SOLAR ENERGY

1. Solar Radiation
2. Solar Cell (Photovoltaic Technology)
3. Solar Thermal Energy

Difference between these panels?

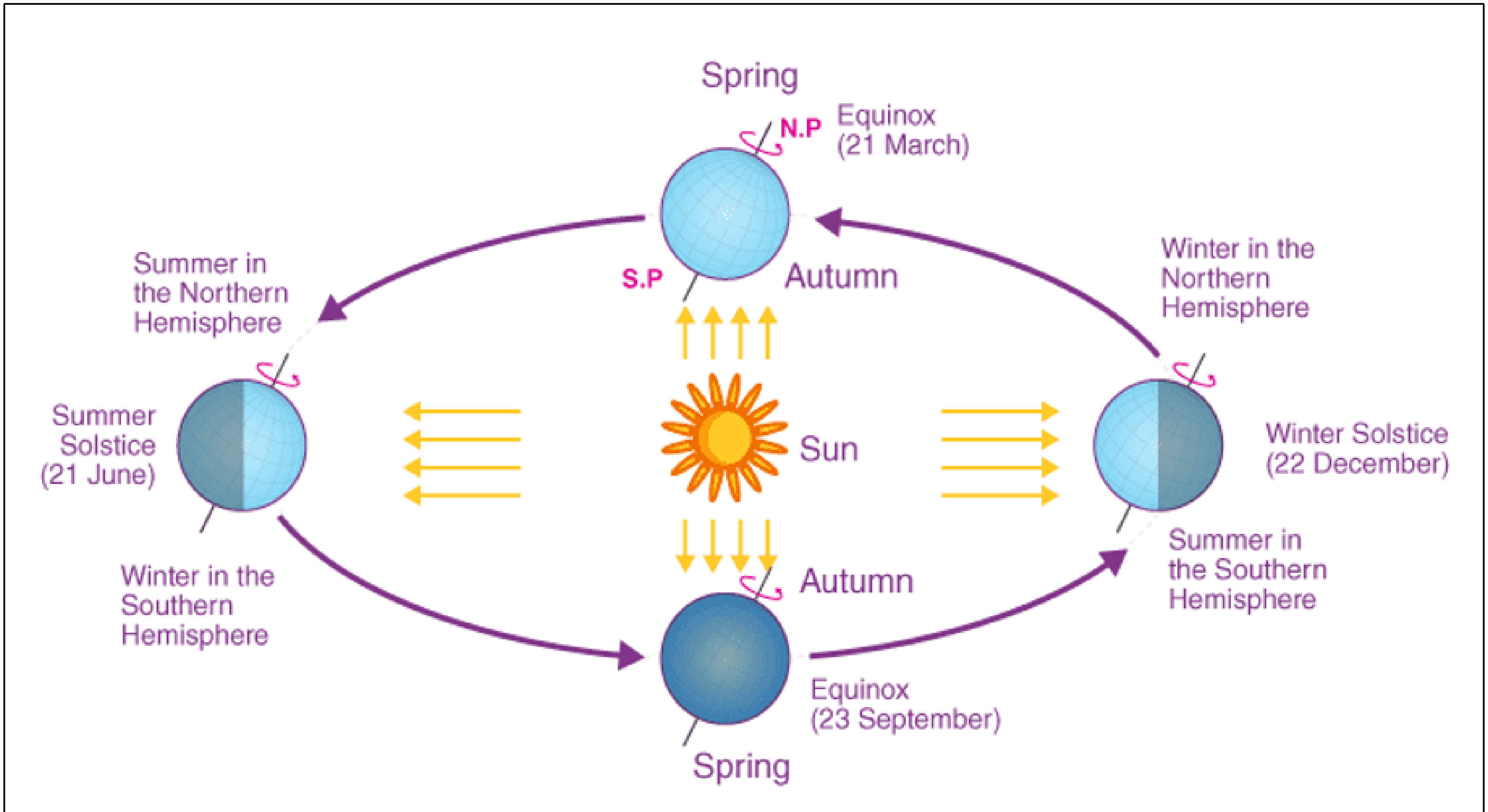
Questions

- From which direction does sun rises and sets?
  - On summer?
  - And on winter?
  - Based on location?
- Best direction for flat plate to receive maximum sunlight?
  - Dependent on time of day?
  - Hemisphere of earth?
  - Best direction and tilt to receive maximum possible sunlight whole day?

