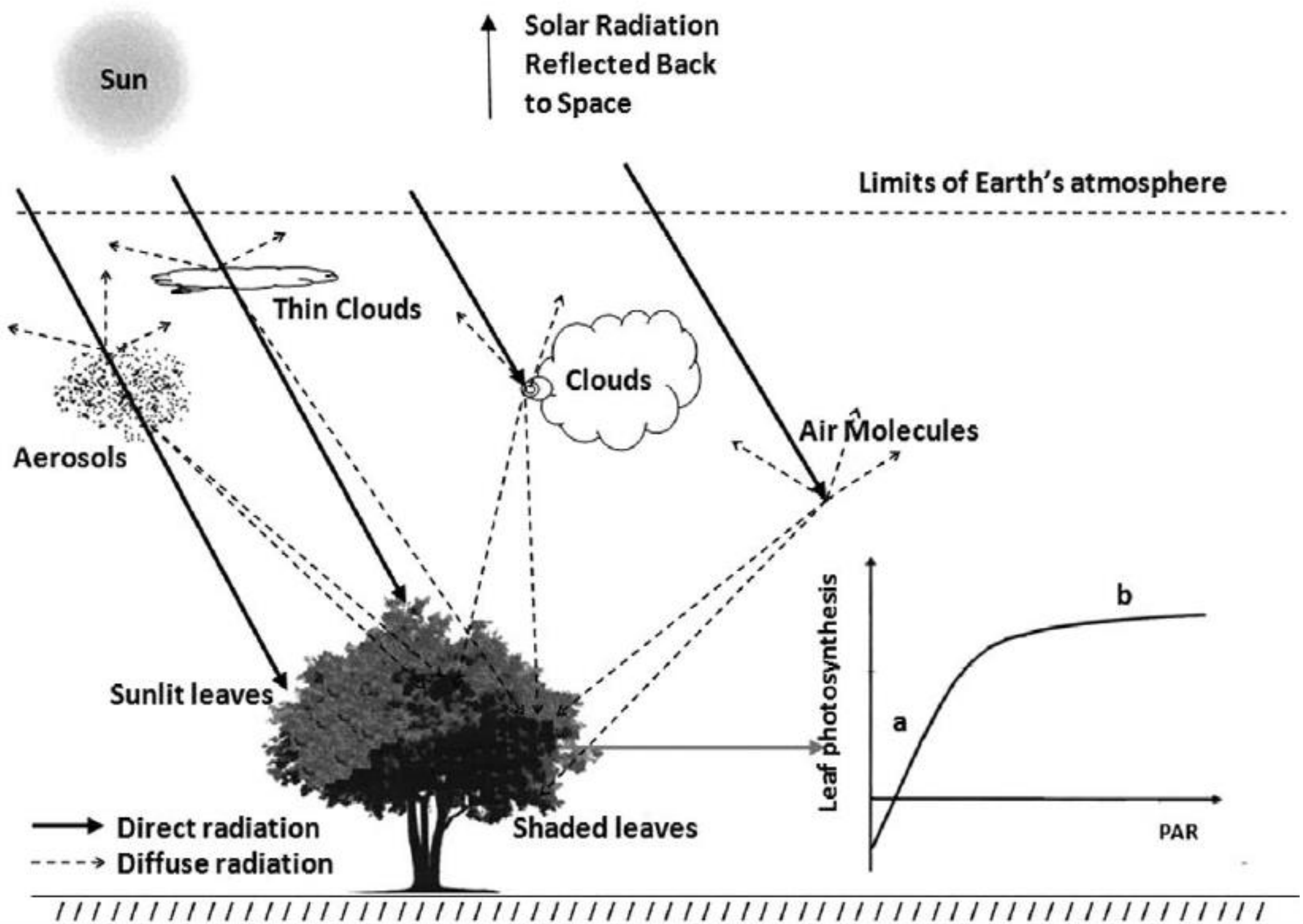


Fig. 6.5 : Direct, diffuse and total radiation


Sun
Solar Radiation
Reflected Back
to Space
Limits of Earth's atmosphere
Thin Clouds
Clouds
Aerosols
Air Molecules
Sunlit leaves
Shaded leaves
Direct radiation
Diffuse radiation
Leaf photosynthesis
PAR
a
b

•Schematic diagram illustrating the interaction of solar radiation with atmospheric particles (aerosols, clouds and air molecules) and penetration of direct (darker line)

•Diffuse (dashed line) radiation in terrestrial vegetation. The effect of direct and diffuse radiation on leaf photosynthesis is shown on the right.

•The response of shade and sunlit leaves to changes in Photo synthetically Active Radiation (PAR) under increased diffuse radiation and decreased direct radiation is shown by a and b, respectively.

•Solar radiation, often called the solar resource or just sunlight, is **a general term for the electromagnetic radiation emitted by the sun**.

•Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies

TYPES OF SOLAR RADIATION

Direct solar radiation. This type of radiation penetrates the atmosphere and reaches the Earth's surface without dispersing at all on the way.

-Direct solar radiation.

-Diffuse solar radiation.

-Reflected solar radiation.

•Beam radiation Or Direct radiation is the solar energy received from the sun without change in direction of radiation

•Diffused radiation is scattered to a receiving surface by the atmosphere and therefore, originates from all parts of the sky hemi-sphere.

•Reflected radiation is the amount of solar energy reflected from a surface, based on the solar reflectance or albedo of the surface material.

•It is also assumed that the diffused radiation is uniformly distributed over the hemisphere.

The sun radiation coming on the earth has to pass through the atmosphere, and remaining comes to the earth.

- The percentage energy falling on the earth at a particular location depends upon the atmospheric condition (dusty, cloudy or clear).
- The sun is considered as a large sphere of diameter 1.39x 106km, consisting of very hot gases.
- The earth's diameter is 1.27x104km and the average distance between the earth and sun is1.496x108km.
- The earth receives the beam radiation from the sun, almost parallel, because of very large distance between the sun and the earth.
- Even though sun's brightness varies from center to its edge, we assume that the brightness is uniform all over the solar disc.
- It is to be noted that, the radiation coming from the sun is almost equal to that of radiation coming from a Black surface which is at 5762 K.

- The energy flux radiated from the sun outside the earth's atmosphere is considered to be constant and this yields the definition of solar constant. Solar constant is the rate at which solar energy reaches at the top of the atmosphere and is denoted by Isc.
- This is the amount of energy received from the sun in unit time on a unit area perpendicular to the sun's direction and at the Mean distance of the earth from the sun.
- The distance between the earth and the sun varies as earth revolves around the sun in a elliptical orbit with a small eccentricity and sun at one of the foci.
- This changes the solar radiation and hence the energy flux reaching the earth's atmosphere.

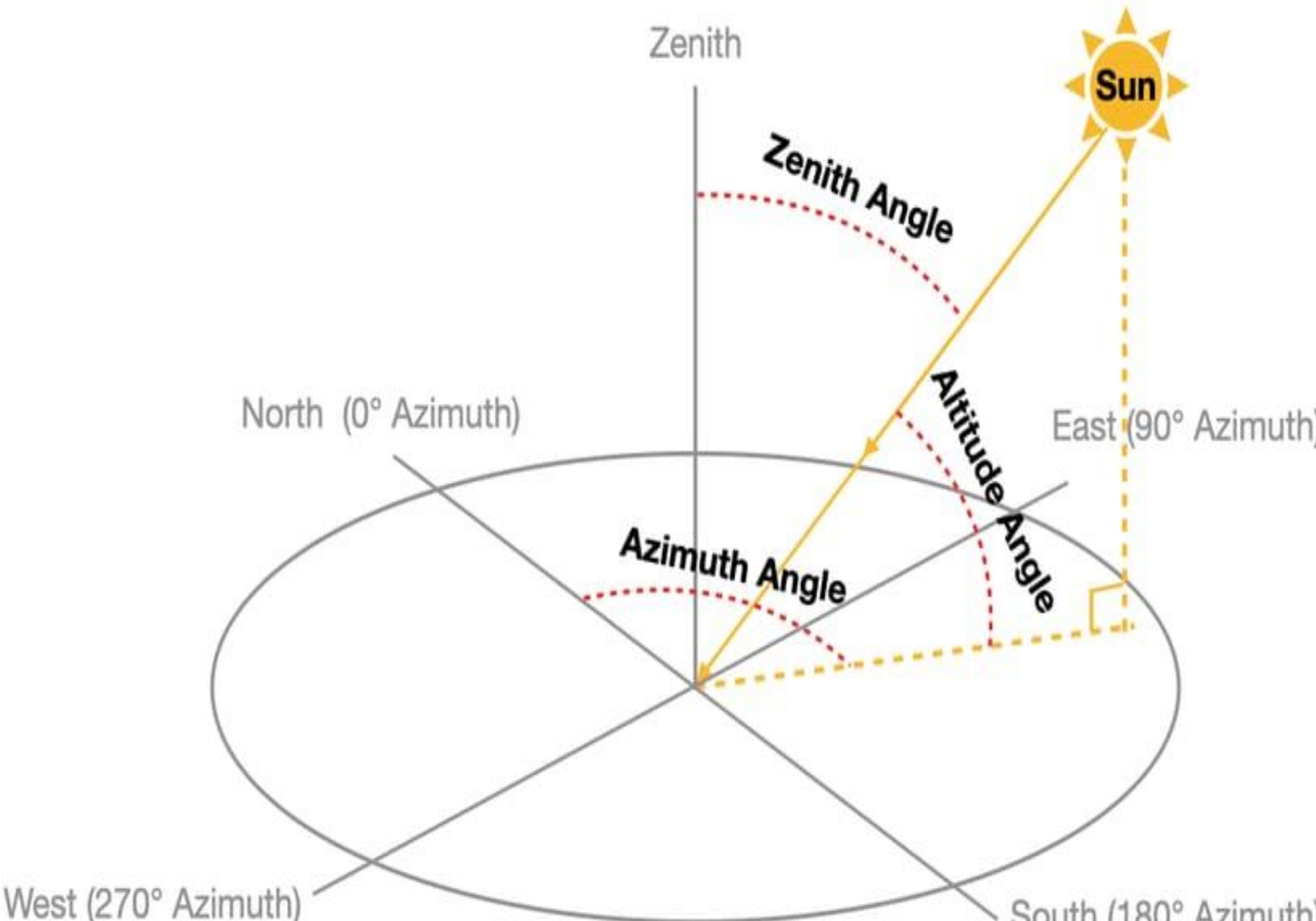
•Thus the solar constant value obtained is the average one and a standard value of 1353W/m2 was adopted in 1971.

•The solar constant value was revised to 1367 W/m2, through measurements.

•The variation in the extra terrestrial flux, outside the earth's atmosphere due to change in distance between earth and the sun produces a sinusoidal variation in the intensity of solar radiation that reaches the earth.

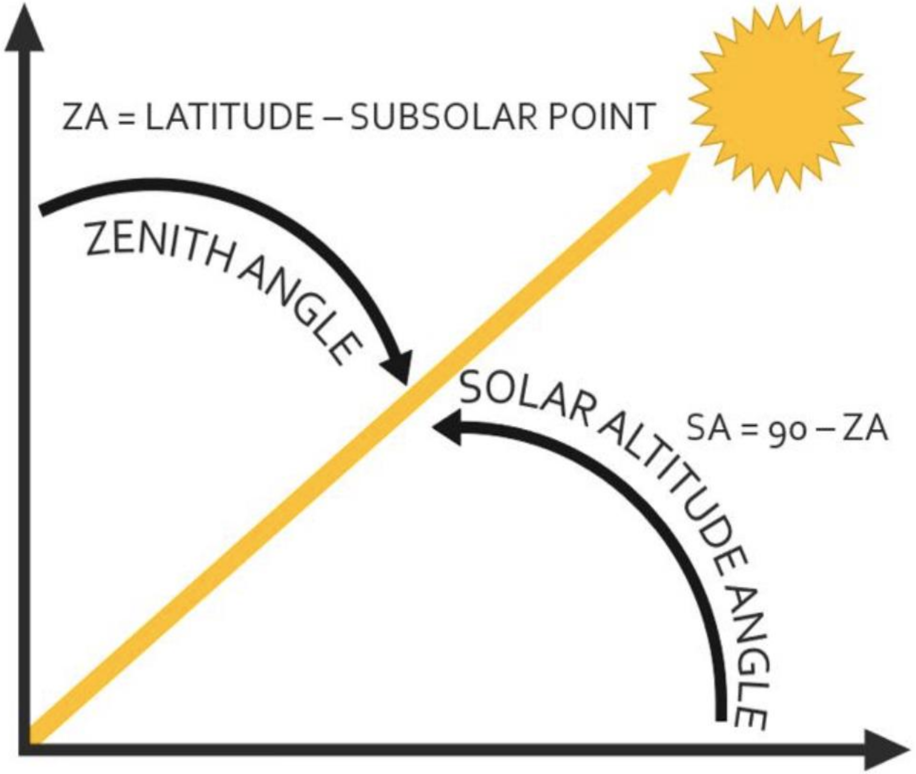
•The value of this extra terrestrial flux on any day of the year can be obtained by using the equation

Solar Radiation Geometry

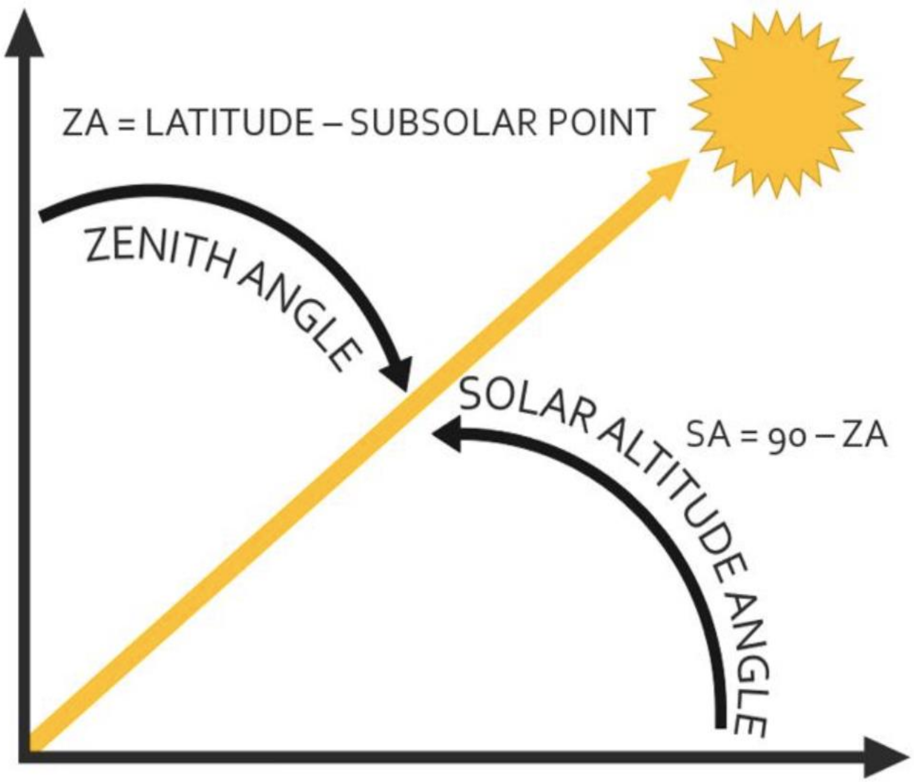


a. Zenith angle :

The zenith angle is **the angle between the sun and the vertical**. The zenith angle is similar to the elevation angle but it is measured from the vertical rather than from the horizontal, thus making the zenith angle = 90° - elevation.



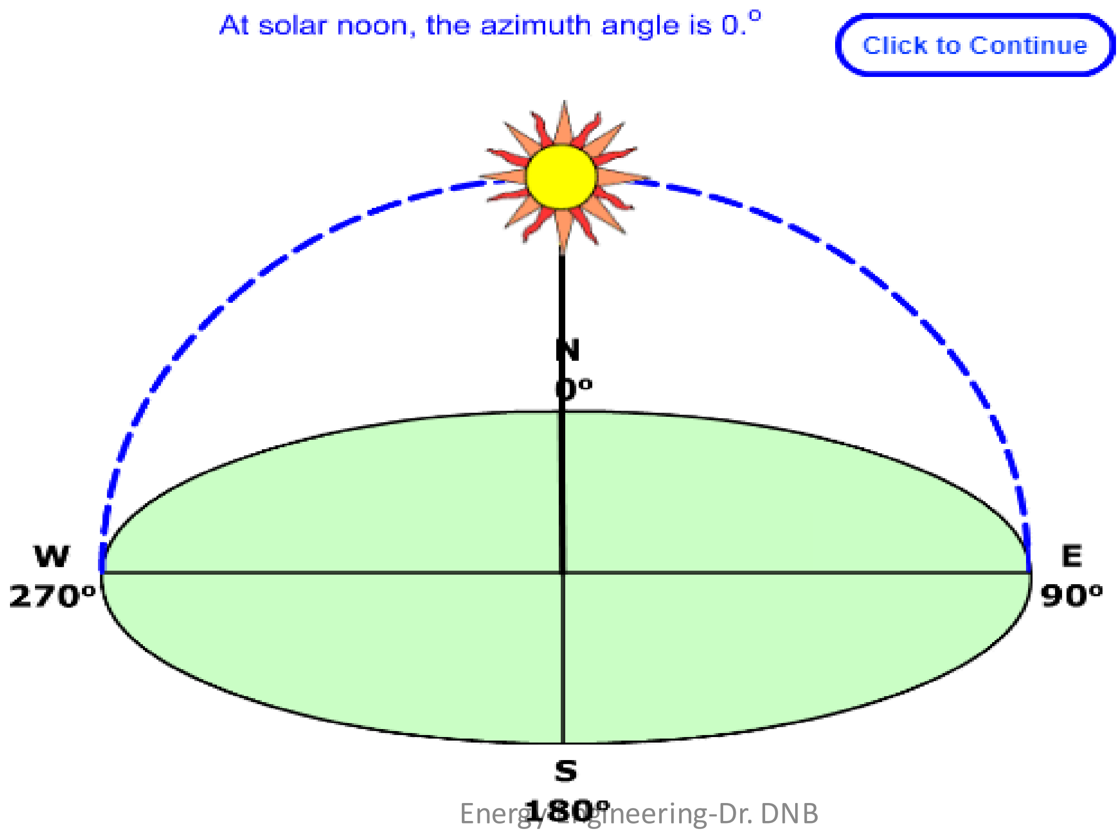
Solar altitude angle : The solar altitude angle is the angle between the sun′s rays and a horizontal plane as shown in Fig. It is related to the solar zenith angle *Φ*, being the angle between the sun′s rays and the vertical



Azimuth angle:

Azimuth angle is defined as **the angle between the projection of sun's centre onto the horizontal plane and due south direction**.

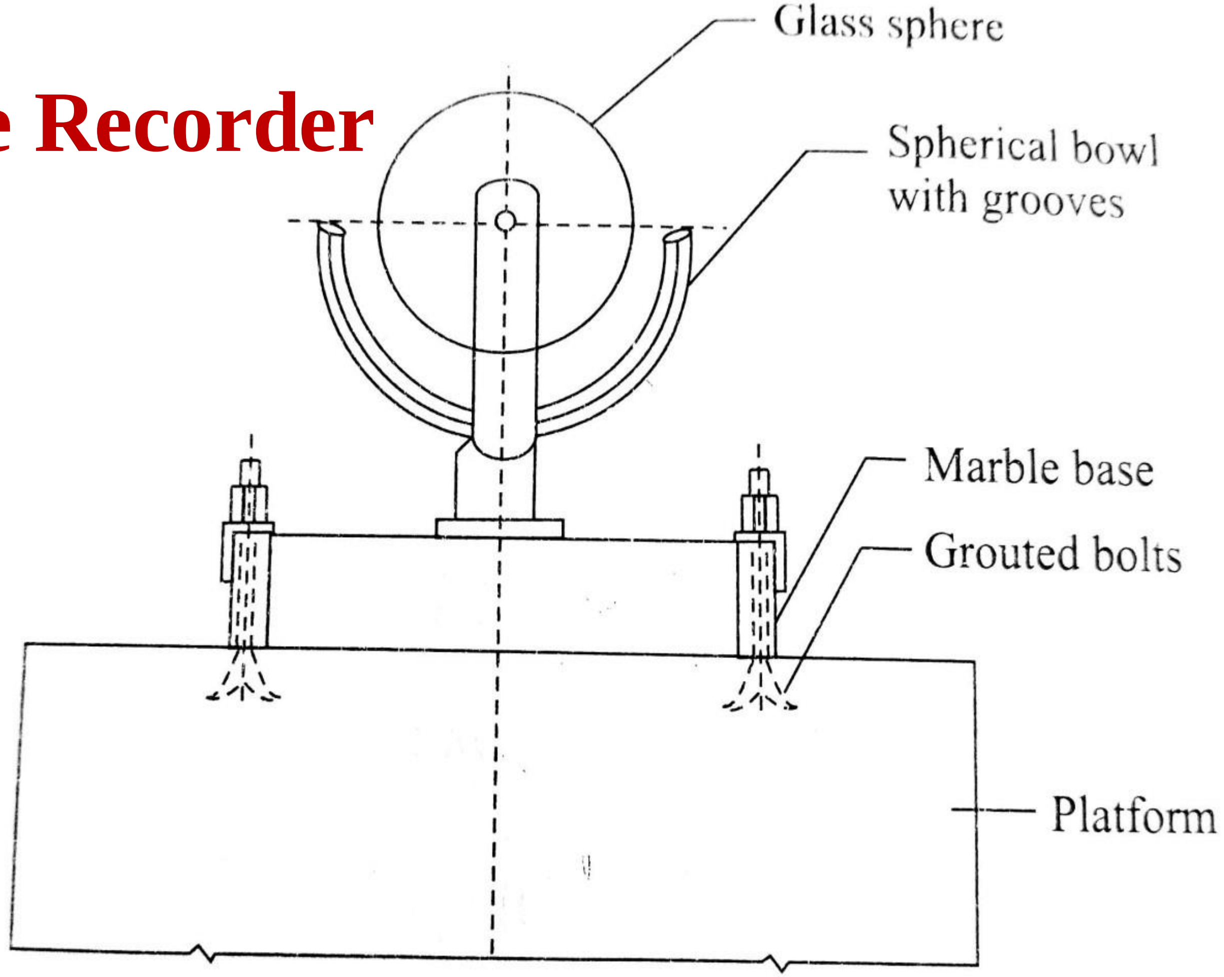
https://www.pveducation.org/pvcdrom/properties-of-sunlight/azimuth-angle



Solar radiation measurements

- Sunshine Recorder
- Pyranometer
- Pyrheliometer

Sunshine Recorder



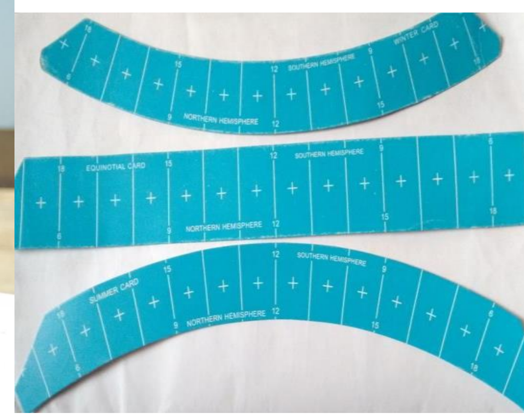
Sunshine Recorder

Sunshine Recorder

A sunshine recorder is a meteorological instrument used for recording the amount of sunlight that a particular location receives throughout a day.

- The sun's rays are focused by a glass sphere to a point on a card strip held in a groove in a spherical bowl mounted concentrically with the sphere.
- Whenever there is bright sunshine, the image formed is intense enough to burn a spot on the card strip.
- Thus a burnt trace whose length is proportional to the duration of sunshine is obtained on the strip.

Sunshine Recorder



Pyranometer

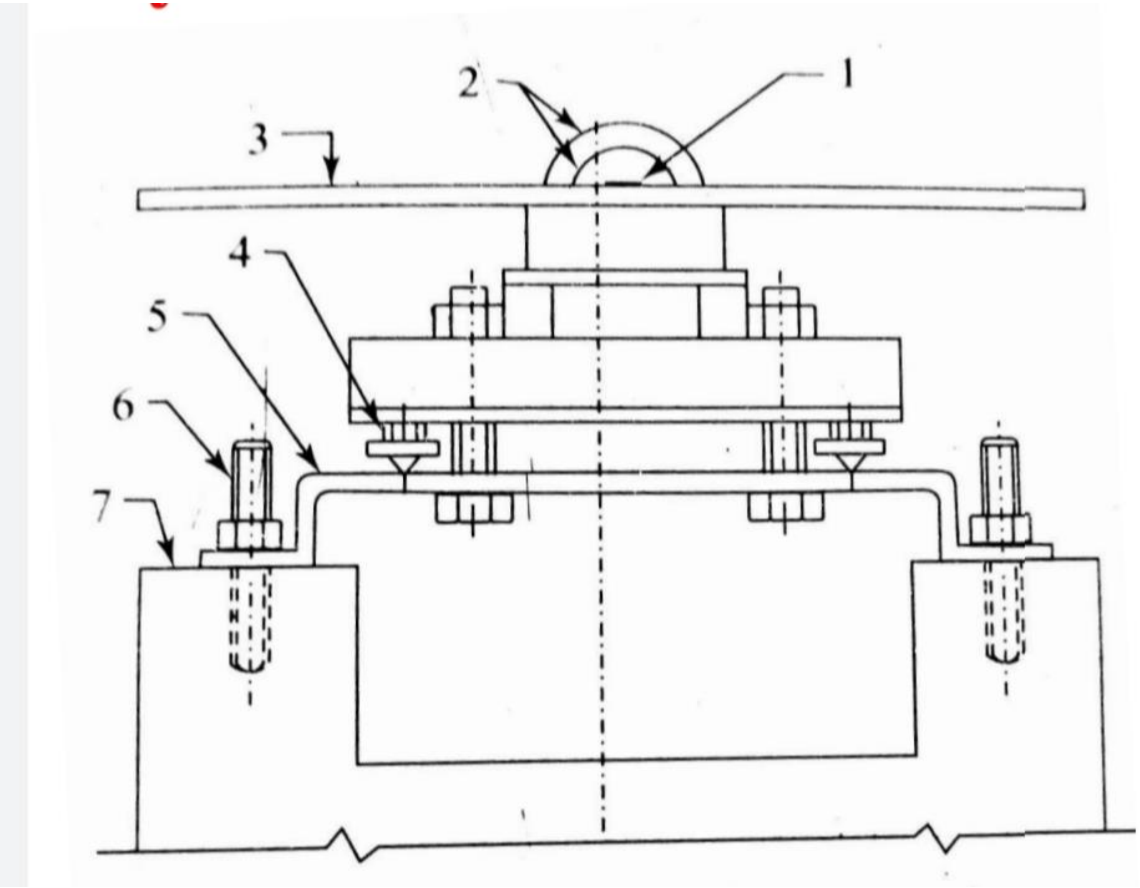


Fig. Pyranometer for measurement of Solar Radiation

1.Black Surface 2. Glass Domes 3. Guard Plate 4.Leveling Screws 5 Mounting Plate 6. Grouted Bolts 7. Platform

- A pyranometer is an instrument which measures either global or defuse radiation falling on a horizontal surface over a hemispherical field of view.
- Basically the 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 junction of a 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 e.m.f is generated. This e.m.f which is usually in the range of 0 to 10 mV can be read, recorded or integrated over a period of time and is a measure of the global radiation.

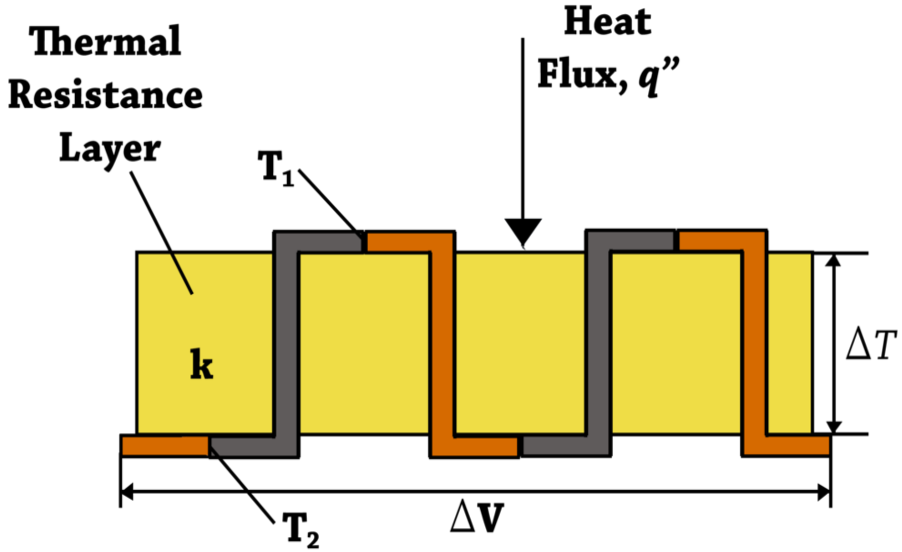
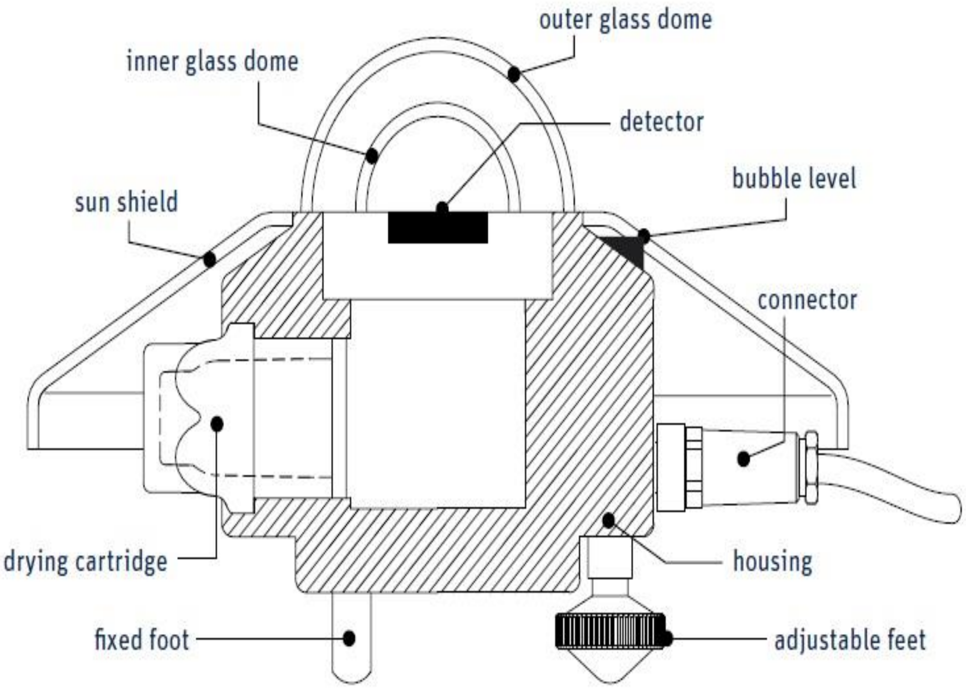
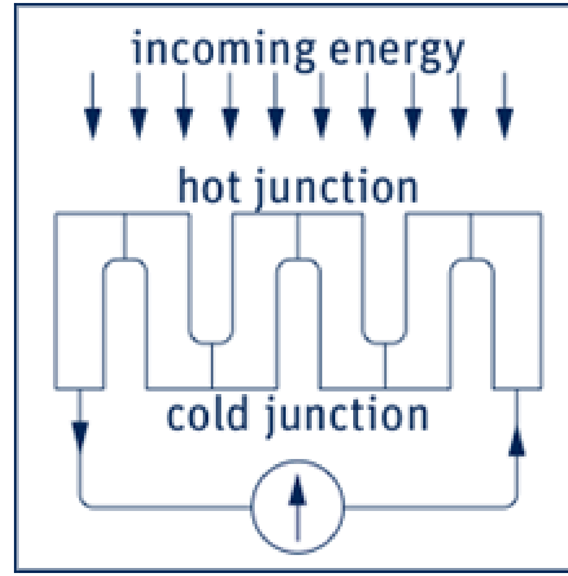