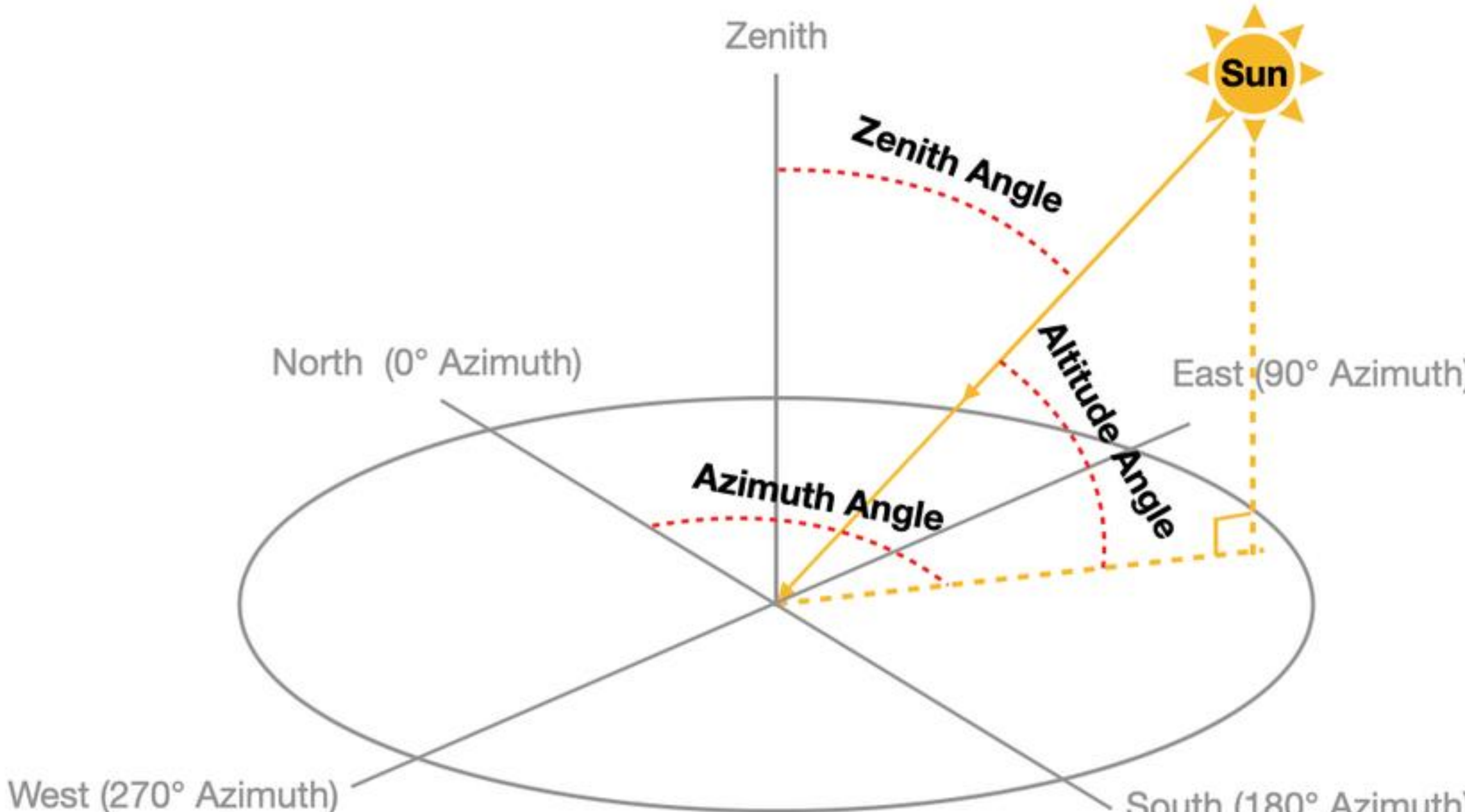
Longest day in Northern Hemisphere

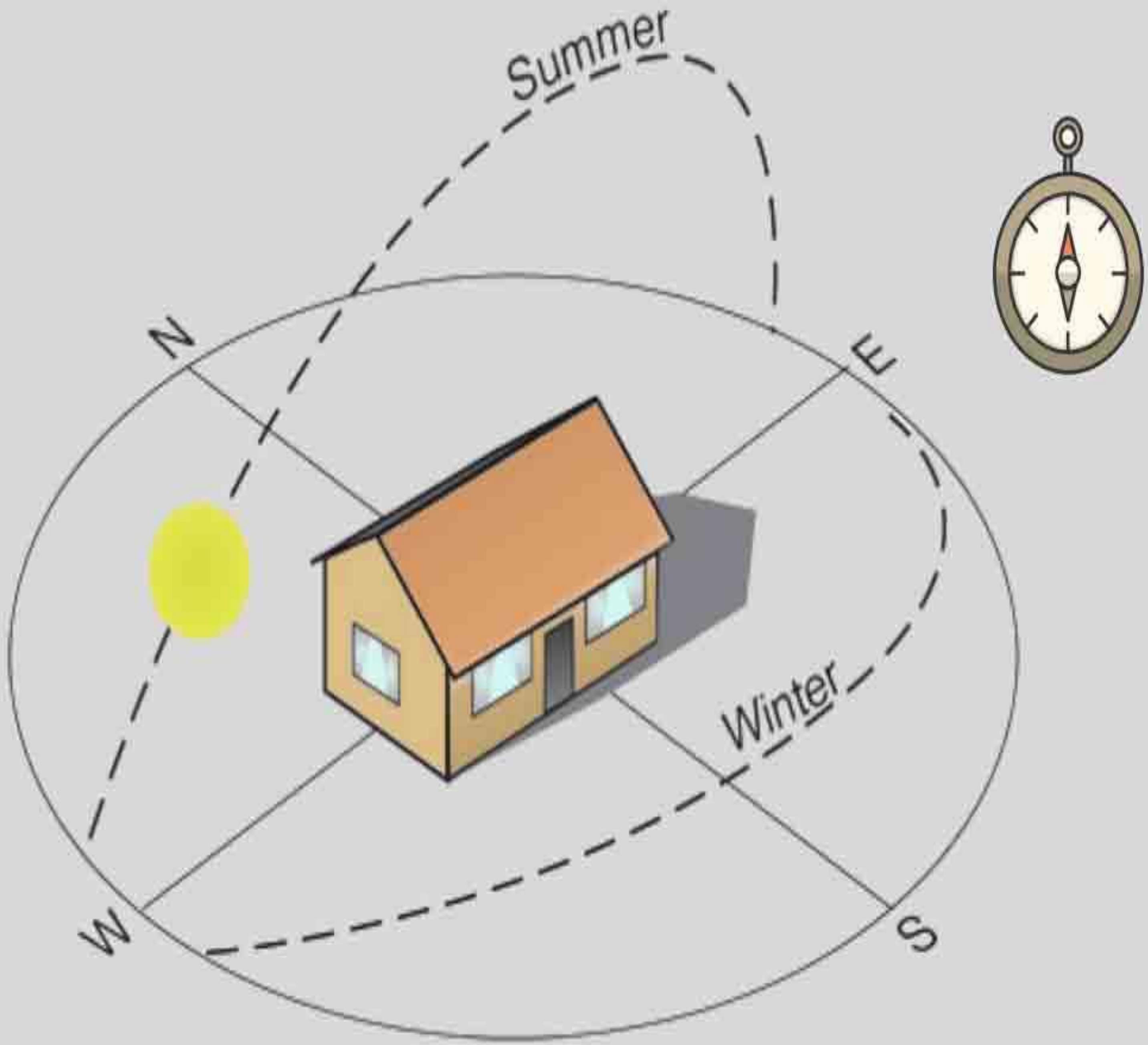
- Longest day in Northern Hemisphere: June 21
- Shortest day in Northern Hemisphere: December 21

- Shortest day in Southern Hemisphere: June 21
- Longest day in Southern Hemisphere: December 21

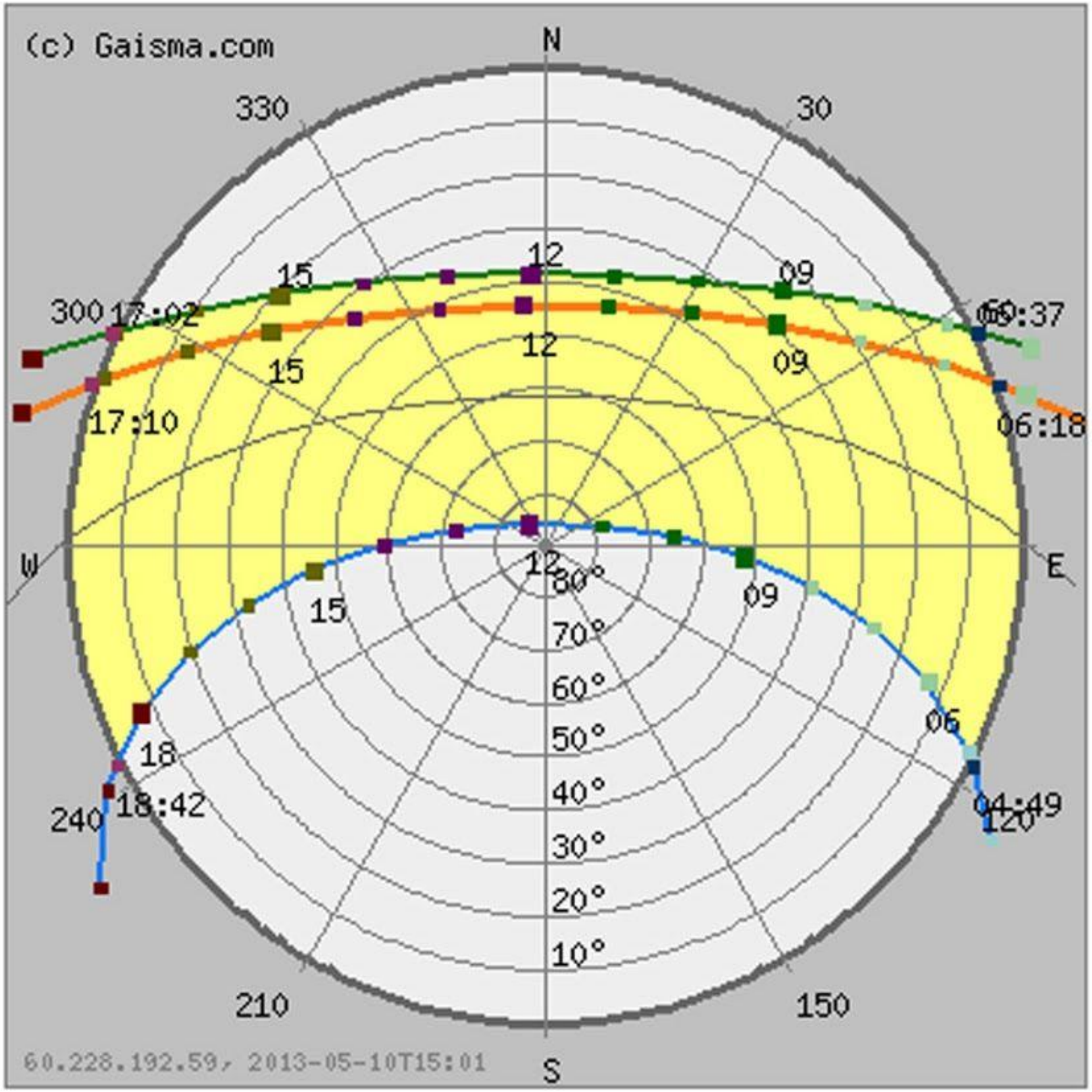

Spring
N.P
Equinox
(21 March)
S.P
Autumn
Summer in
the Northern
Hemisphere
Winter in the
Northern
Hemisphere
Summer
Solstice
(21 June)
Sun
Winter Solstice
(22 December)
Winter in the
Southern
Hemisphere
Summer in
the Southern
Hemisphere
Autumn
Equinox
(23 September)
Spring

Solar Geometry




Summer
N
E
Winter
W
S

Brisbane, Australia - Sun path diagram

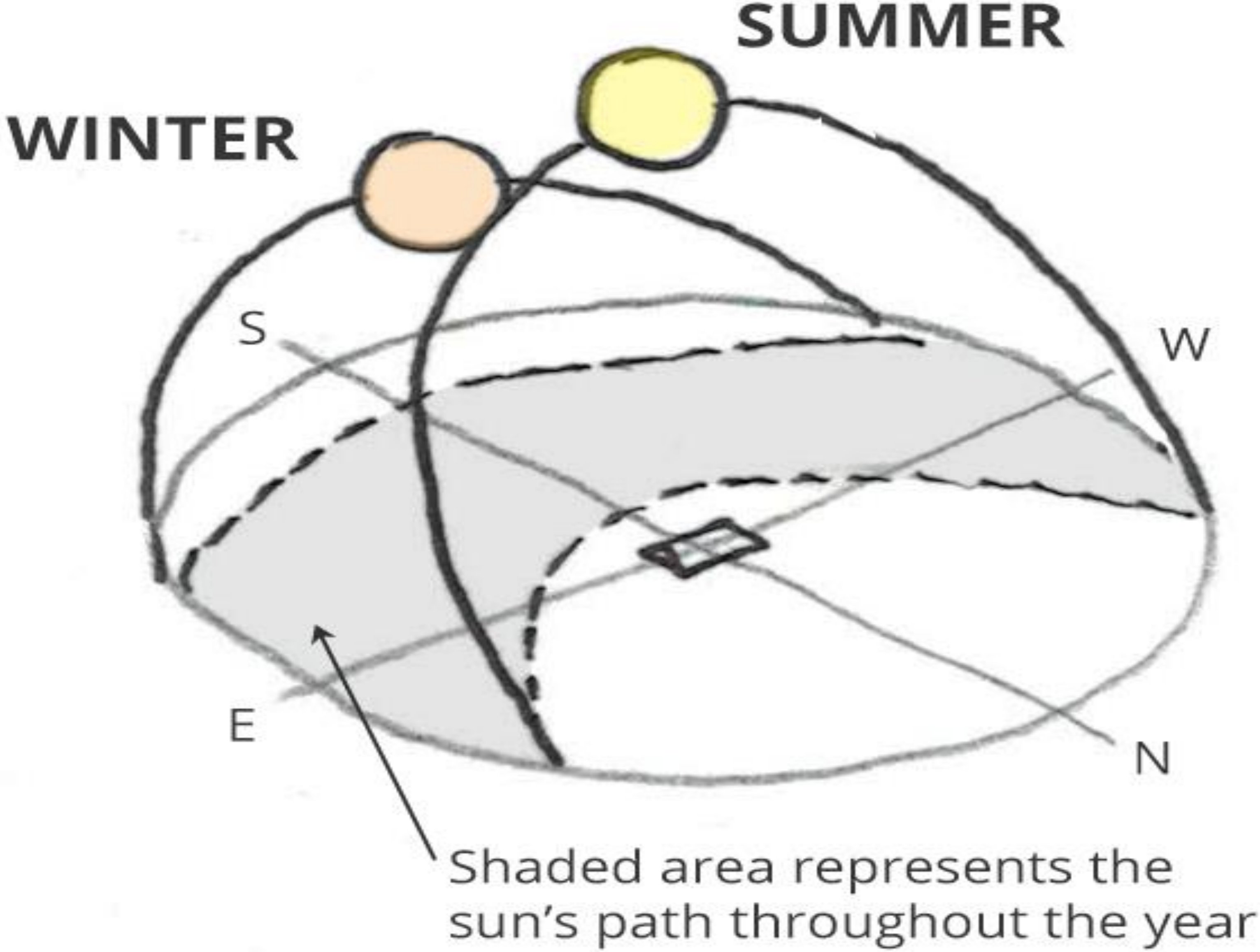


Sun path
- Today
- June 21
- December 21
- Annual variation
- Equinox (March and Septembe