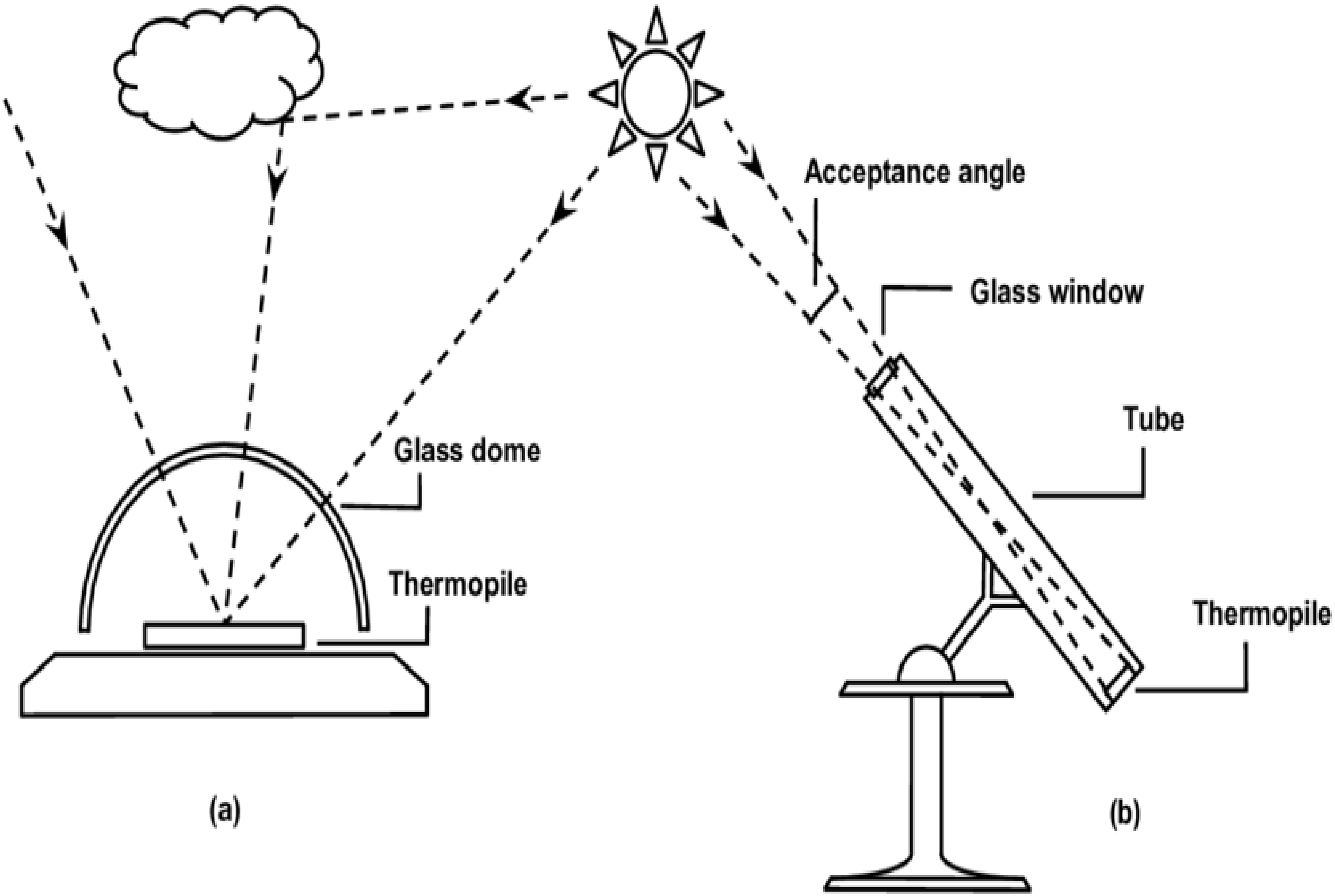
Diagram of a differential temperature thermopile with two sets of thermocouple pairs connected in series. The two top thermocouple junctions are at temperature T_1 while the two bottom thermocouple junctions are at temperature T_2. The output voltage from the thermopile, ΔV, is directly proportional to the temperature differential, ΔT or $T_1 - T_2$, across the thermal resistance layer and number of thermocouple junction pairs. The thermopile voltage output is also directly proportional to the heat flux, q'', through the thermal resistance layer.

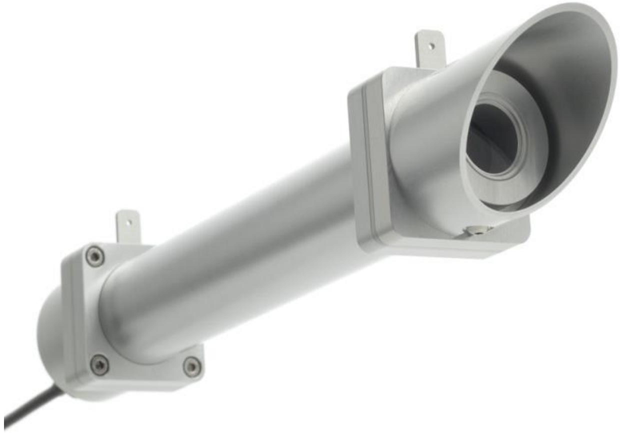
A **thermopile** is an electronic device that converts thermal energy into electrical energy. It is composed of several thermocouples connected usually in series or, less commonly, in parallel. Such a device works on the principle of the thermoelectric effect, i.e., generating a voltage when its dissimilar metals (thermocouples) are exposed to a temperature difference.


outer glass dome
inner glass dome
detector
bubble level
sun shield
connector
drying cartridge
housing
fixed foot
adjustable feet


incoming energy
hot junction
cold junction

Pyrheliometer





•A Pyrheliometer is an instrument for measurement of direct beam solar radiation.

•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.

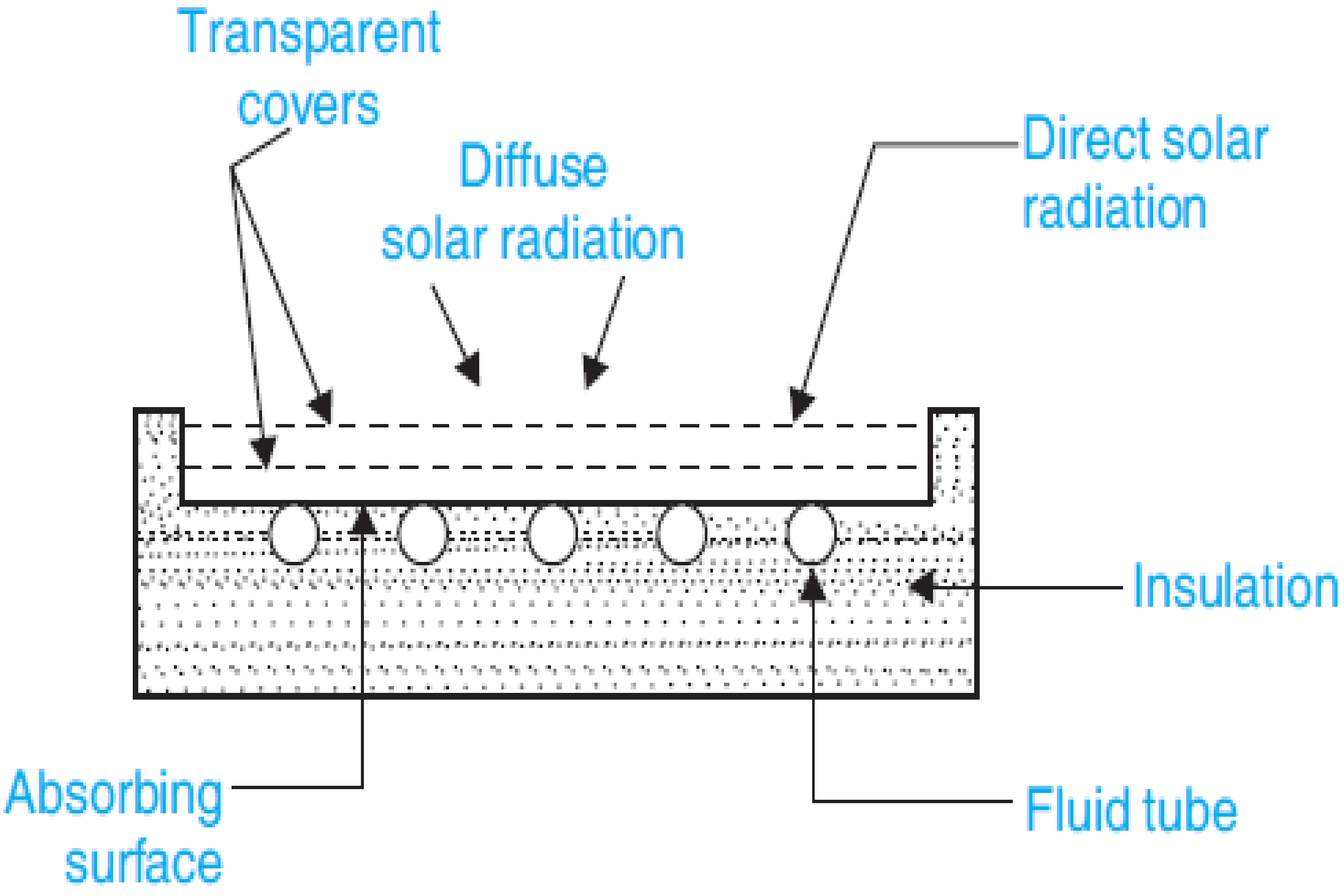
A Pyrheliometer is in instrument which measures beam radiation falling on a surface normal to the sun’s rays.

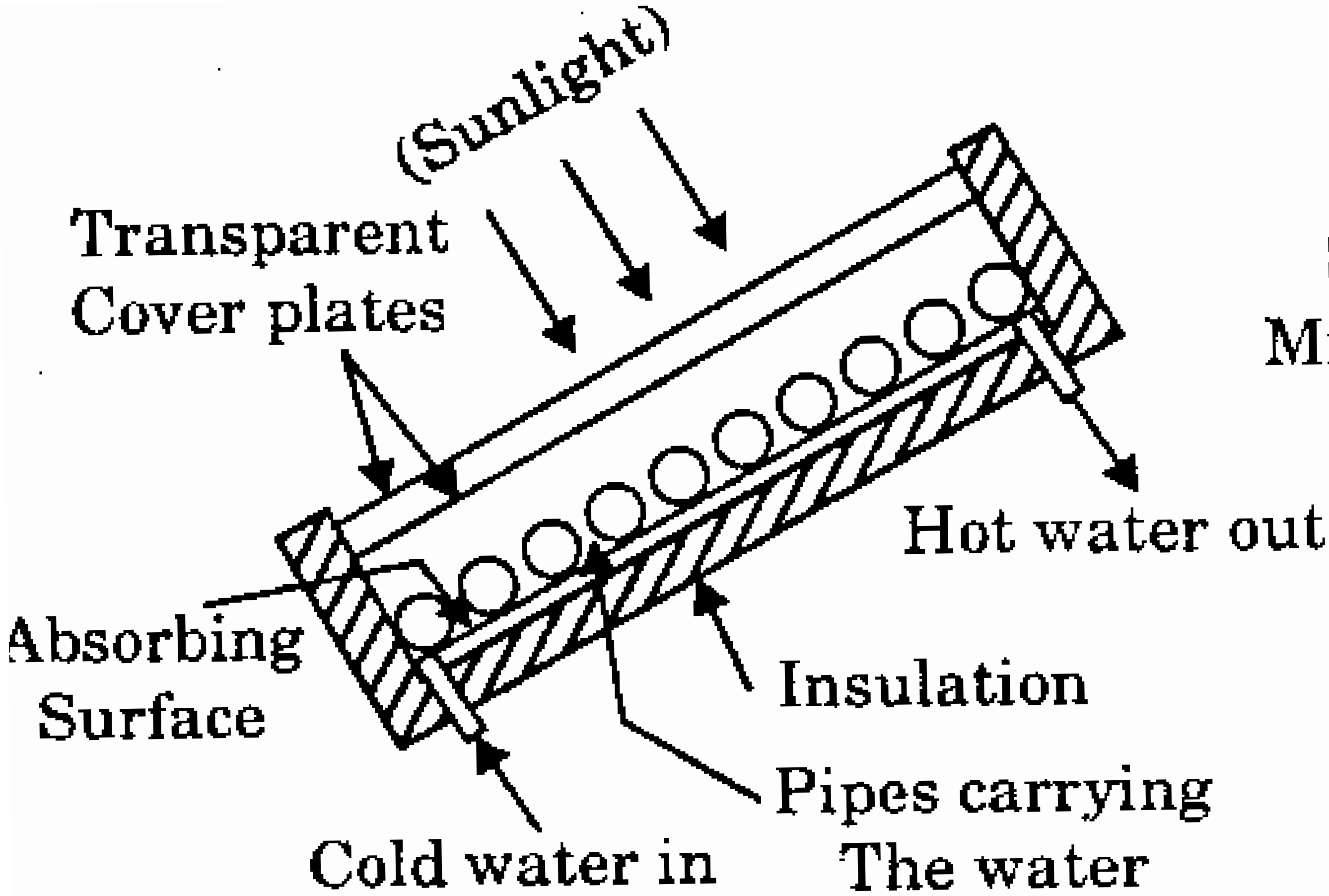
•In contrast to a pyranometer, the black absorber plate is located at the base of collimating tube.

•The tube is aligned with the direction of the sun’s rays with the help of a two axis tracking mechanism and an 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.

Solar Flat Plate Collector





(a) Flat plate collector.

A **flat plate collector** is a type of solar thermal collector designed to absorb and convert solar energy into heat, typically used for heating water or air. The fluid (generally water) is circulated through the flat plate collector and it carries the heat which falls on the collector surface.

Working Principle

Sunlight passes through the transparent cover and is absorbed by the absorber plate, heating it up. This heat is transferred to the fluid circulating through the tubes, which can then be stored in a tank or used directly, depending on the system.

Key Components

1. **Absorber Plate**: A dark-colored, flat surface made from materials like copper or aluminum, which efficiently absorbs sunlight. The plate heats up when exposed to the sun.
2. **Transparent Cover (Glazing)**: Typically made of glass or plastic, this cover allows sunlight to enter and reach the absorber plate while minimizing heat loss.

1.Insulation: Insulating materials line the bottom and sides of the collector to reduce heat loss and retain the energy absorbed.

2.Fluid Tubes: Tubes attached to or embedded in the absorber plate allow a fluid (like water or an antifreeze solution) to circulate, picking up the absorbed heat.

Applications

Flat plate collectors are common in:

•Domestic water heating

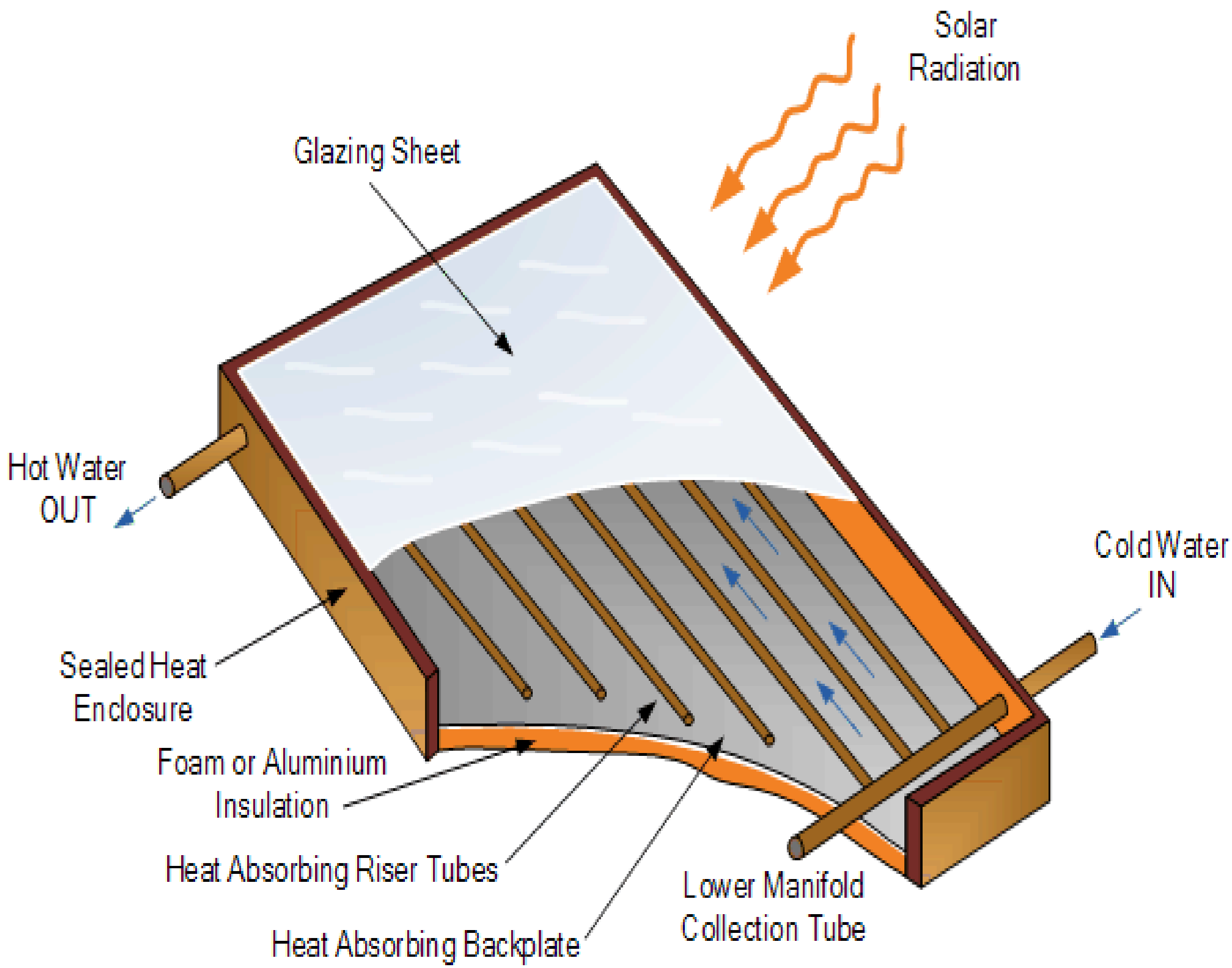
•Space heating (e.g., in residential or commercial buildings)