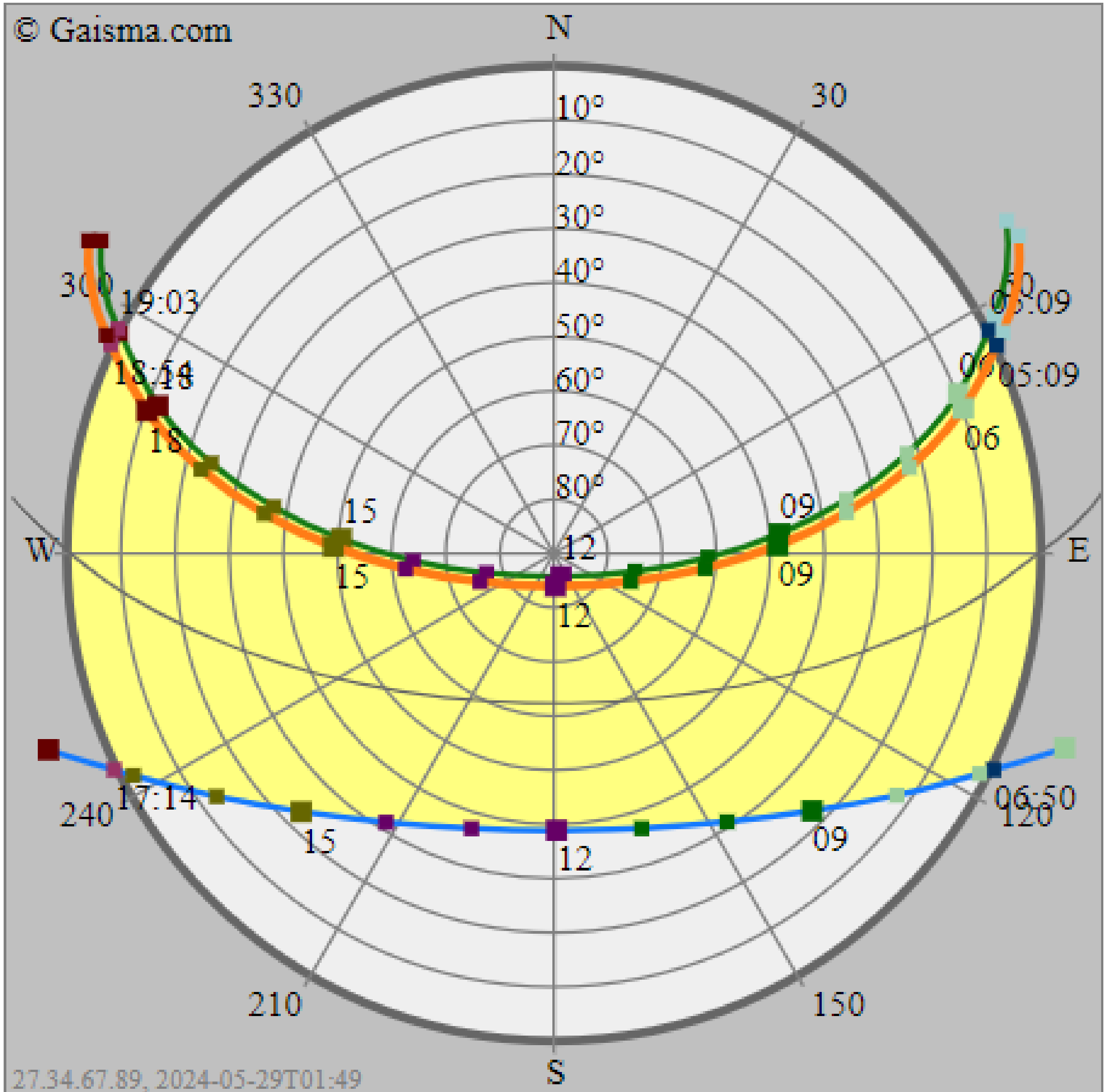
Sunrise/sunset
- Sunrise
- Sunset

Time
- 00-02
- 03-05
- 06-08
- 09-11
- 12-14
- 15-17
- 18-20
- 21-23

Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.


SUMMER
WINTER
S
W
E
N
Shaded area represents the sun's path throughout the year

Kathmandu, Nepal - Sun path diagram



Sun path

- Today
- June solstice
- December solstice
- Annual variation
- Equinox (March and

Sunrise/sunset

- Sunrise
- Sunset

Time

- 00-02
- 03-05
- 06-08
- 09-11
- 12-14
- 15-17
- 18-20
- 21-23

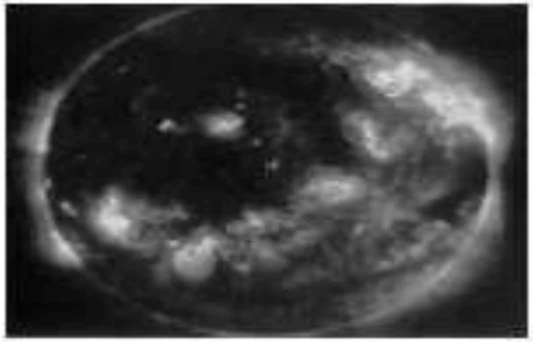
SUN

Characteristics of the Sun

Diameter $= 1.4 \times 10^{6}$ *km*

Mass $= 2 \times 10^{30}$ *kg*

Density $= 1.1\ g\ cm^{-3}$



Core Temperature $= 15 \times 10^{6}$ *K*

Surface Temperature = *5800 K*

Sizewise, the sun's diameter is about 109 x that of Earth, and the sun's volume is 1,300,000 x bigger!

SUN

Composition of Sun's Core

72% Hydrogen
26 % Helium
Trace amt of O, C, N, Si, Mg, Fe, S

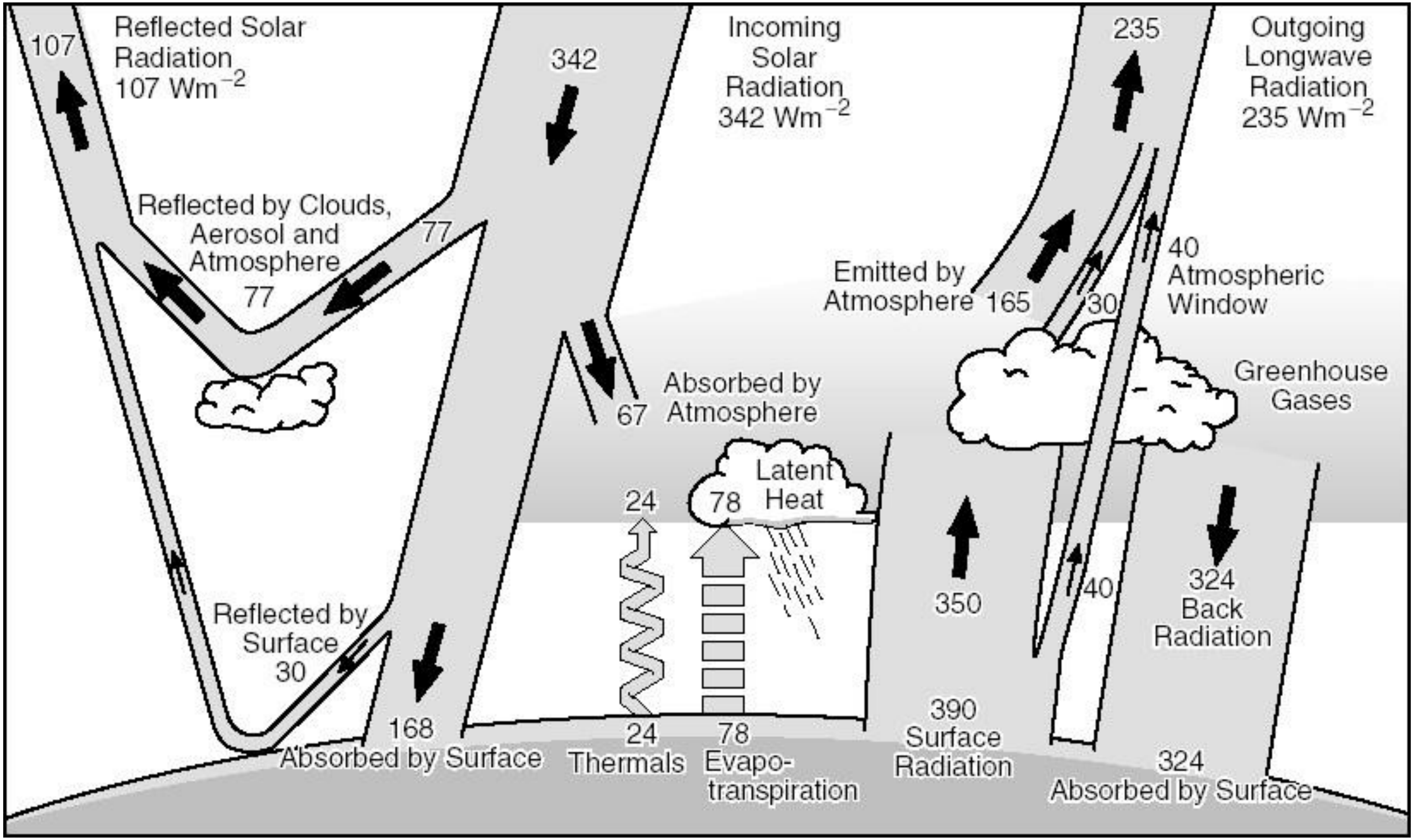
Solar Radiation

- Solar radiation is the primary natural energy source of the Earth. (Other natural sources are: geothermal heat flux from the earth interior, natural terrestrial radioactivity, cosmic radiation. These are negligible!)
- Solar radiation mainly emanates as electromagnetic radiation from the surface of the sun (photosphere). It is originated by several nuclear fusion processes in the interior of the sun.