•Pre-heating fluids for industrial processes

Advantages and Limitations

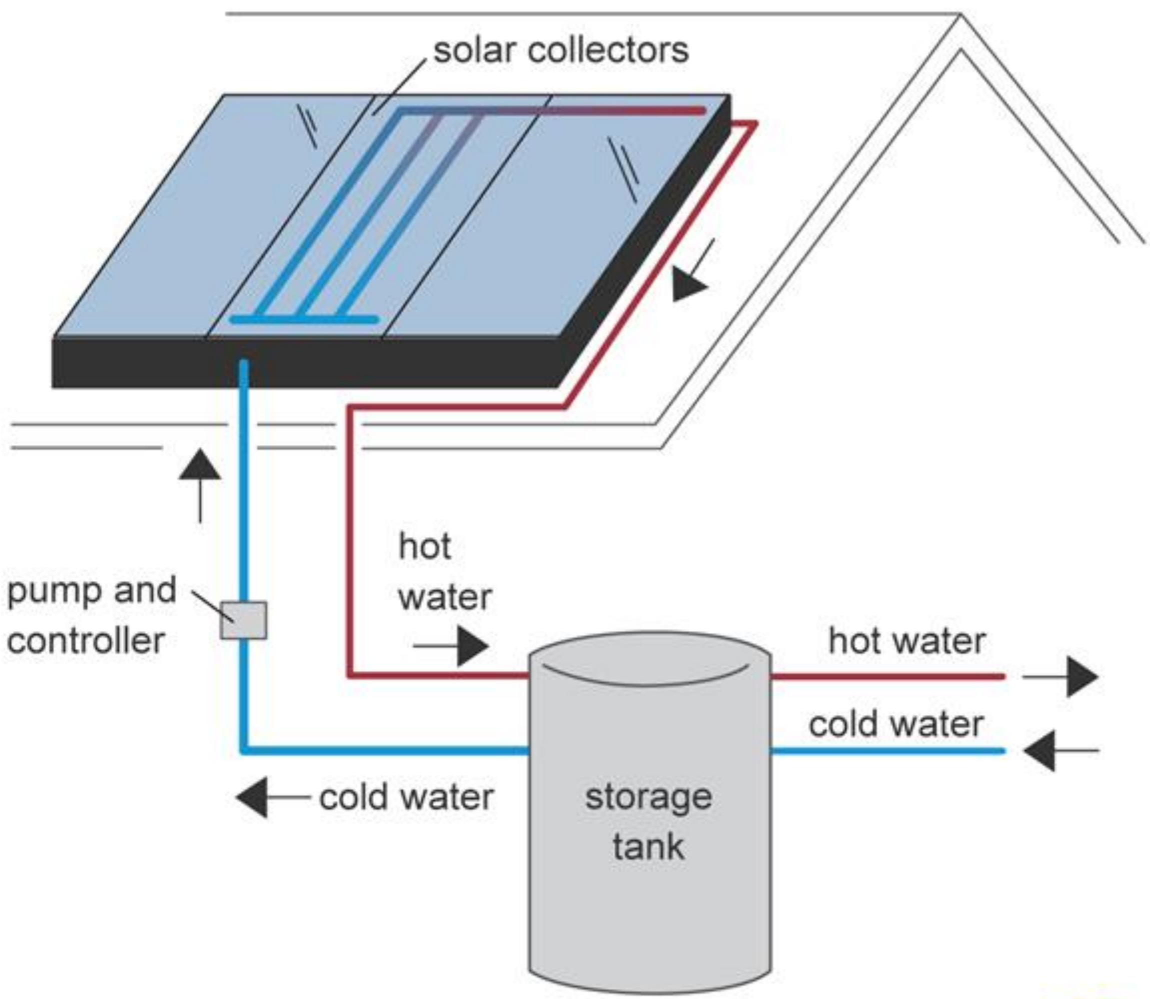
•**Advantages:** Simple design, cost-effective, low maintenance, efficient for temperatures up to 80°C.

•**Limitations:** Less efficient in colder climates or when higher temperatures are needed compared to other types, like evacuated tube collectors.


Solar Radiation
Glazing Sheet
Hot Water OUT
Cold Water IN
Sealed Heat Enclosure
Foam or Aluminium Insulation
Heat Absorbing Riser Tubes
Heat Absorbing Backplate
Lower Manifold Collection Tube

Solar Water Heating System

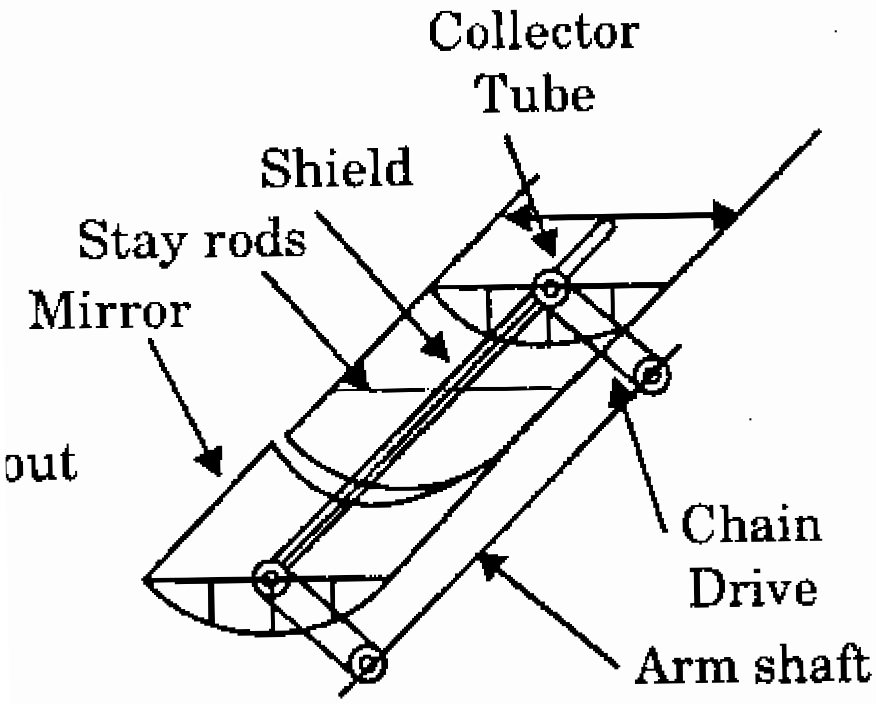
Basic components of a solar water heating system



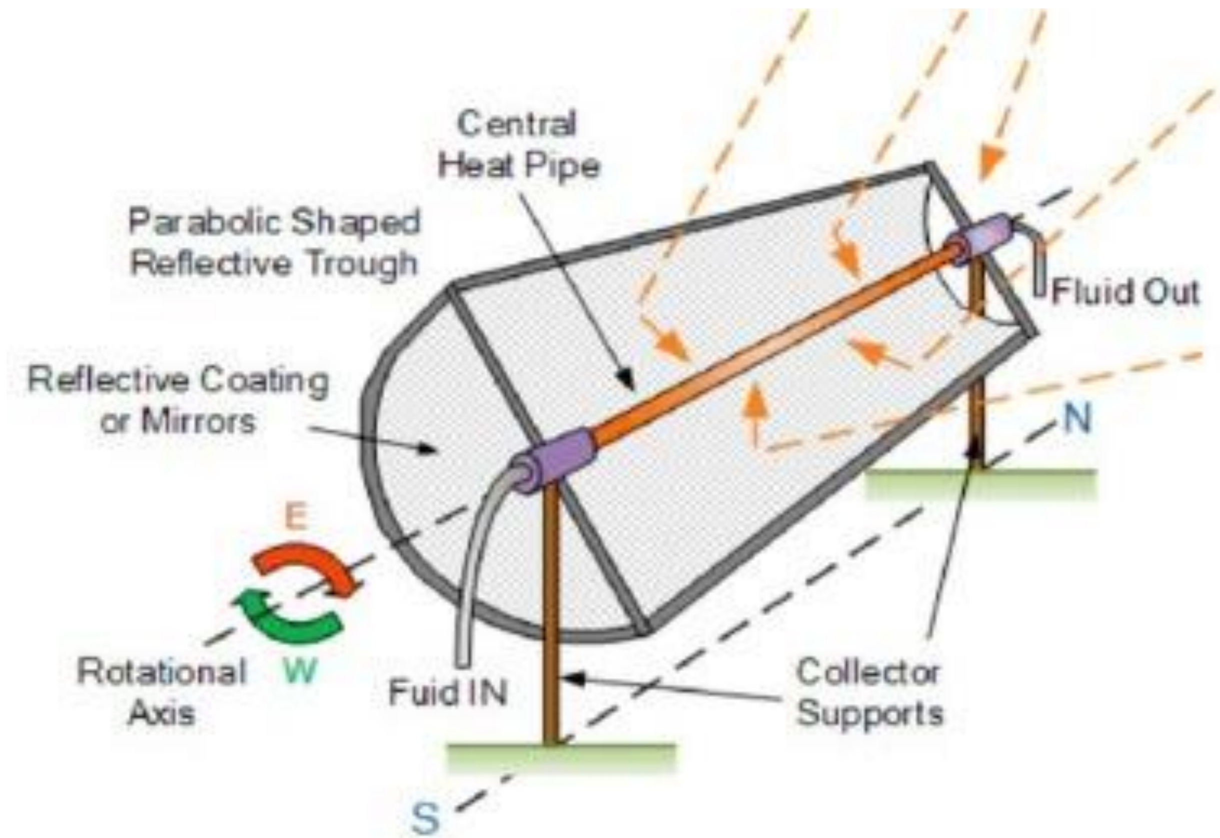
Note: This is a simplified diagram of a drainback-type solar water heating system.
Source: U.S. Energy Information Administration

Concentrator type of collector

Parabolic solar collector



(b) Parabolic concentrated type collector.


Central
Heat Pipe
Parabolic Shaped
Reflective Trough
Fluid Out
Reflective Coating
or Mirrors
N
E
W
Rotational
Axis
Fuid IN
Collector
Supports
S

A parabolic solar collector is a type of solar energy device that uses a parabolic-shaped reflective surface to concentrate sunlight onto a specific focal point. This design allows for high efficiency in capturing and converting solar energy into heat. Here’s a breakdown of how it works and its applications:

Structure and Working Principle

1. **Parabolic Shape**: The collector is shaped like a parabola, which naturally reflects incoming sunlight to a single focal point.
2. **Reflective Surface**: The inside of the parabolic dish is covered with a reflective material (often mirrors or polished metal) to direct sunlight towards the focal point.
3. **Absorber/Receiver**: At the focal point, an absorber or receiver (usually a metal pipe or coil) is placed to capture concentrated solar energy. The heat transfer fluid (e.g., oil, water, or molten salt) passes through the absorber to collect heat.
4. **Tracking System**: Parabolic collectors are often mounted on a tracking system that follows the sun throughout the day, maximizing the amount of sunlight collected.

Applications

•**Solar Power Generation**: Used in concentrated solar power (CSP) plants to generate electricity.

•**Industrial Heating**: Provides high-temperature heat for various industrial processes.

•**Desalination**: Used to power desalination systems for converting seawater into fresh water.

•**Cooking and Water Heating**: Smaller-scale parabolic collectors are used in solar cookers and solar water heaters.

Advantages

•**High Efficiency**: Concentrates sunlight effectively, leading to higher temperatures and improved efficiency.

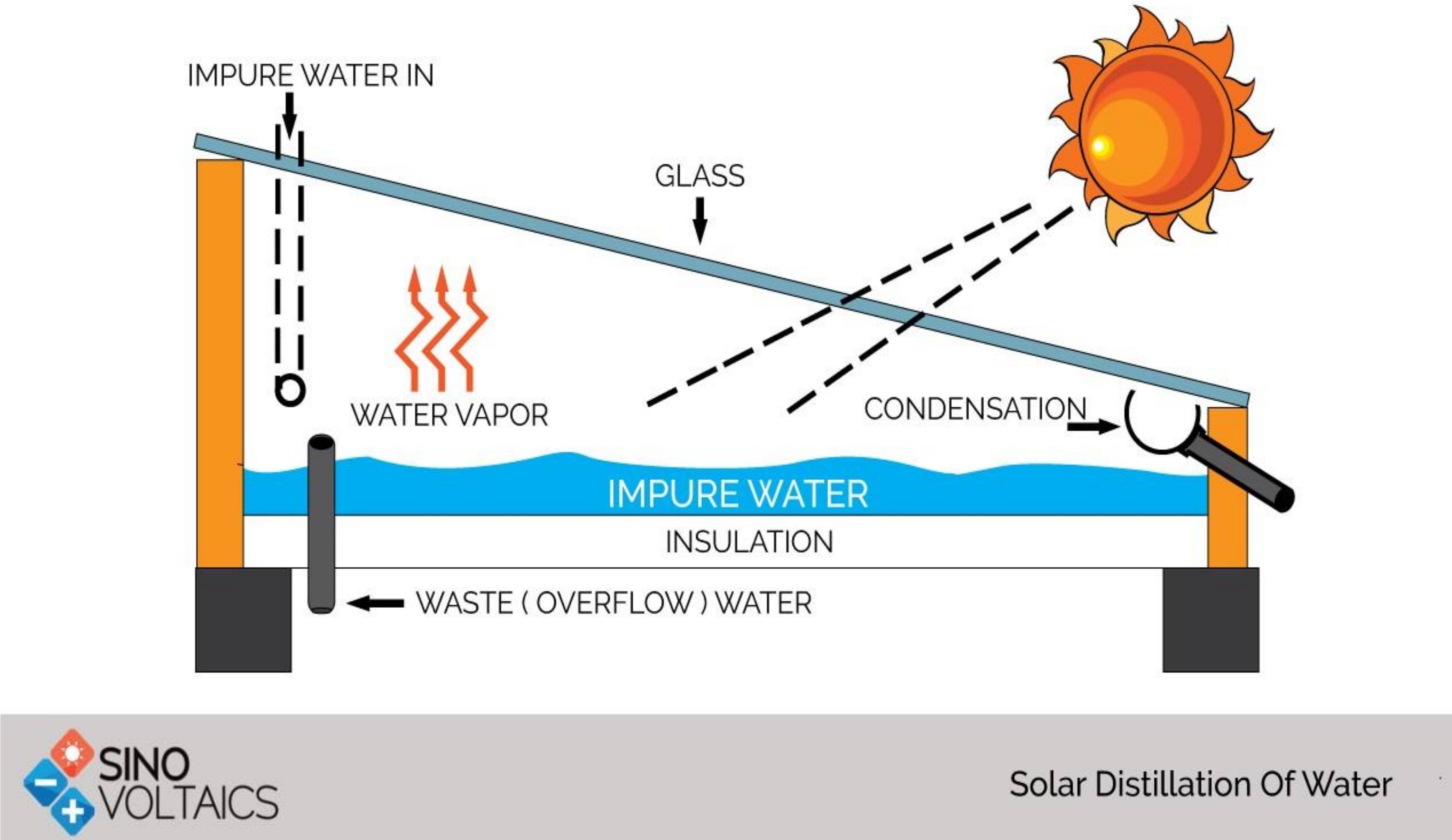
Limitations

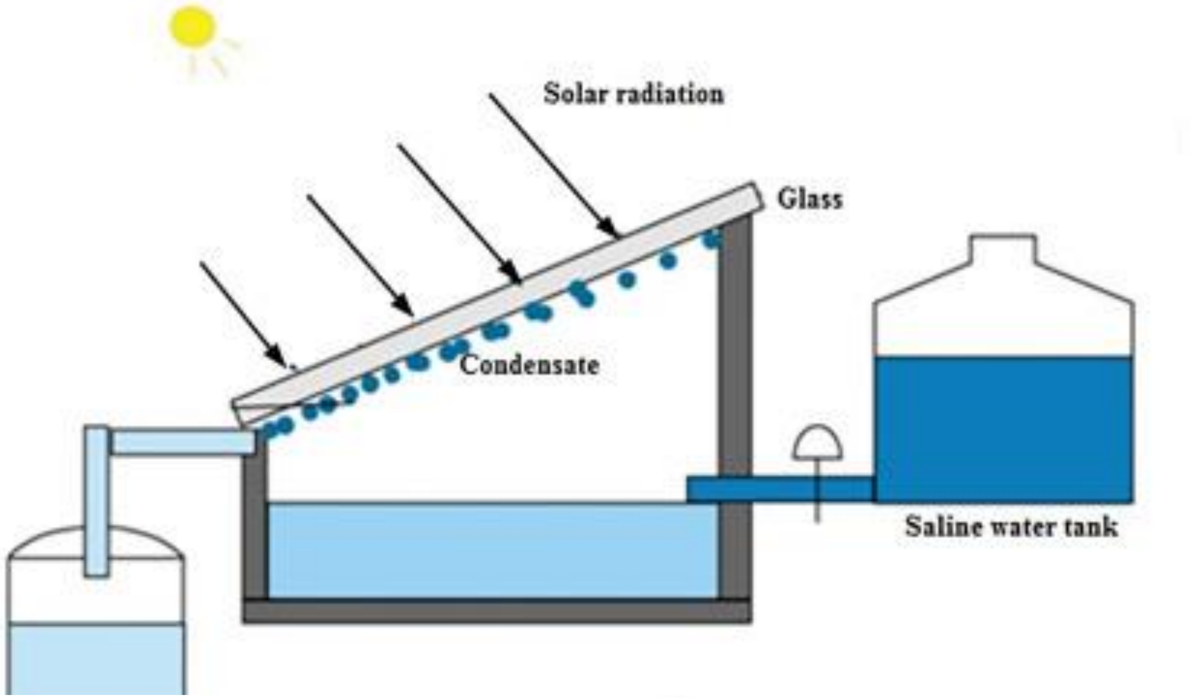
•**High Initial Cost**: Requires precise manufacturing, making it expensive compared to flat-plate collectors.

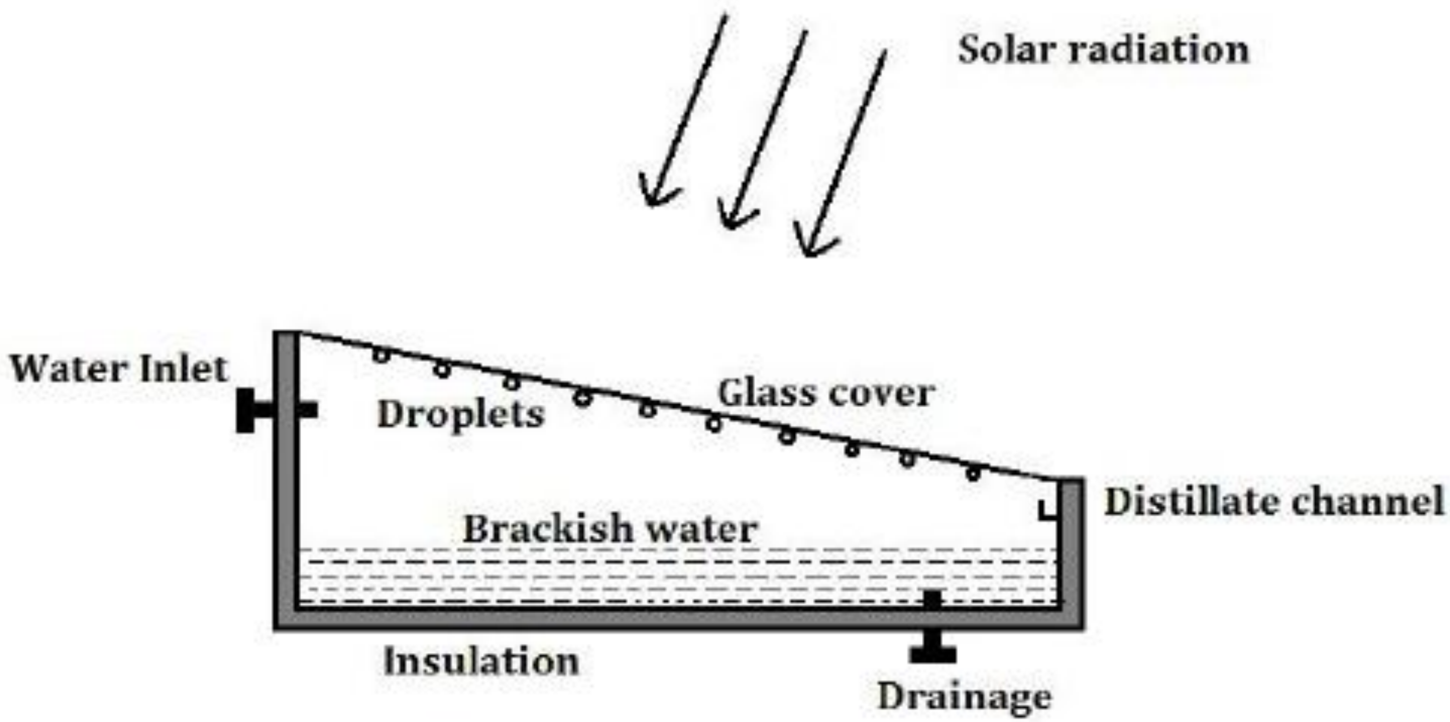
•**Requires Clear Skies**: Performance is heavily dependent on direct sunlight, which makes it less effective on cloudy days.

- In flat plate collectors, the radiation energy falls on a flat surface which is coated with paint having high absorbing capacity.
- In concentrator type of collector, the solar energy falling on the collector surface is reflected and focused along a line where the absorber is located.
- As the large quantity of energy falling of the collector surface is collected over a small surface, therefore, the temperature of the absorber fluid is considerably higher than in flat plate collectors.
- Flat plate collectors are successfully designed to heat water up to 80 degree Celsius. The concentrating type of collectors are also designed to heat water to a higher temperature or even to generate steam at lower pressures (2 to 2.5 bar).

SOLAR DISTILLATION




Solar radiation
Glass
Condensate
Saline water tank


Solar radiation
Water Inlet
Droplets
Glass cover
Distillate channel
Brackish water
Insulation
Drainage

•Solar water distillation is **the process of using energy from the sunlight to separate freshwater from salts or other contaminants**.

•The untreated water absorbs heat, slowly reaching high temperatures. The heat causes the water to evaporate, cool, and condense into vapour, leaving the contaminants behind

•Solar stills purify water through distillation, where pure water is vaporized out of collected dirty water and then condensed.

• In some cases, such as extremely poor quality or salty water, solar stills may be the most practical way to treat the water.

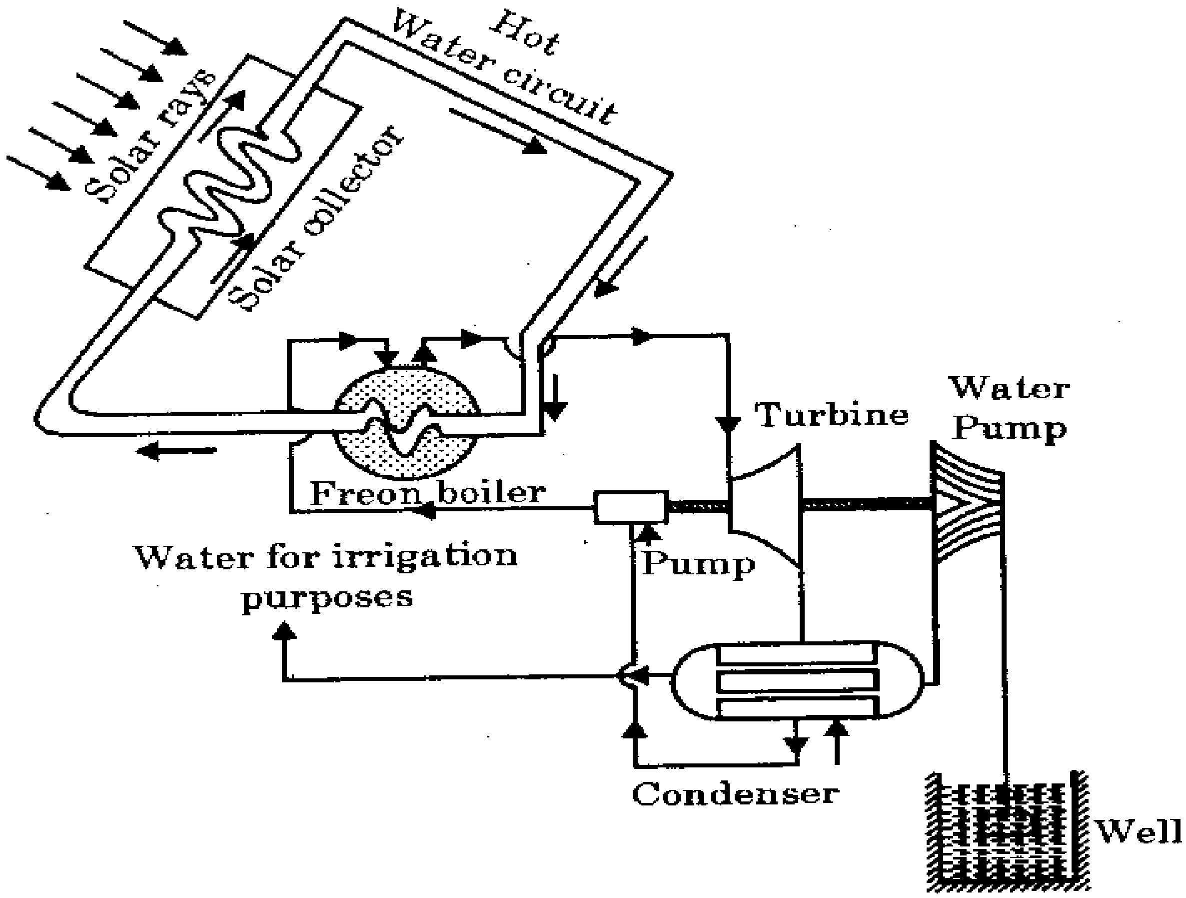
•The basic concept of the typical solar still starts with the sun’s energy going through a glass (or Plexiglas) window and evaporating the water in the pool at the bottom of the still.

•The evaporated water condenses on the glass and flows along the glass surface to channels at the bottom where it is collected

SOLAR POWER PLANTS

1) ***Low Temperature***
2) ***Medium Temperature***
3) ***High Temperature***

LOW TEMPERATURE SOLAR POWER PLANT



This plant also works as Rankine Cycle but hardly with 10 to 15% efficiency as pressure-range of working is very low compared with conventional thermal plants

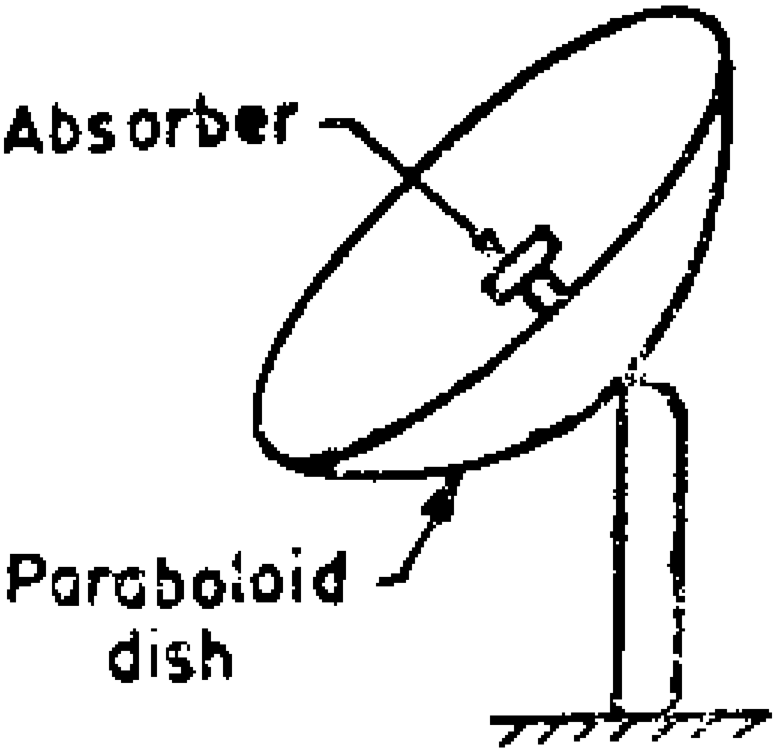
- The basic components of solar power plant using hot water coming out of the collector as a source of energy is shown in figure.

The water heated in solar collector to 80 is used for boiling the Freon-12 at high pressure in the Freon-Boiler.

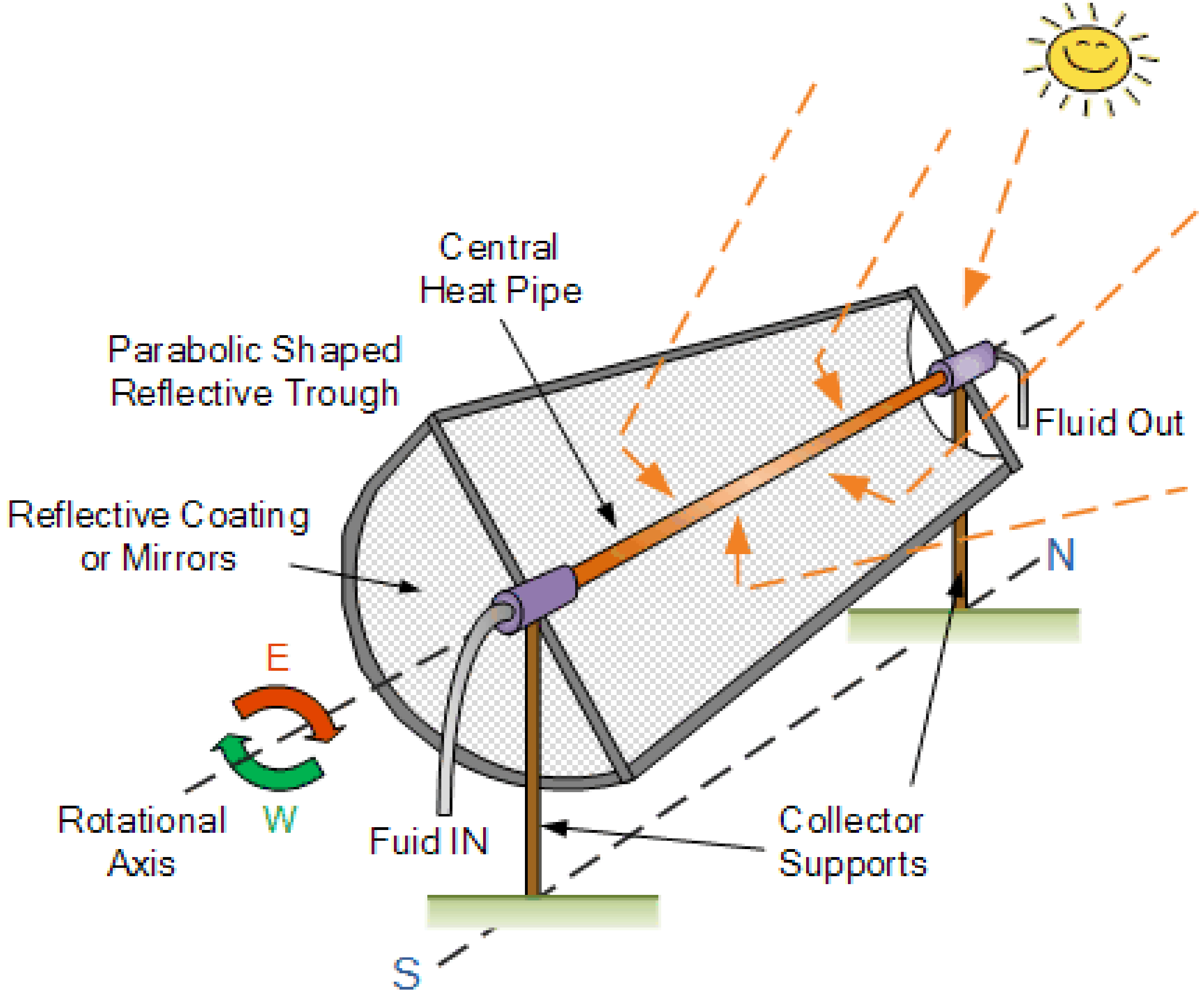
- The vapour generated at high pressure is used to run the vapour turbine which drives the electrical generator.
- The vapour coming out of the turbine at lower pressure is condensed in a condenser with the help of water at atmospheric temperature.
- The condensed liquid-Freon is fed back to the Freon boiler with the help of the feed pump.
- The generated vapours at high pressure are used to run a turbine.
- The turbine is coupled to a pump which lifts the water and used for irrigation purposes.
- The vapour coming out of turbine at low pressure is condensed in a condenser with the help of water pumped by a pump as shown in the figure. The condensed liquid is fed back to the solar boiler with the help of a pump.
- The leakage is one of the major problems in the design and construction of the plant. The whole plant must be made perfectly air-tight