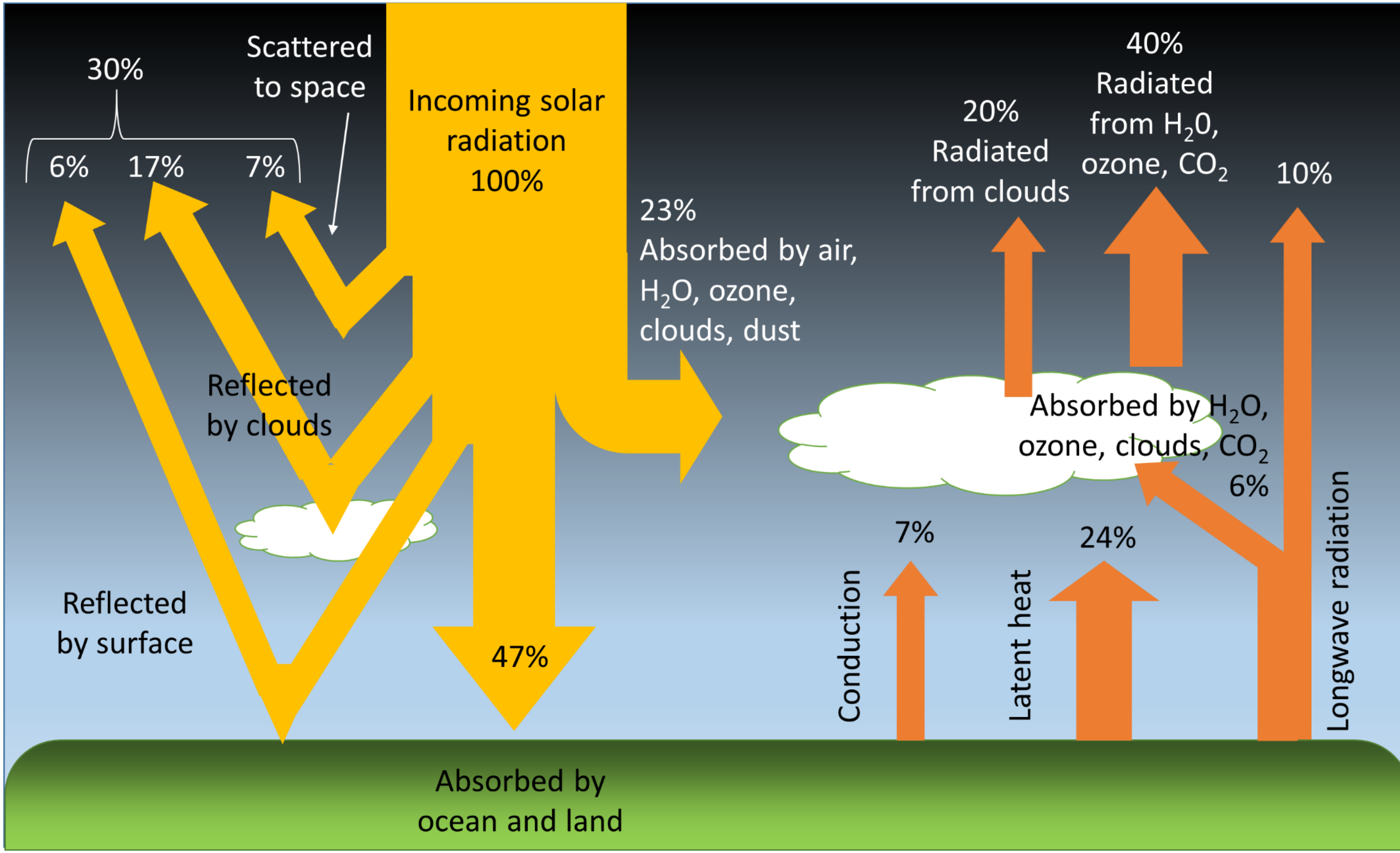
The Sun as a Radiation Source

- All matter emits electromagnetic radiation at all wavelengths due to its atomic and molecular agitation unless it is at a temperature of 0 K.

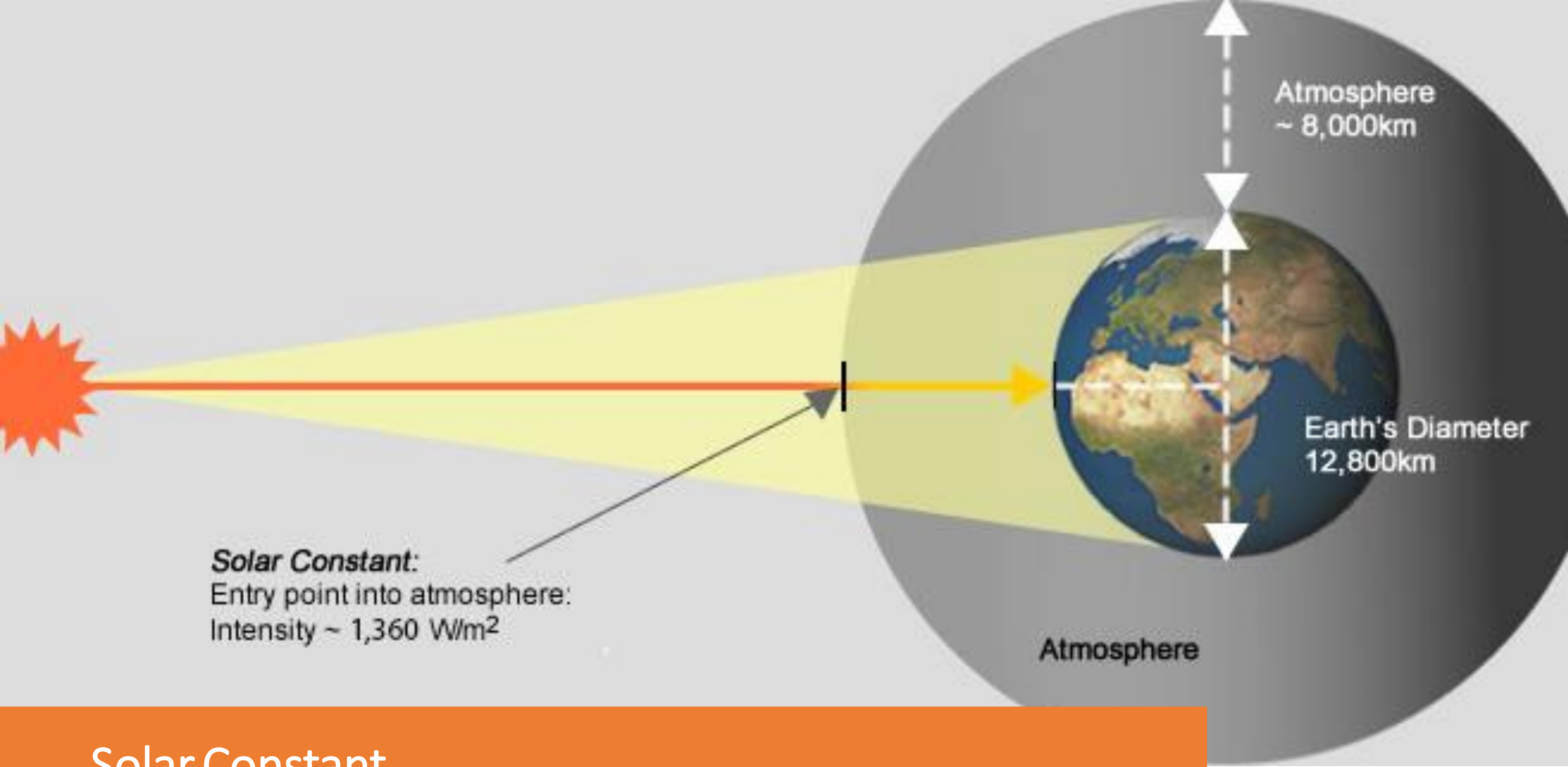
- The intensity and the spectral distribution of the radiation is solely determined by the temperature and the material properties of the emitting body (particularly of its surface). Both are described by the famous radiation laws of Kirchhoff and Planck.



The Earth's annual and global mean energy balance. Of the incoming solar radiation, 49% (168 Wm-2) is absorbed by the surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal infrared radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface. This causes a greenhouse effect. Source: Kiehl and Trenberth, 1997: Earth's Annual Global Mean Energy Budget, *Bull. Am. Met. Soc*. 78, 197-208.



30%
Scattered to space
6%
17%
7%
Incoming solar radiation 100%
23% Absorbed by air, H_2O, ozone, clouds, dust
20% Radiated from clouds
40% Radiated from H_20, ozone, CO_2
10%
Reflected by clouds
Absorbed by H_2O, ozone, clouds, CO_2 6%
7%
24%
Reflected by surface
47%
Conduction
Latent heat
Longwave radiation
Absorbed by ocean and land



Solar Constant

- The solar constant is the amount of energy received in unit time on a unit area of surface perpendicular to the direction of propagation of the radiation at the mean distance of the earth from the sun.
- In the literature a value of 1360 W/m^2 is given frequently.

Irradiance

- Irradiance, I, is defined as the intensity of solar radiation received on a unit surface area of the earth per unit time.
- The unit of I is taken as W/m2.

Insolation

- Insolation is the total energy received from the sun in a day in a unit surface area on the earth.
- The unit of insolation is watt-hour per sq.m. per day.
- For Nepal the yearly average insolation can be taken around 4500 to 5500 Wh/m2/day.