SOLAR ENERGY COLLECTORS

Parabolic Dish type solar collector

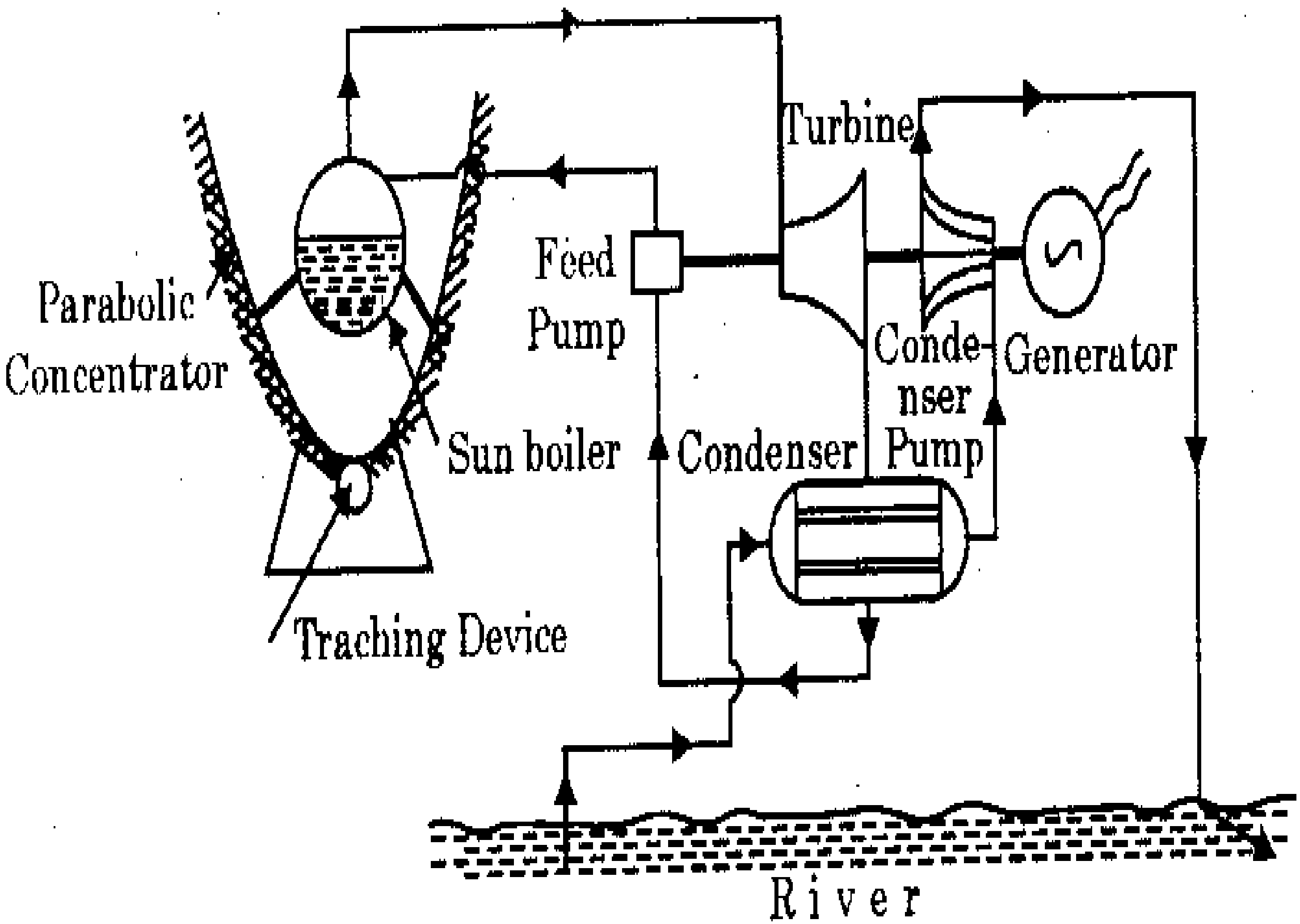


Parabolic Trough Solar Collector



Central
Heat Pipe
Parabolic Shaped
Reflective Trough
Fluid Out
Reflective Coating
or Mirrors
N
E
Rotational
Axis
W
Fuid IN
Collector
Supports
S

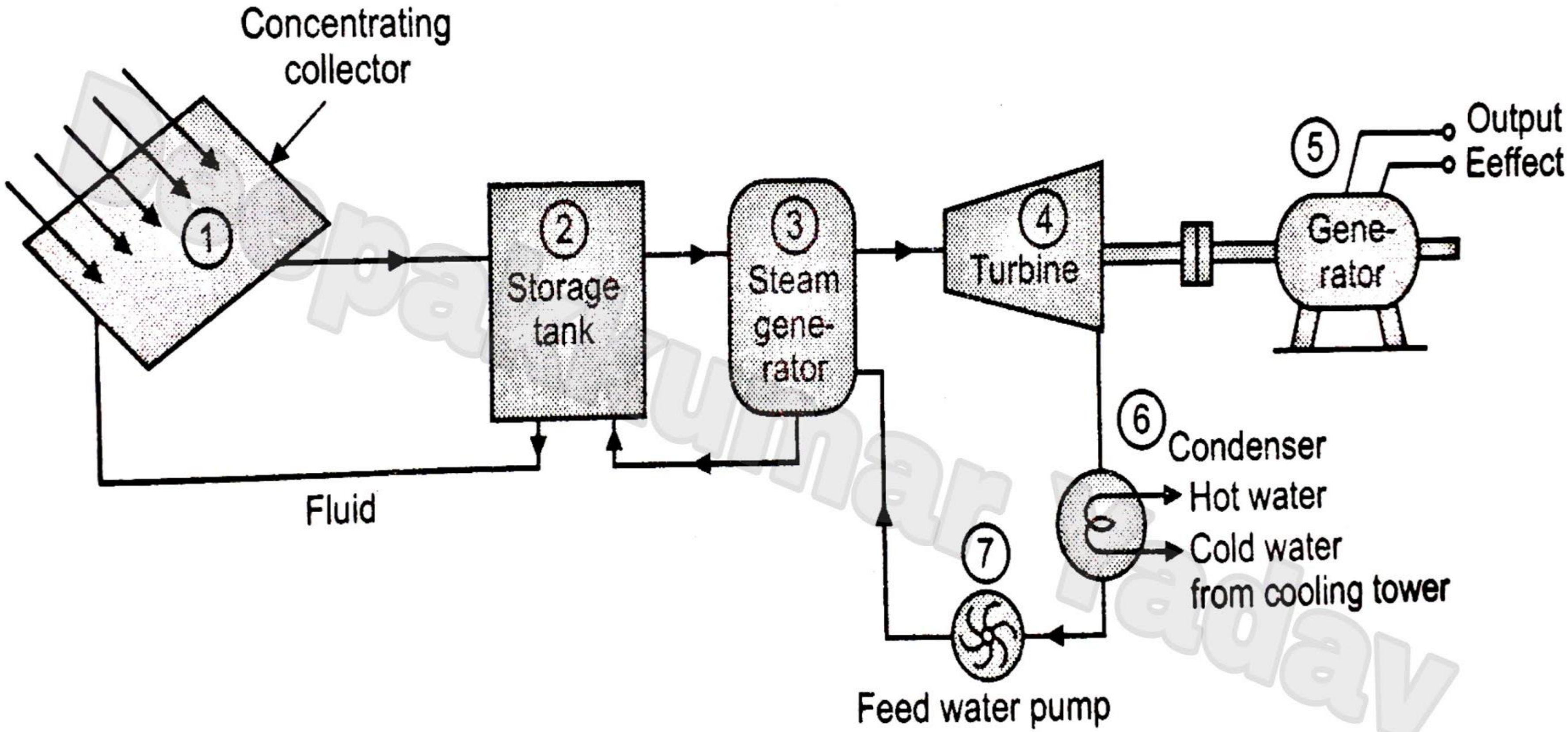
Solar Power Plant Working at Medium Temperature



Solar Power Plant Working at Medium Temperature

(Temperature range 100°C to 200°C)

- In this type of arrangement, water is used as working fluid.
- Water is converted into steam in a solar boiler where the solar energy is concentrated using a parabolic concentrator.
- The steam coming out of the boiler is used to run a turbine and then it is condensed and fed back to the boiler with the help of a pump as shown in figure.
- The power developed by the turbine is used to run a generator for producing electric power.
- The capital cost of this type of power plant is higher as concentrator type of collectors are to be used.



Medium Temperature Solar Power Plant

Concentrating collectors are used in such plant.

Temperature limit is 250° to 400°C.

Water is used to heat carrier from collector.

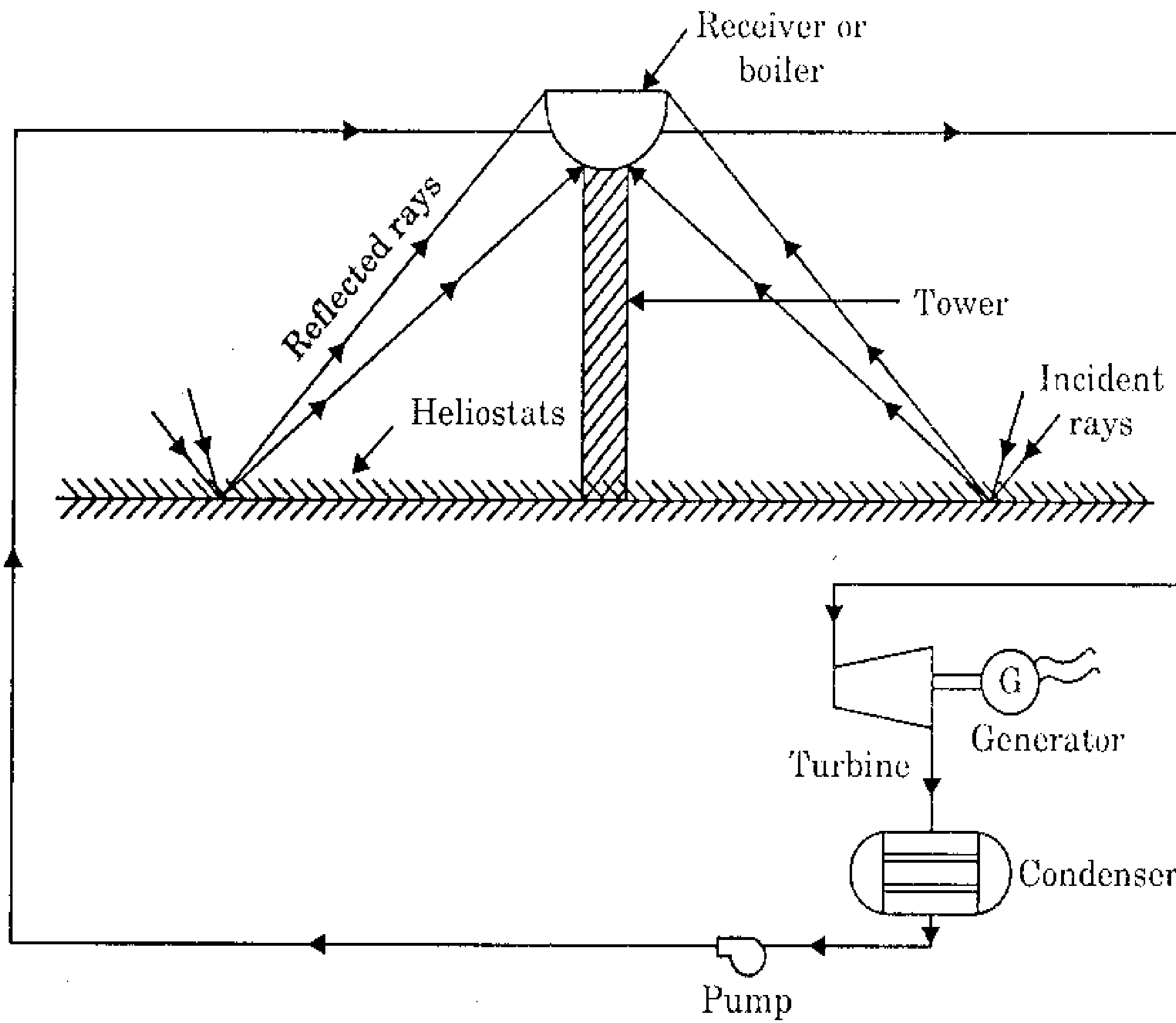
Components of Medium Temperature Solar Power Plant

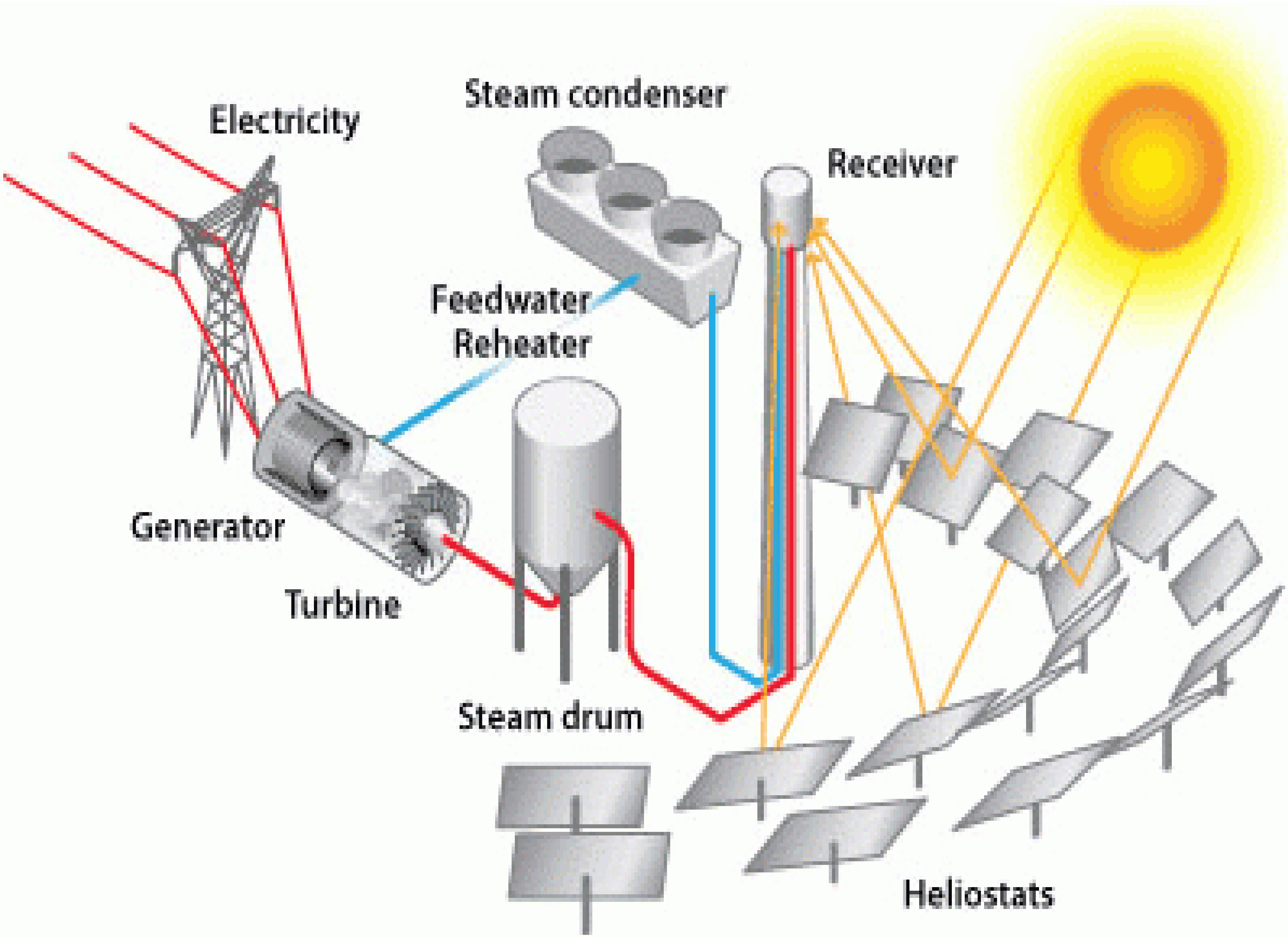
1. Array of solar concentrating collector
2. Storage tank,
3. Steam generator
4. Steam turbine
5. Generator
6. Condenser

- Array used is concentrated parabolic trough type, collects solar radiations.
- Heat carried to storage tank. Further in the steam generator.
- Steam goes to drive steam-turbine.
- Mechanical energy of turbine drives the generator.
- It converts It into electrical energy. Exhaust steam comes to condenser
- Where it is condensed by cooled water from cooling tower and pumped Back to steam generator.