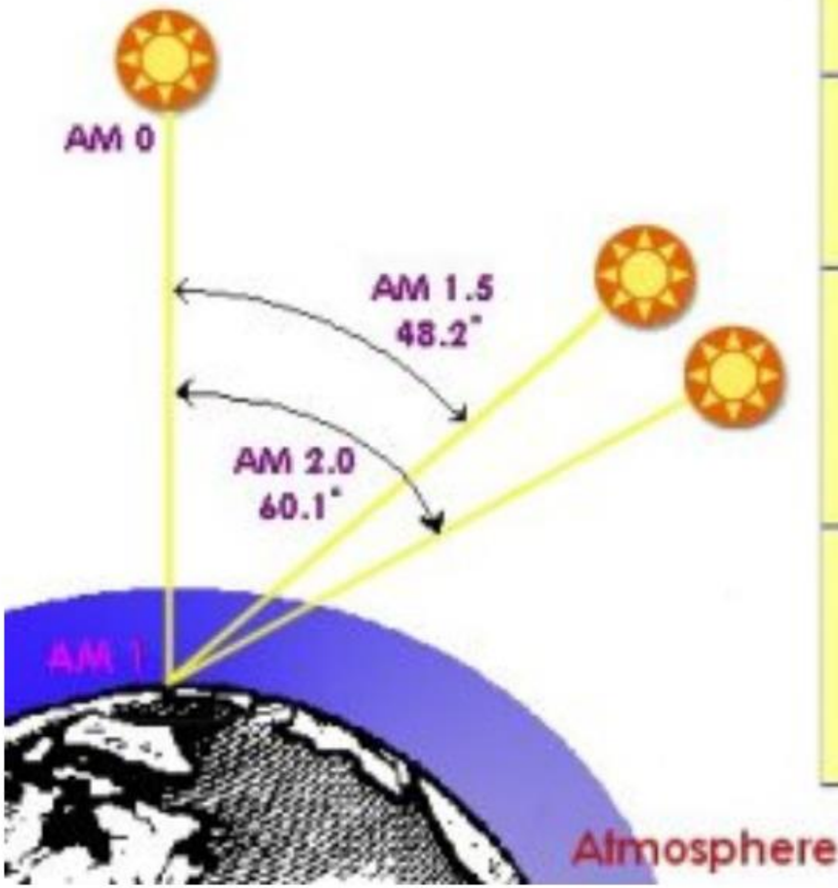
Peak Sun

- The definition of **a peak sun hour** is one hour of the sun shining with an intensity of 1000 watts per square meter.
- Peak sun is the number obtained by division of insolation by 1000 W per sq.m. per day.
- In most cases, the peak sun or the insolation is treated as a single parameter because they are interrelated by a constant coefficient.

Air Mass

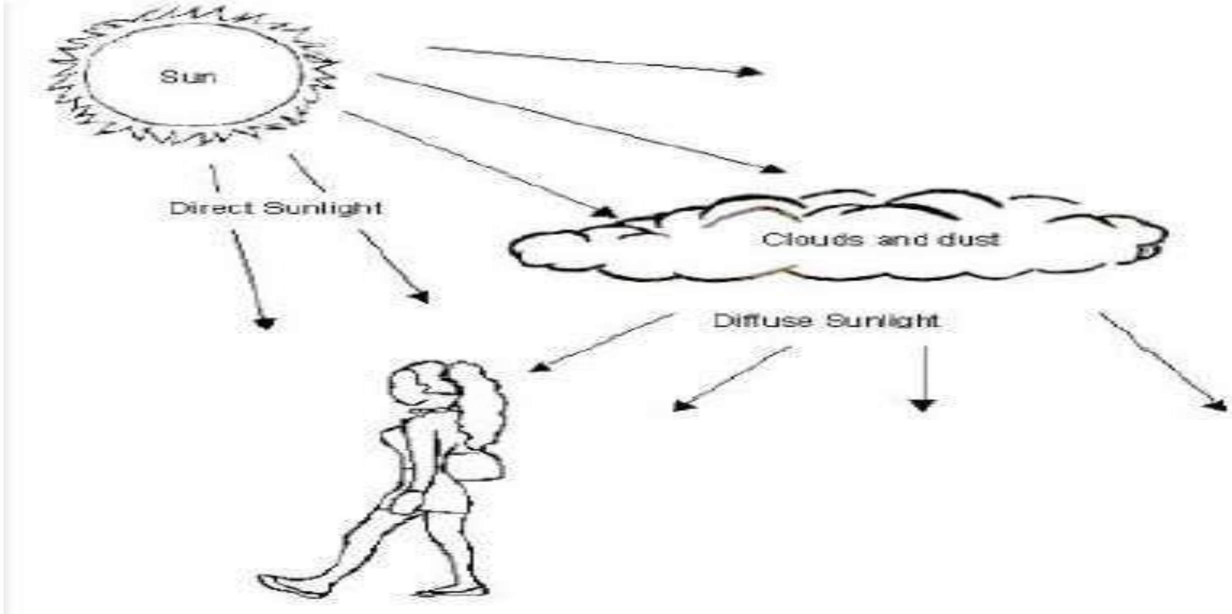
- Although radiation from the sun's surface is reasonably constant, when reaching the Earth it is highly variable due to absorption and scattering in atmosphere.
- When skies are clear, the maximum radiation strikes the Earth's surface when the sun is directly overhead, and sunlight has the shortest path length through the atmosphere.
- This path length is usually referred to as the "Air Mass" through which solar radiation must pass to reach the Earth's surface.
- The entry point into the atmosphere is called “Air Mass – 0” or “AM-0”, where “0” points out that there is no air mass.
- The condition when the sun is directly overhead, the distance through which the sunrays penetrate the atmosphere is shortest and is referred to as Air Mass 1 or AM1.
- AM1.5 (equivalent to a sun angle of 48.2º from overhead or 41.8º from horizontal plane) has become the standard for photovoltaic standards. The air mass can be estimated at any location using the following formula:
  - $AM=\sqrt{1+(s/h)^2}$
    - Where s is the length of the shadows cast by a vertical post of height h.

Designation of Solar Air Masses



AM 0.0	Alters simulator's output to match extraterrestrial solar spectrum
AM 1.0	Alters simulator's output to match terrestrial solar spectrum when sun's position vector is perpendicular to the Earth's surface.
AM 1.5	Alters simulator's output to match terrestrial solar spectrum occuring when the sun's position vector has rotated 48.3 degrees away from its perpendicular position.
AM 2.0	Alters simulator's output to match terrestrial solar spectrum occuring when the sun's position vector has rotated 60.1 degrees away from its perpendicular position.

Figure showing change of air mass with zenith angle value



Direct Radiation:

The solar radiation received from the sun without scattered by the atmosphere is called **Direct Radiation.** It is also often referred as **Beam Radiation.**

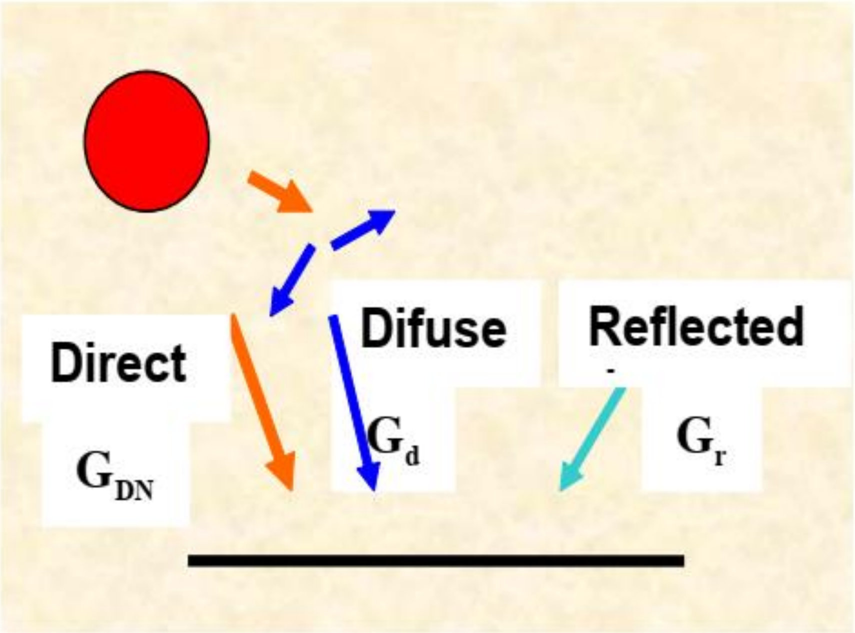
Diffused Radiation:

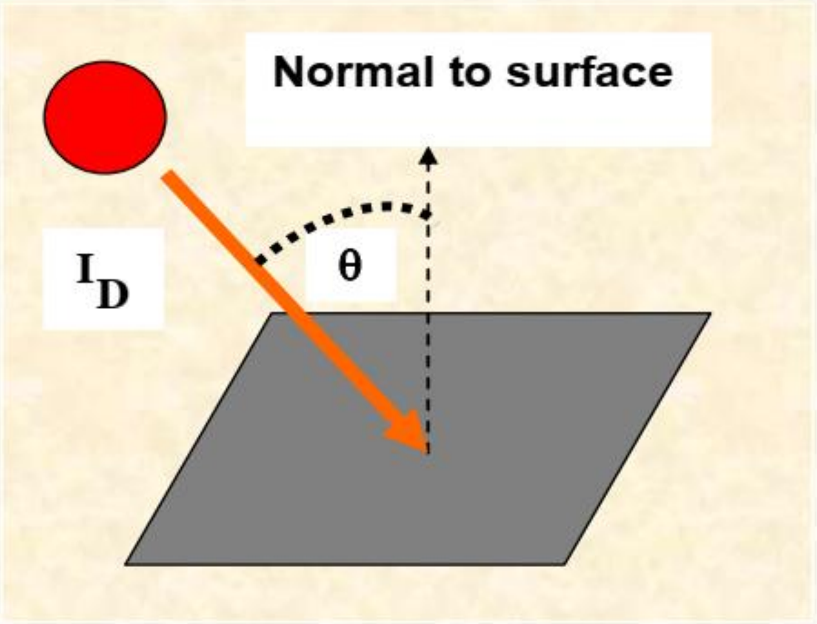
The solar radiation received from the sun after its direction has been changed by scattering in the atmosphere is called **Diffused Radiation**. It is also referred to in some meteorological literature as **sky radiation or solar sky radiation**

Total Solar Radiation

The sum of the beam and the diffuse solar radiation on a surface is called **total solar radiation**. The most common measurements of solar radiation are total radiation on a horizontal surface, often referred to as **global radiation** on the surface.

Total Incident Radiation





$$G_t = G_{ND} \cos\theta + G_d + G_r$$

Relationship between direct, diffused and total solar radiation

Measurement of **Direct, Diffused and Global** Solar Radiation

In order to assess the availability of solar energy arriving on the earth, measurement of solar radiation at desired location is required .

Measurement of Diffused, Global and Direct Solar Radiation

- There are three types of solar radiation measuring instruments

1. PYRHELIOMETER
2. PYRANOMETER
3. PYRANOMETER WITH SHADING DEVICE

Measurement of Diffused, Global and Direct Solar Radiation

1. <u>Pyrheliometer</u>

   It is an instrument for measuring direct solar radiation flux at normal incidence

Measurement of Diffused, Global and Direct Solar Radiation

2. Pyranometer

- It is an instrument for measure of the direct and diffuse irradiance arriving from the whole hemisphere, i.e, from the complete sky dome.

- A Pyranometer can be used in a tilted position as well, in which case it will also receive the ground – reflected radiation.

Measurement of Diffused, Global and Direct Solar Radiation

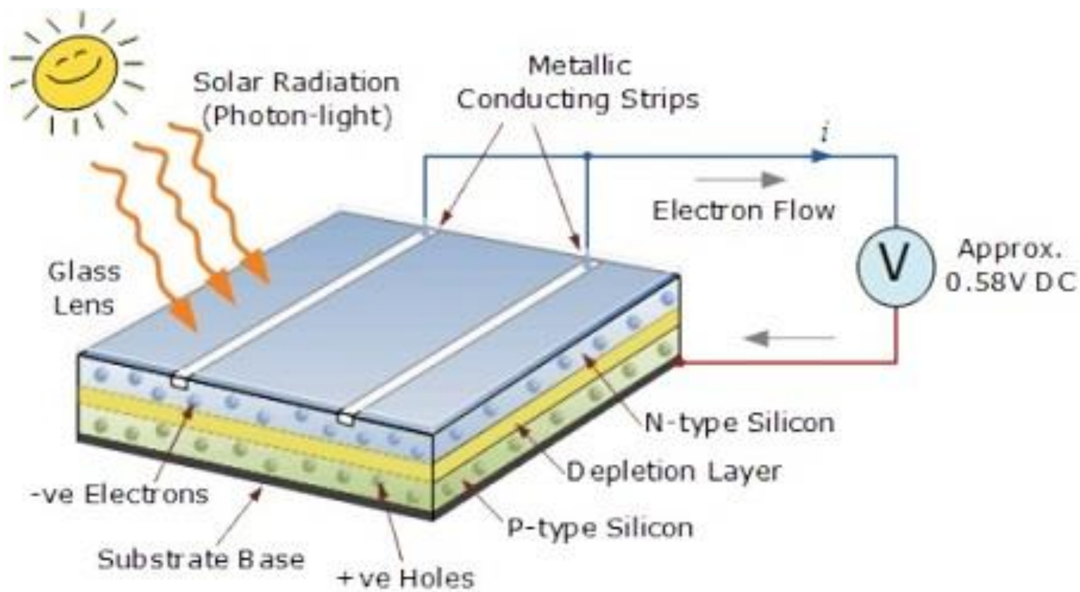
Pyranometer with Shading Device

It is an instrument that measures diffused solar irradiance.

SOLAR CELL PHOTOVOLTAIC (PV) TECHNOLOGY

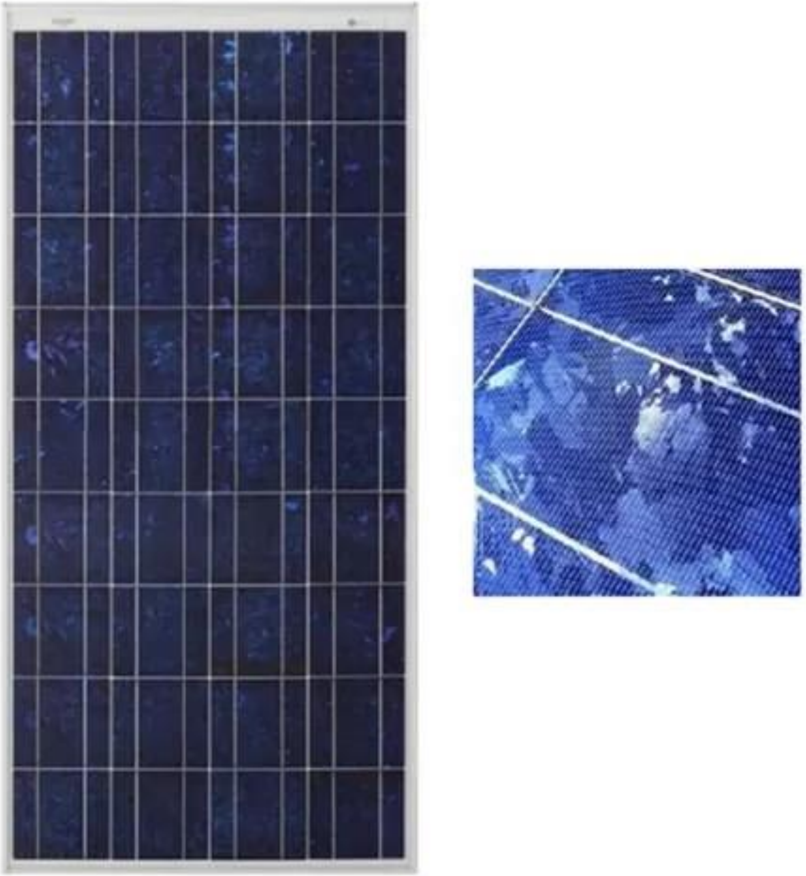
Solar Cell

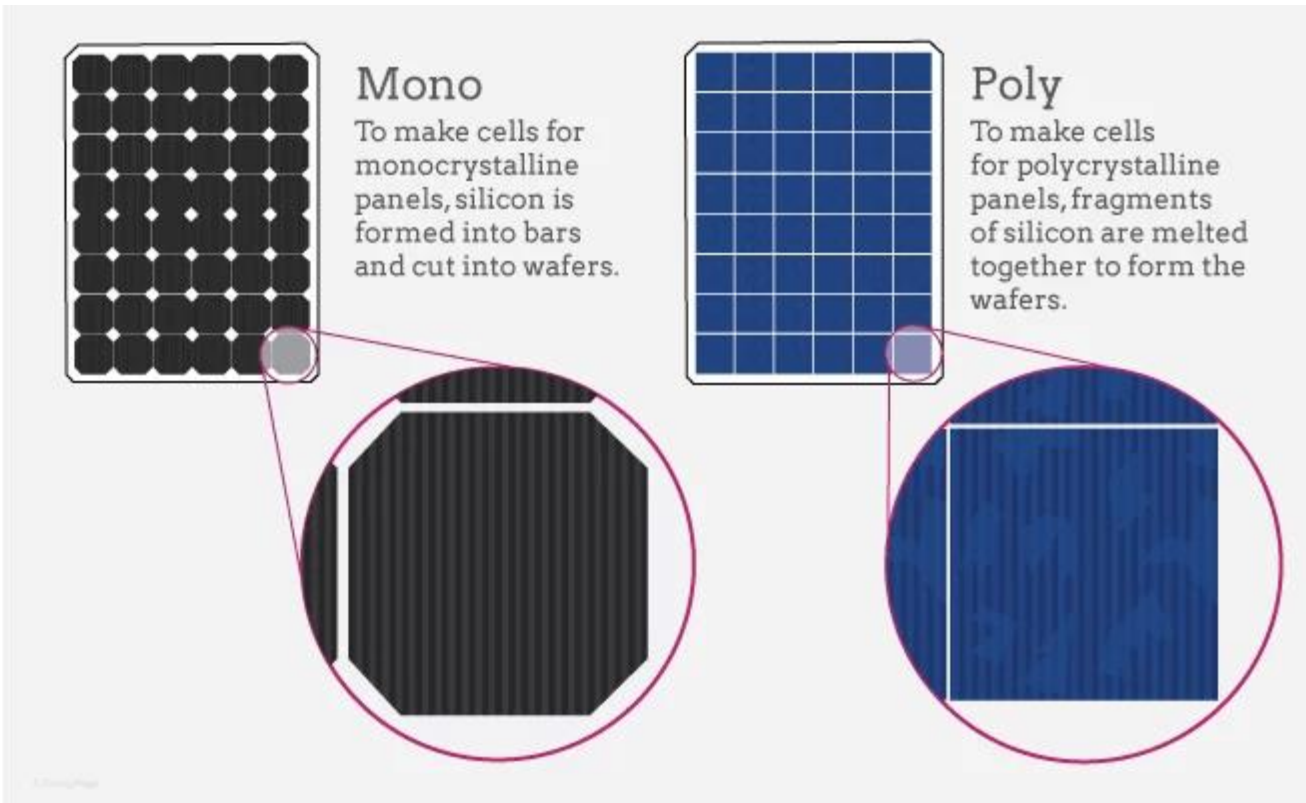
- The solar cell is nothing but a large area PN interface or junction.
- It is the internal electric field of the PN junction that sweeps electrons out of the cell.
- When light penetrates the semiconductor material, knocking free electrons and giving them potential energy, the freed electrons wander until they are pushed by the electric field across the PN junction. They are forced out of the cell and are available for useful work.
- The electrons with higher energy level flow out of the cell through the wire to the load. After releasing the excess energy into the load these electrons return to the cell and fall into the holes.
- So as soon as an electron leaves the cell from one side and enters the wire, an electron at the other end of the wire moves into the cell. So, the solar cell cannot “run down” like a battery, nor can it “run out of electrons”.
- Solar Cell produces output (electrical energy) in response to the input “fuel” (light energy).
- A solar cell thus cannot store electrical energy; it can only convert light energy into electrical energy.