This type of plant is running Rajasthan of capacity 30 MW. Temperature

High Temperature Solar Power Plant





Steam condenser
Electricity
Receiver
Feedwater
Reheater
Generator
Turbine
Steam drum
Heliostats

High Temperature Solar Power Plant

(Temperature > 400^{o}C)

- This is also known as solar tower plant because, the receiver (boiler) is located on a tower and whole field which reflects the solar energy on the receiver is tracked throughout the day so that the receiver should get maximum energy throughout the day.
- This type of system works at a much higher temperature (500 deg C) and generally used for high power generating capacity.
- The general arrangement of this system is shown in figure. In this arrangement, a field of reflectors (heliostats) is arranged separately on sun-tracking frames to reflect the sun rays on the boiler mounted on a tower as shown in figure.
- All the three systems (low, medium and high temperatures) described above works on basic Rankine cycle but with a different working fluid.

In this type of arrangement, water is used as working fluid.

•Water is converted into steam in a solar boiler where the solar energy is concentrated using a parabolic concentrator.

•The steam coming out of the boiler is used to run a turbine and then it is condensed and fed back to the boiler with the help of a pump as shown in figure.

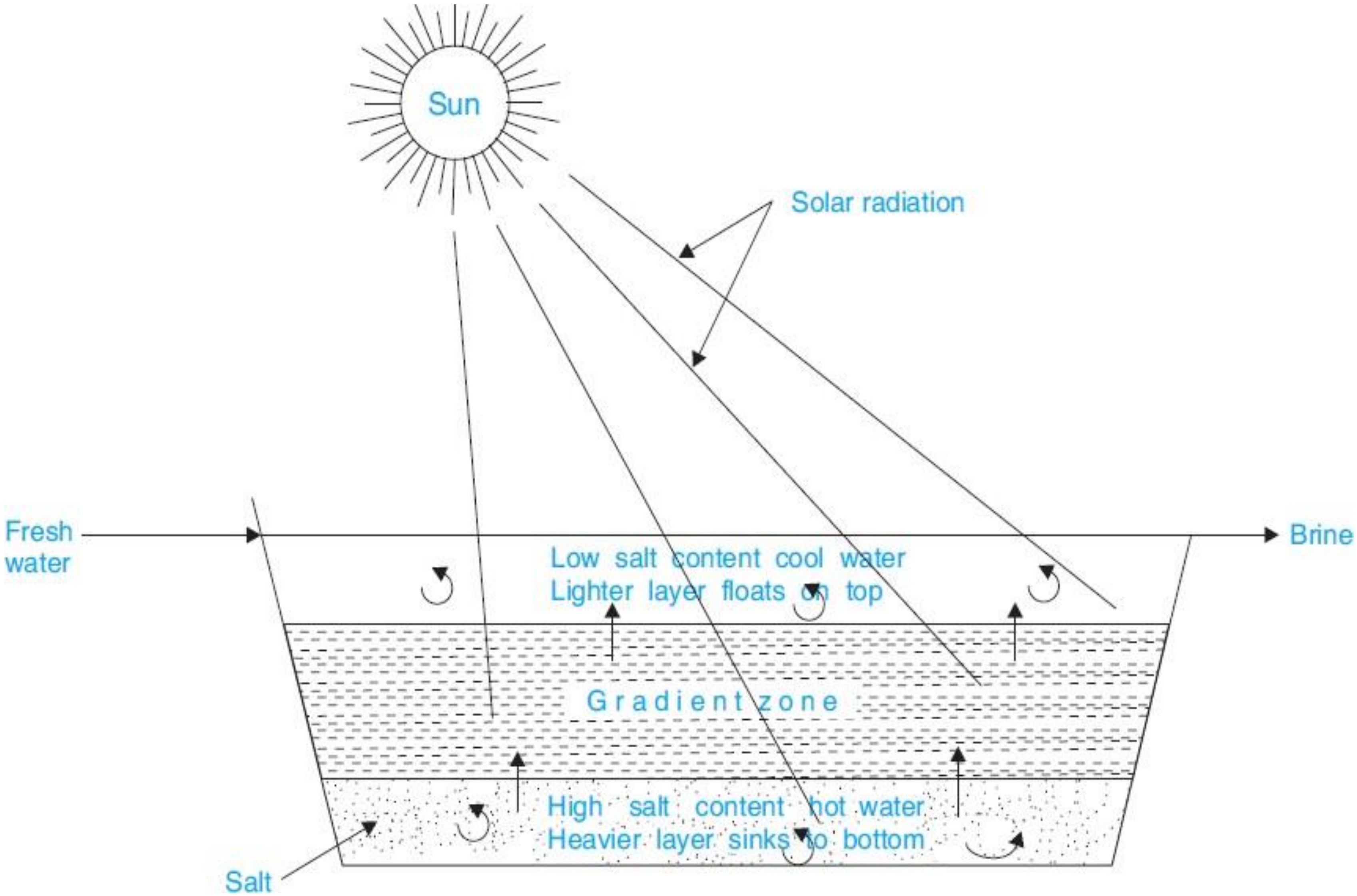
•The power developed by the turbine is used to run a generator for producing electric power.

Comparison between Flat plate and Focusing collectors

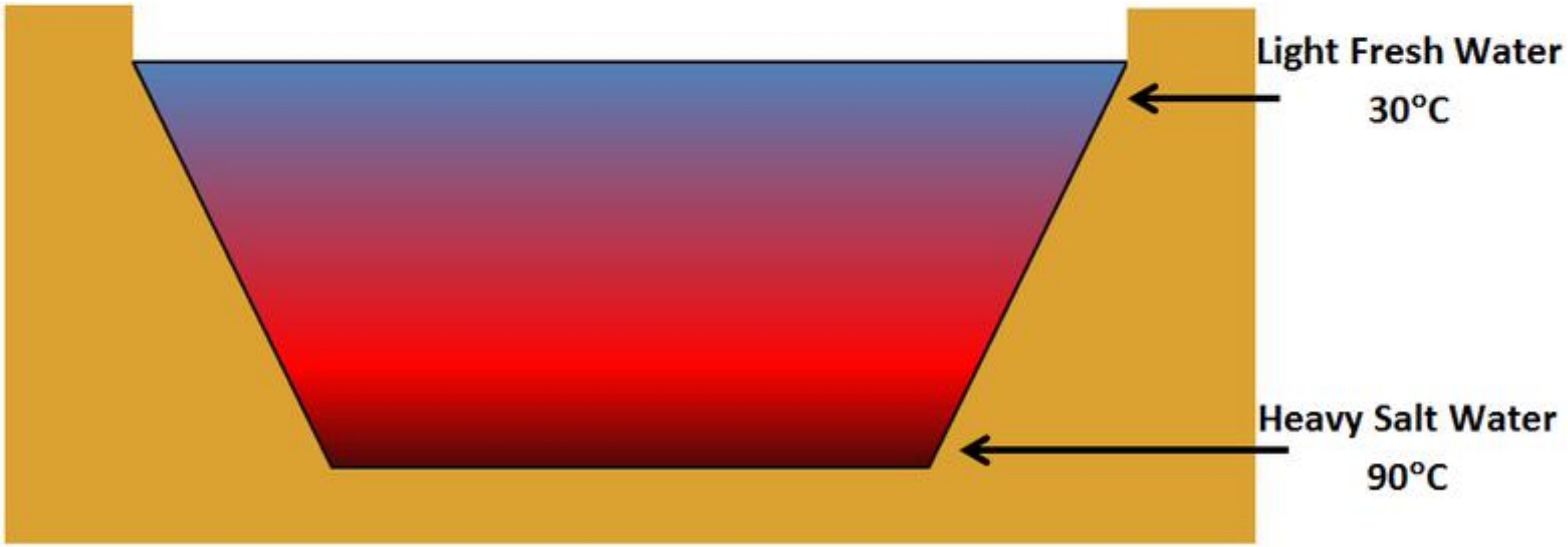
- The absorber area of concentrator system is smaller than that of a flat-plate system of the same solar energy collection area and the insulation intensity is therefore greater.
- Because the area from which heat is lost to the surroundings per unit of the solar energy collecting area is less than that for a flat plate collector and because the insulation on the absorber is more concentrated, the working fluid can attain higher temperatures in a concentrating system than in a flat-plate collector of the same solar energy collecting surface.

- Owing to the small area of absorber per unit of solar energy collecting area, selective surface treatment and/or vacuum insulation to reduce heat losses and improve collector efficiency are economically feasible.
- Since higher temperatures can be achieved, the focusing collector can be used for power generation.
- Little or no anti-freeze is required to protect the absorber in a concentrator system whereas the entire solar energy collection surface requires anti-freeze protection in a flat-plate collector.
- Out of the beam and diffuse solar radiation components, only beam component is collected in case of focusing collectors because diffuse component cannot be reflected and is thus lost.
- Costly orienting systems have to be used to track the sun.
- Non-uniform flux on the absorber whereas flux in flat-plate collectors in uniform.

Solar pond


Sun
Solar radiation
Fresh water
Brine
Low salt content cool water
Lighter layer floats on top
Gradient zone
High salt content hot water
Heavier layer sinks to bottom
Salt

Solar pond



•A solar pond is simply a pool of saltwater which collects and stores solar thermal energy.

•The saltwater naturally forms a vertical salinity gradient also known as a "halocline“(Salt slope), in which low-salinity water floats on top of high-salinity water.

•The layers of salt solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration.

•There are 3 distinct layers of water in the pond: •

-The top layer, which has a low salt content.

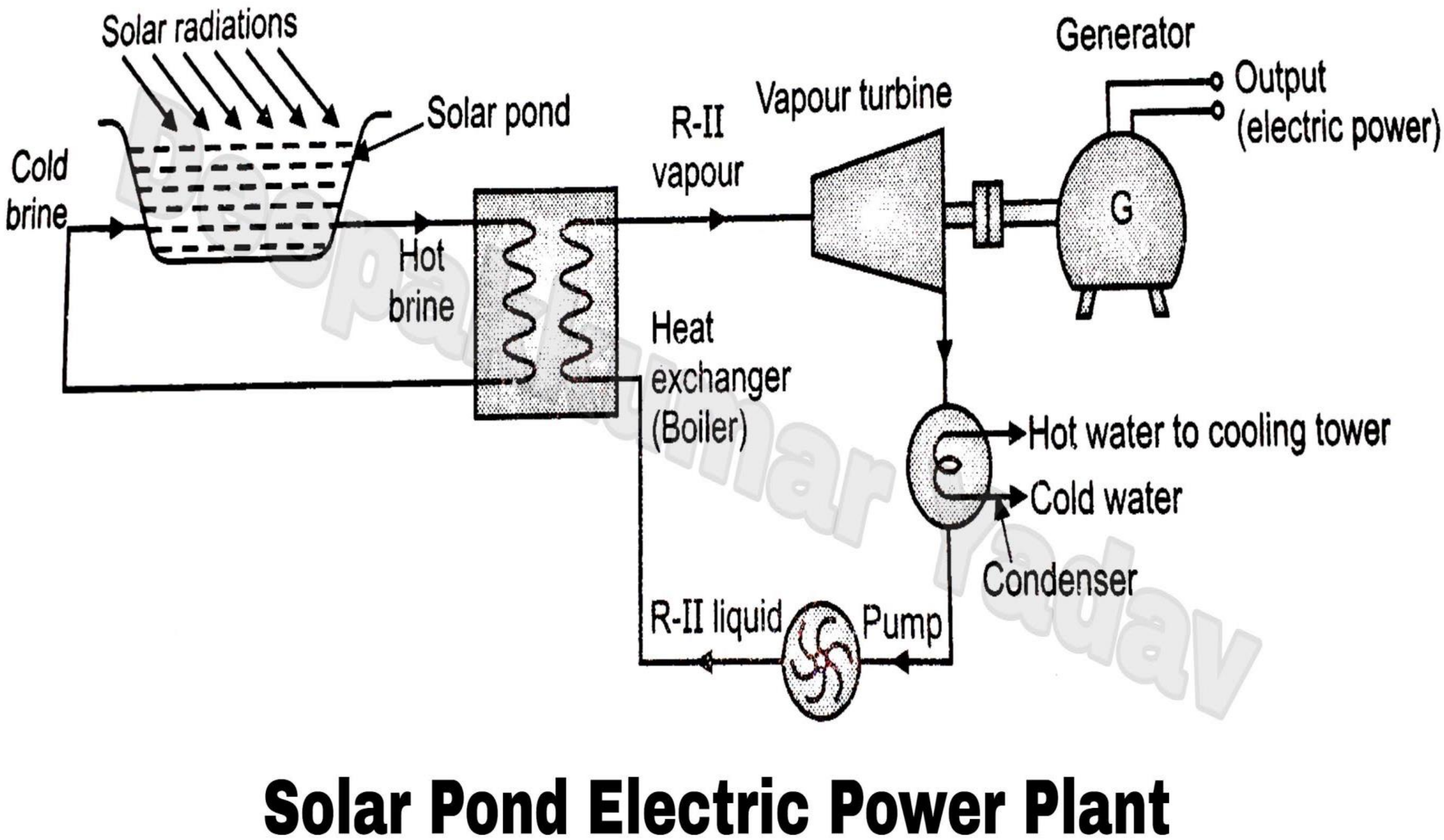
-An intermediate insulating layer with a salt gradient, which establishes a density gradient that prevents heat exchange by natural convection.

-The bottom layer, which has a high salt content.

If the water is relatively translucent, and the pond's bottom has high optical absorption, then nearly all of the incident solar radiation (sunlight) will go into heating the bottom layer.

- When solar energy is absorbed in the water, its temperature increases causing thermal expansion and reduced density. If the water were fresh, the low-density warm water would float to the surface, causing convection current.
- The temperature gradient alone causes a density gradient that decreases with depth.
- However the salinity gradient forms a density gradient that increases with depth, and this counteracts the temperature gradient, thus preventing heat in the lower layers from moving upwards by convection and leaving the pond.
- This means that the temperature at the bottom of the pond will rise to over 90°C while the temperature at the top of the pond is usually around 30 °C.

Solar Pond Electric Power Plant



Solar pond filled with brine, receives solar radiations and temperature of brine increases-goes to boiler.

The Working substance R-II evaporates-Vapour goes to turbine-Converted mechanical power drives the generator to produce electrical energy output.

R-II liquid goes back to heat exchanger (Boiler) The basic system consists of the following components:

1) Solar Pond.

2) Heat Exchanger

3) Boiler or Heat exchanges.