Monocrystalline

Polycrystalline




Mono
To make cells for monocrystalline panels, silicon is formed into bars and cut into wafers.
Poly
To make cells for polycrystalline panels, fragments of silicon are melted together to form the wafers.

Monocrystalline Vs Polycrystalline Solar Panels

Monocrystalline Panels	Polycrystalline Panels
Monocrystalline wafers are made from a single silicon crystal formed into a cylindrical silicon ingot.	Instead of using a single silicon crystal, manufacturers melt many silicon fragments together to form wafers for the panel.
More expensive	Less expensive
More efficient (over 23 %)	Less efficient (not more than 20 %)
Solar cells are a black hue	Solar cells have a blue-ish hue
25+ years life	25+ years life
Lower temperature coefficient/more effective when temperature changes	Higher temperature coefficient/less effective when temperature changes

Characteristics of Solar Cells

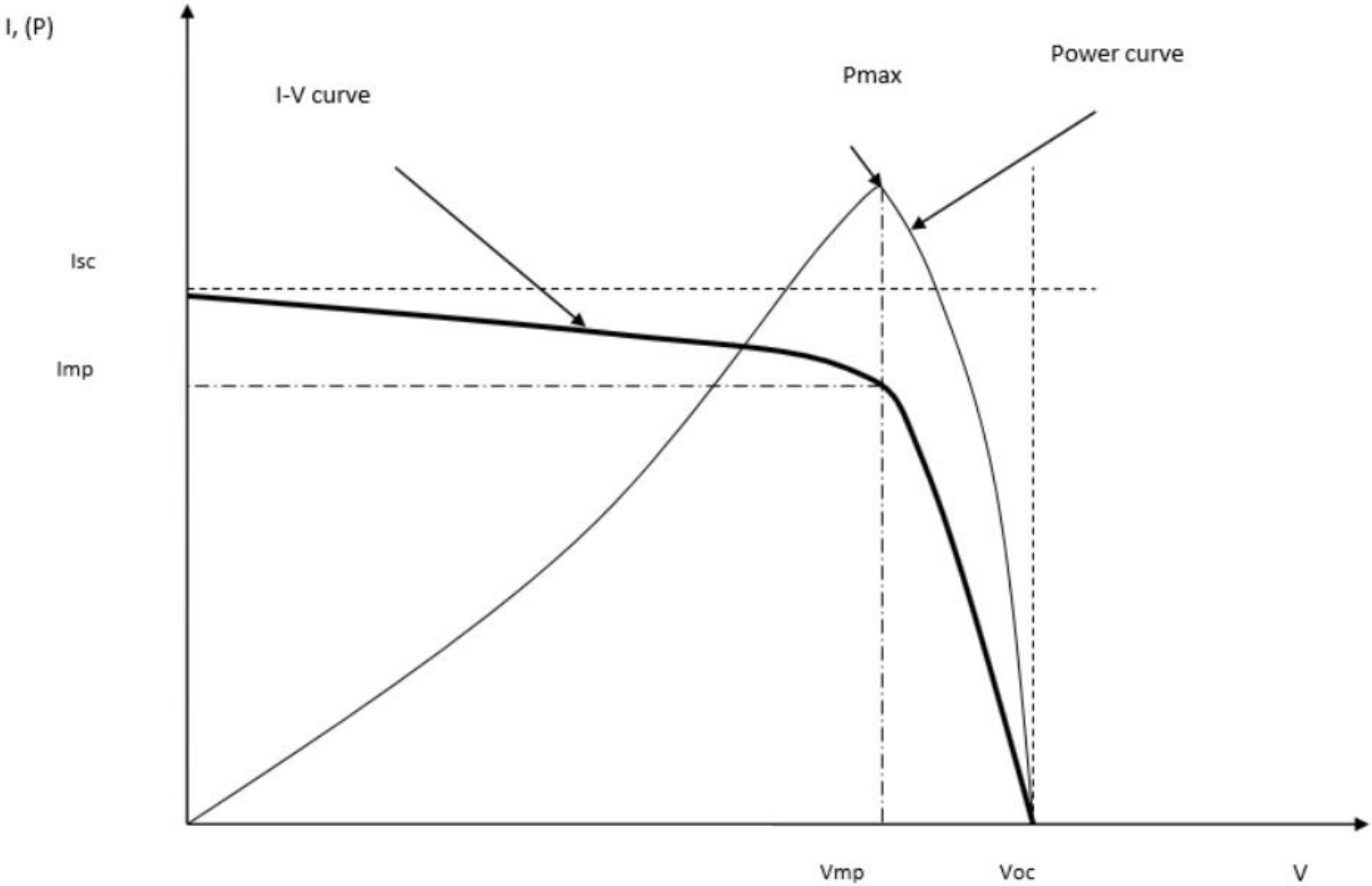
The power of solar cells depends on various factors:

- Voltage (V)
- Current (A)
- Solar Radiation (W/ m2)
- Area (m2)
- Temperature of cells (°C)

Solar PV terminologies

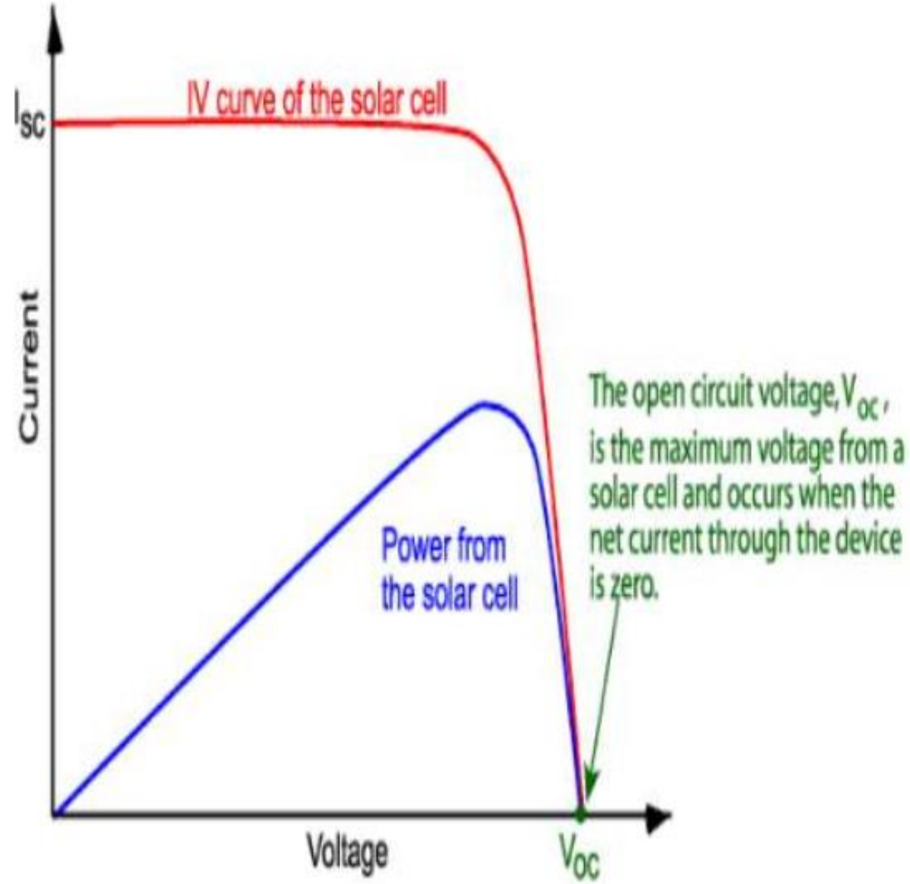
- Open circuit voltage
- Short circuit current
- Voltage at maximum power
- Fill factor
- Efficiency

The IV curve



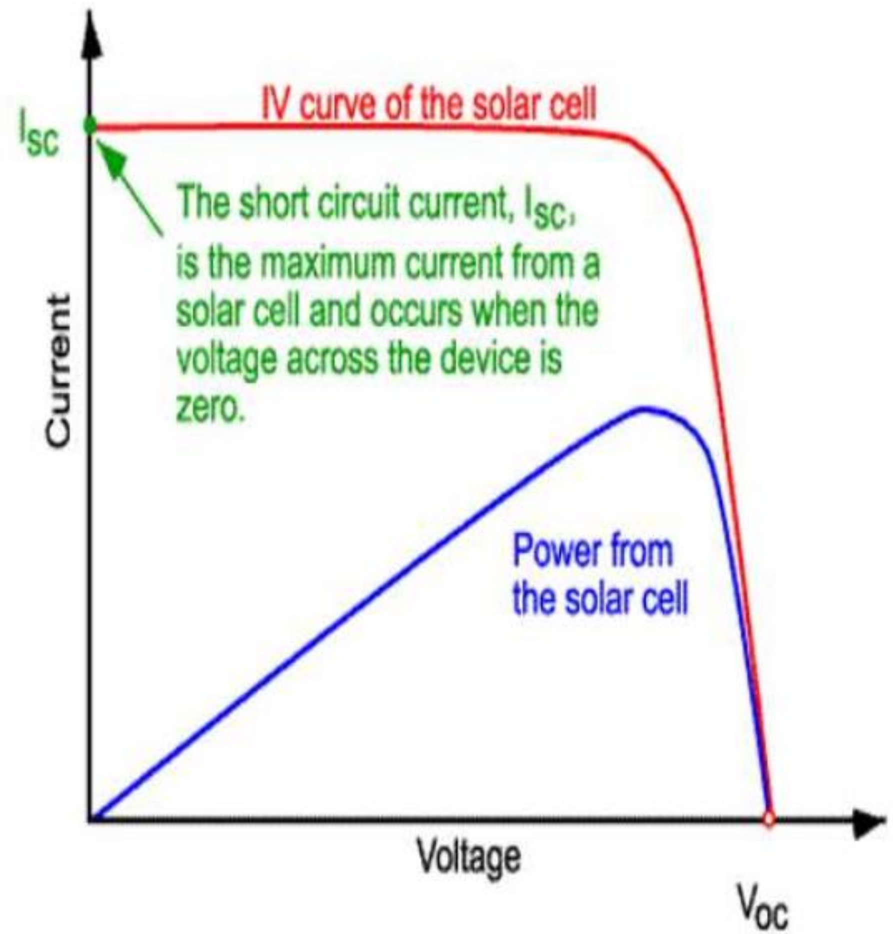
Open-circuit voltage

- **Open Circuit Voltage (Voc)** – It is the maximum voltage generated by the cell under given conditions of light and temperature. Voc is the voltage when the load is open-circuited, i.e. the output current is zero. The output power at this point is again essentially zero.