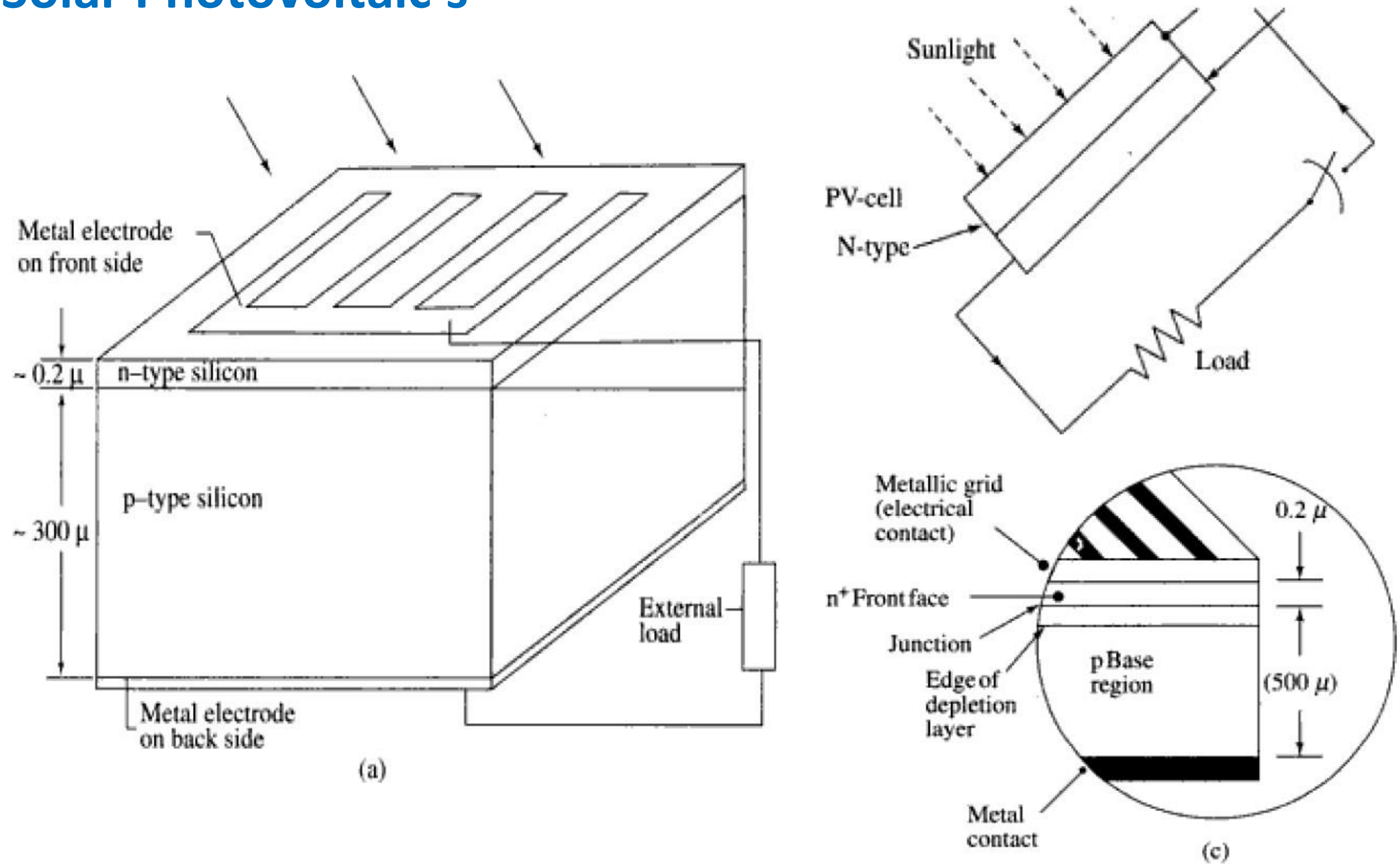
4) Vapour Turbine

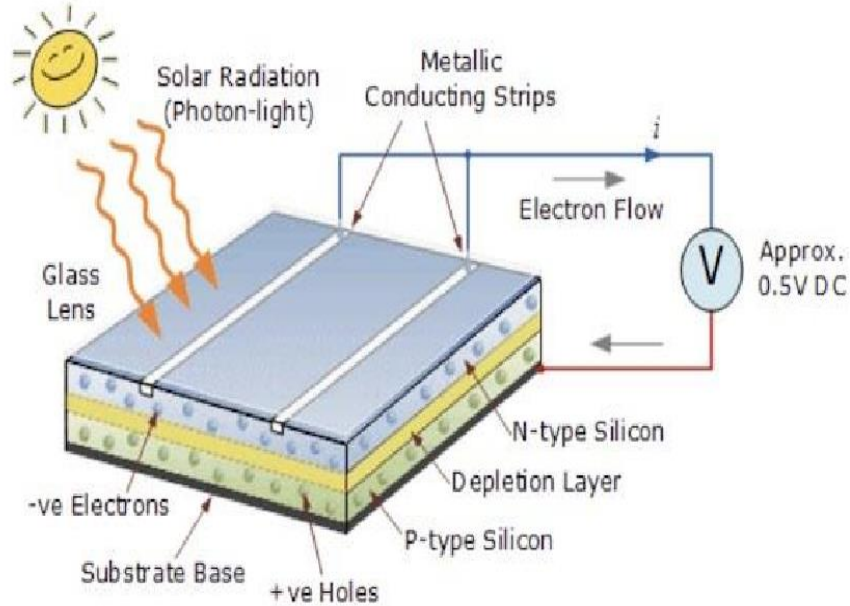
5) Condenser

- Hot water from solar pond about 80° C to 90° C is passes to heat exchanger and exchange the heat from water to R-11 refrigerant and it becomes vapour with a super heated condition
- The hot vapour from the heat exchanger is enter to vapour turbine and gives mechanical work and then it is converted into electrical energy which is coupled by D C generator
- The exhaust wet vapour from the turbine passes to condenser and converted in to saturated liquid refrigerant R-11
- The liquid refrigerant then pumped to vapour boiler or Heat exchanger and cycle repeated.

Solar Electric Power Generation

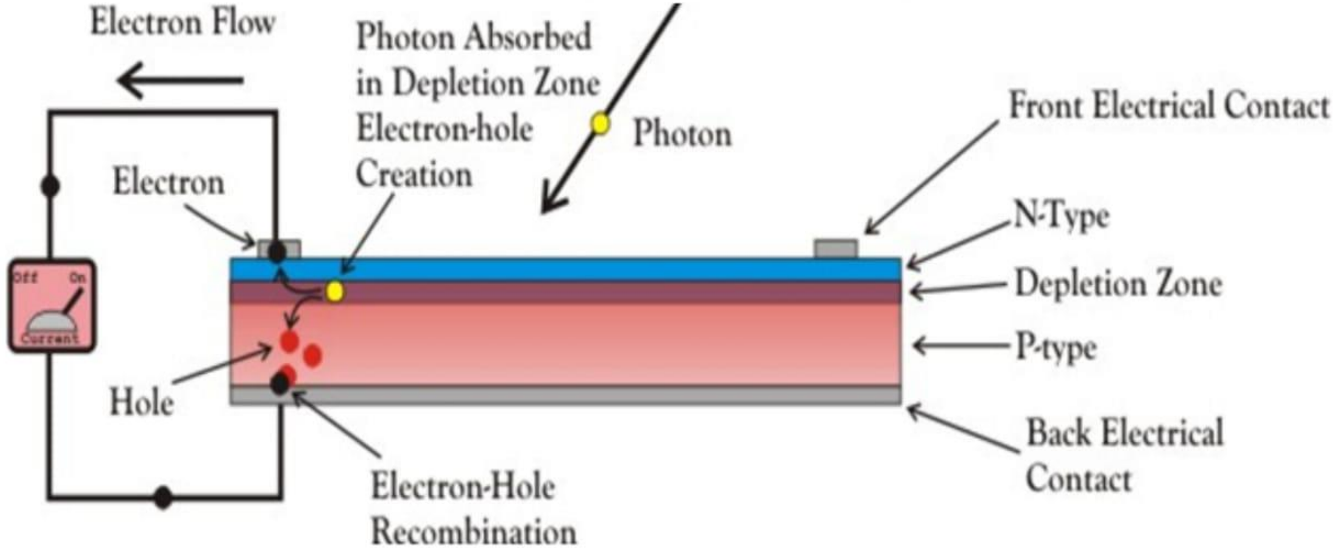
Solar Photovoltaic's





•A **solar cell** (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect.

•A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.



Working Principle of Solar Cell

•When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer.

•The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs.

•The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction.

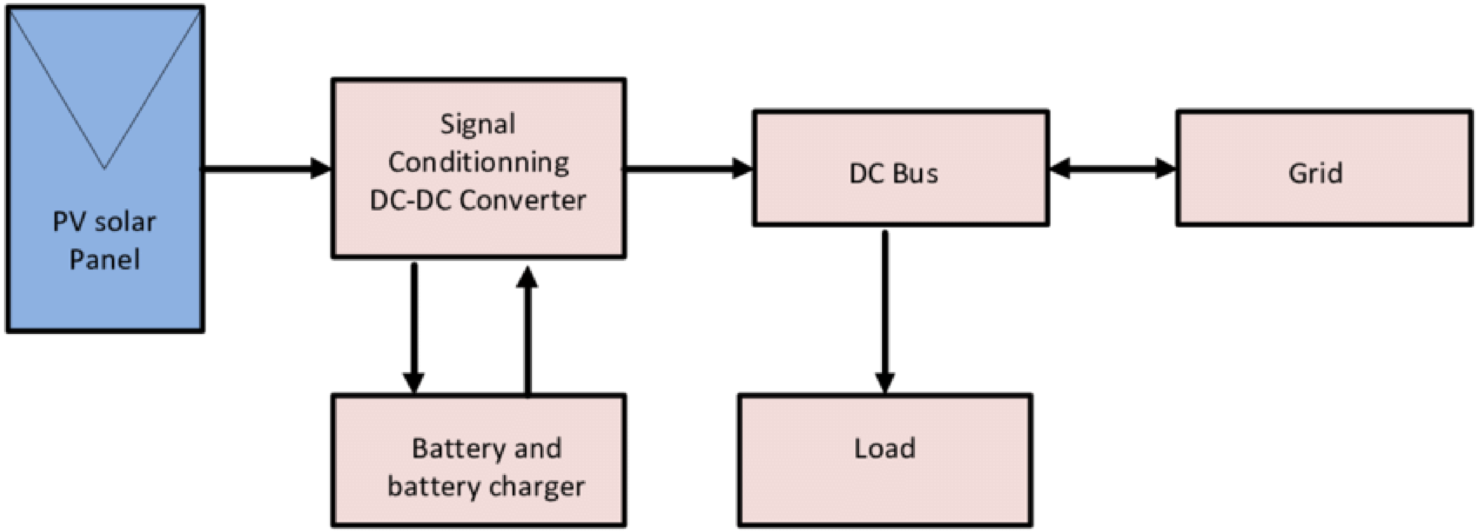
•The holes in the depletion can quickly come to the p-type side of the junction.

•Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction.

•The newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction.

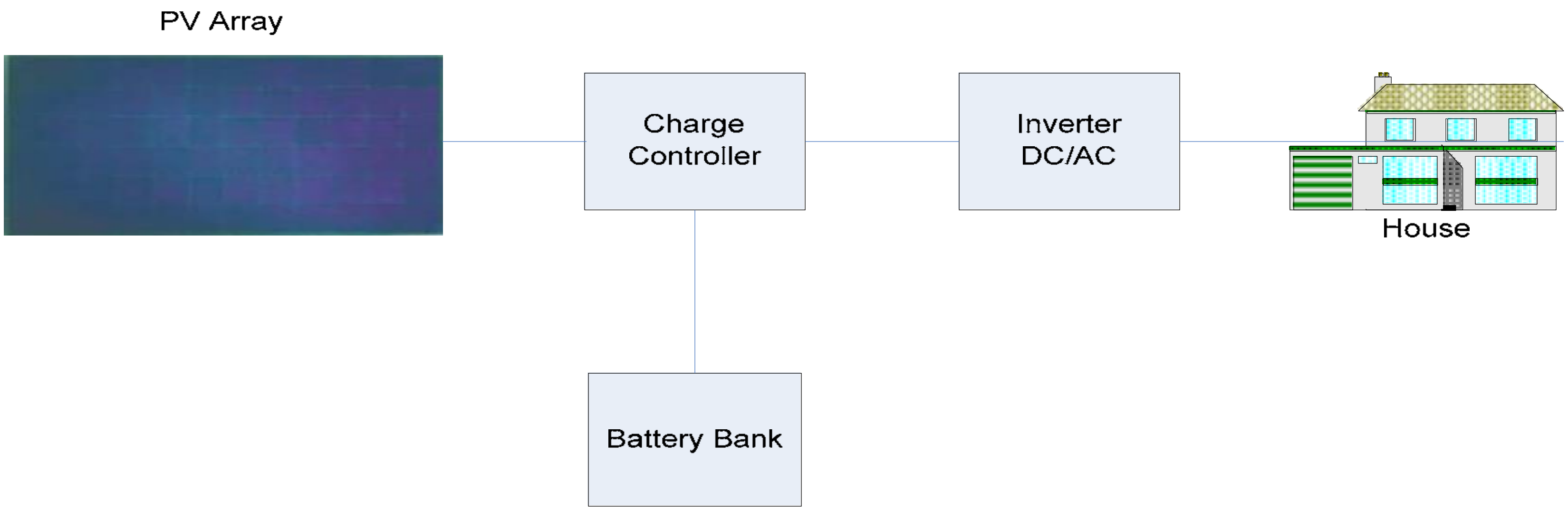
•As the concentration of electrons becomes higher in one side, i.e. n-type side of the junction and concentration of holes becomes more in another side, i.e. the p-type side of the junction, the p-n junction will behave like a small battery cell.

•A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.



- A photovoltaic (PV) system is able to supply electric energy to a given load by directly converting solar energy through the photovoltaic effect.
- The system structure is very flexible. PV modules are the main building blocks; these can be arranged into arrays to increase electric energy production.
- Normally additional equipment is necessary in order to transform energy into a useful form or store energy for future use.
- The resulting system will therefore be determined by the energy needs (or loads) in a particular application. PV systems can be broadly classified in two major groups:

1. Stand-Alone Solar Power plant



•The system described in Figure is actually one of the most complex; and includes all the elements necessary to serve AC appliances in a common household or commercial application.

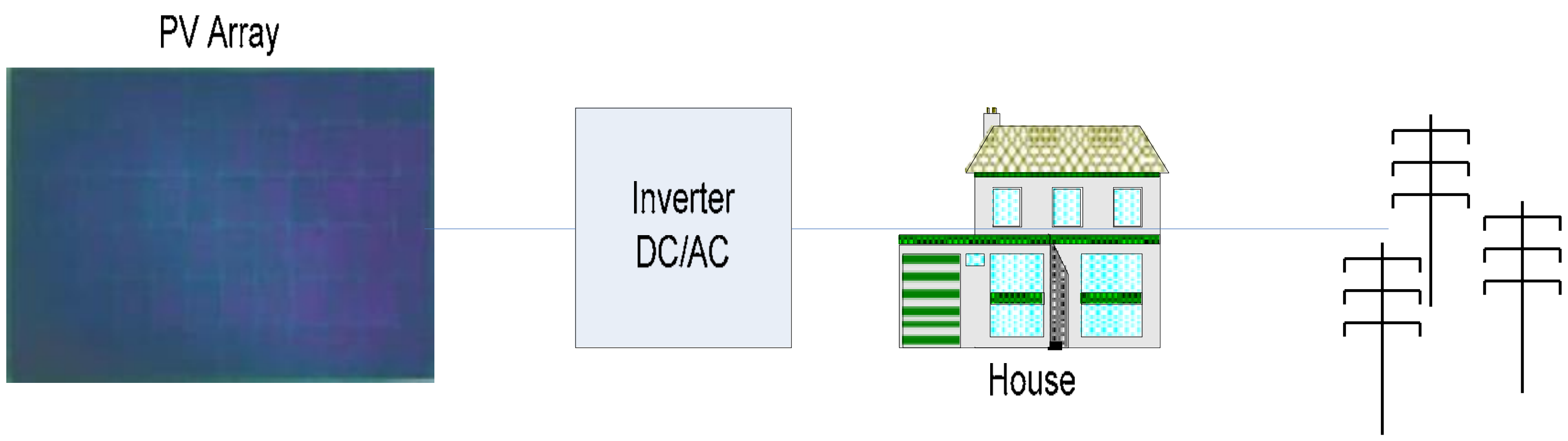
•The inverter could be eliminated or replaced by a DC to DC converter if only DC loads are to be fed by the PV modules.

•These systems are isolated from the electric distribution grid. Figure describes the most common system configuration.

•It is also possible to directly couple a PV array to a DC load when alternative storage methods are used or when operating schedules are not of importance.

• A good example may be water pumping applications were a PV module is directly coupled to a DC pump, water is stored in a tank through the day whenever energy is available.

2. Grid-Tied or On Grid Solar Power plant



- These systems are directly coupled to the electric distribution network or grid and do not require battery storage. Figure describes the basic system configuration.
- Electric energy is either sold or bought from the local electric utility depending on the local energy load patterns and the solar resource variation during the day, this operation mode requires an inverter to convert DC currents to AC currents.
- There are many benefits that could be obtained from using grid-tied PV systems instead of the traditional stand-alone schemes. These benefits are
- Smaller PV arrays can supply the same load reliably.
- Comparable emission reduction potential taking advantage of existing infrastructure.

- Eliminates the need for energy storage and the costs associated to substituting and recycling batteries for individual clients. Storage can be included if desired to enhance reliability for the client.
- Takes advantage of the existing electrical infrastructure.
- Efficient use of available energy. Contributes to the required electrical grid generation while the client's demand is below PV output.
- On the other hand solar energy can alone use for independently for system is called Off-Grid connection by battery storage or directly apiliances

Advantages of Solar energy

1) Sun is essentially an infinite source of energy. Therefore solar energy is a very large inexhaustible and renewable source of energy and is freely available all over the world.
2) It is environmentally very clean and is hence pollution free.
3) It is a dependable energy source without new requirements of a highly technical and specialized nature for its wide spread utilization.
4) It is the best alternative for the rapid depletion of fossil fuels.

Disadvantages of Solar energy

1) It is available in a dilute form and is at a low potential. The intensity of solar energy on a sunny day in India is about 1.1 kW/sq.m. area. Hence very large collecting areas are required.

2) Also the dilute and diffused nature of the solar energy needs large land area for the power plant; for instance, about 30 sq.km area is required for a solar power station to replace a nuclear plant on a 1 sq.km site. Hence capital cost is more for the solar plant.

3) Solar energy is not available at night or during cloudy or rainy days.