The short-circuit current

- **Short Circuit Current (Isc)** – It is the maximum current (in A or mA) produced by the cell under given conditions of irradiance and surrounding temperature. Isc is the current when the load is short-circuited, i.e. the output voltage is zero. The output power at this point is essentially zero.



Short-Circuit Current depends upon

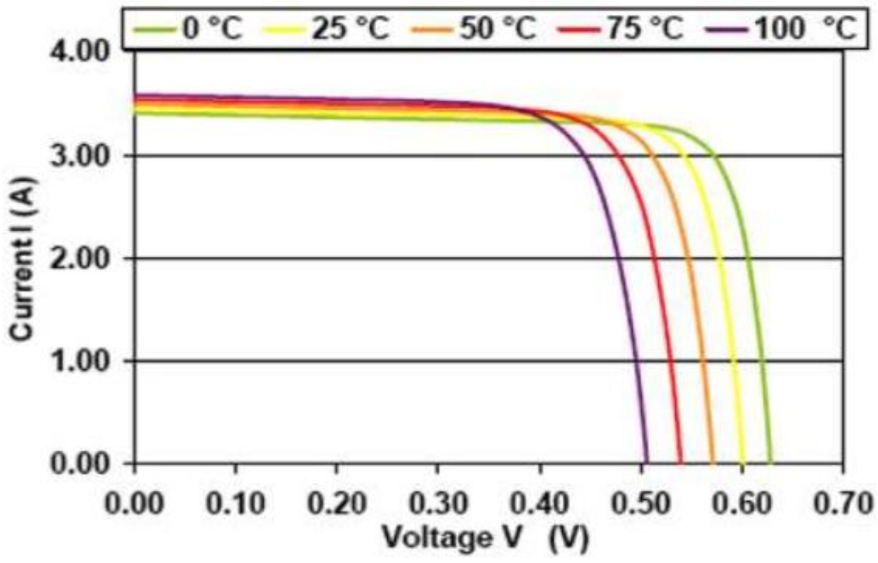
- the area of the solar cell.
- the number of photons
- the spectrum of the incident light.
- the optical properties

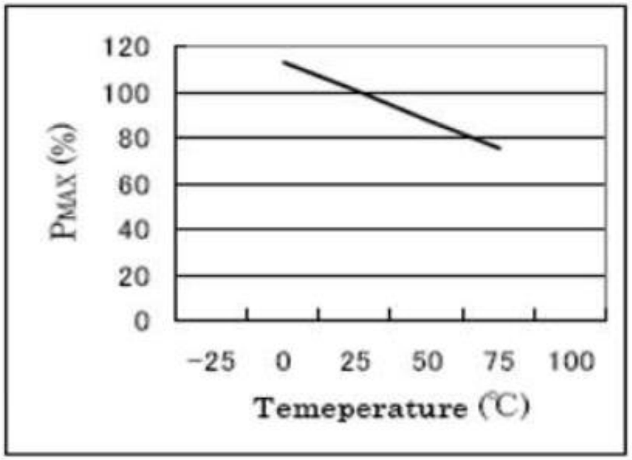
- **Voltage at Maximum Power (Vmp)** – The voltage that results in maximum power output is called Voltage at maximum power. Vmp is also called “Rated” voltage of the cell.
- **Fill Factor (FF)** – The fill factor is a figure of merit that indicates the “squareness” of the I-V curve. It is the ratio of the actual maximum power Pmax to the unattainable but ideal power that would result from operating at Isc and Voc.
- **Total Area Efficiency** – It is the ratio of electrical power output (typically the Pmax) to the total light power incident on the entire cell area including frames (if applicable), interconnects and pattern lines on the surface

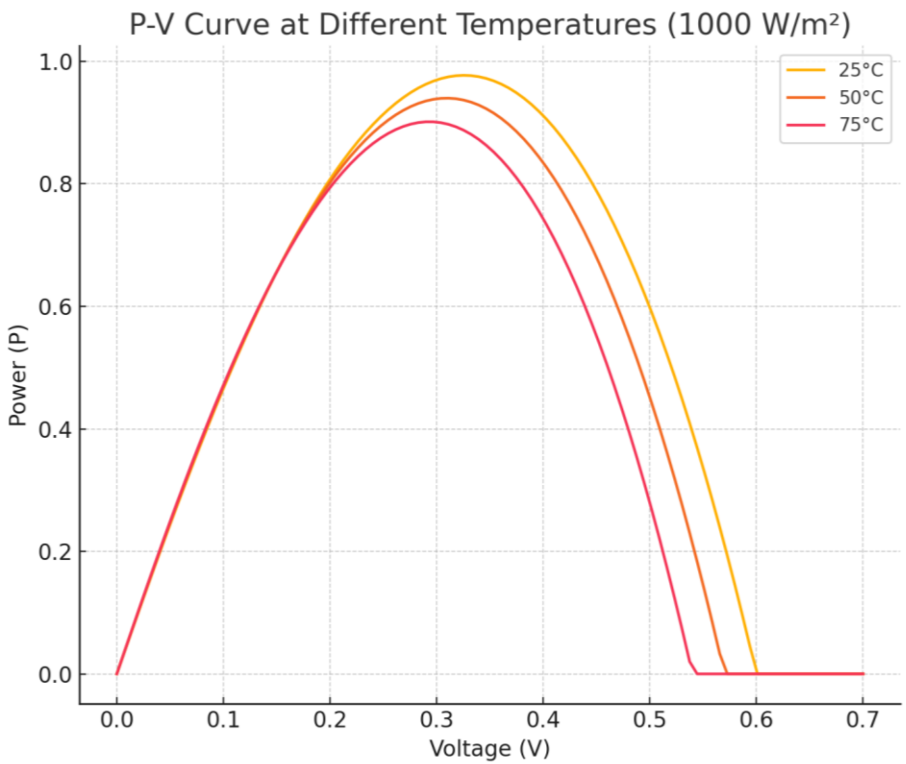
$$P_{\max} = I_{mp} \times V_{mp}$$

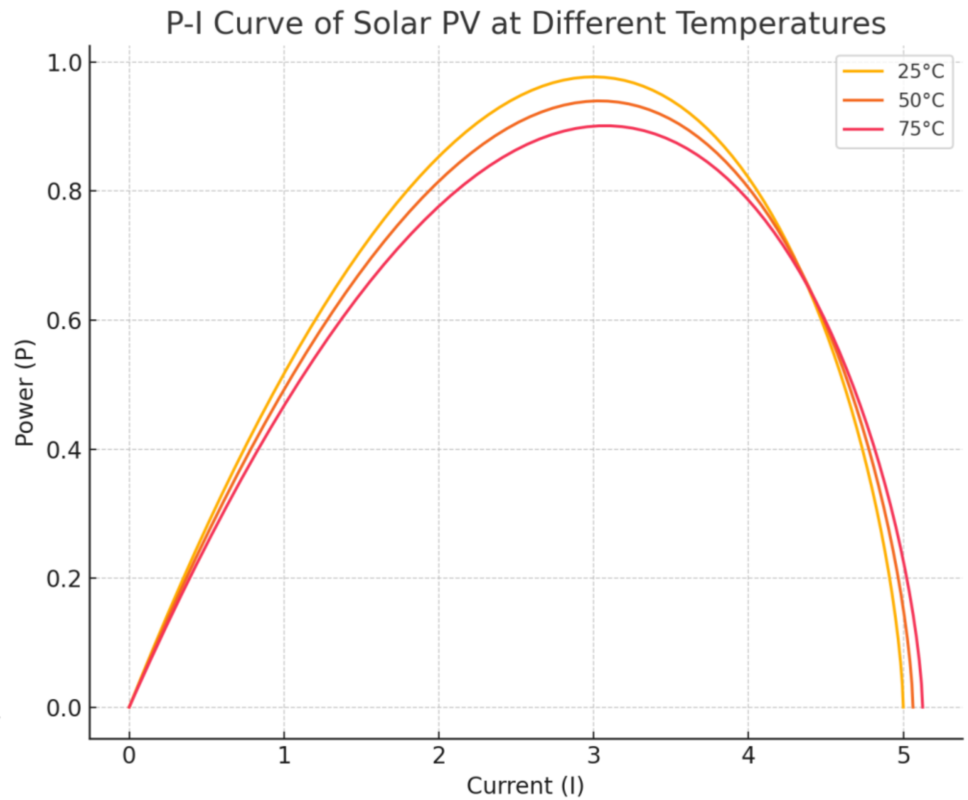
$$FF = \frac{\left(I_{mp} \times V_{mp}\right)}{\left(I_{sc} \times V_{oc}\right)}$$

I-V and P-V Characteristics at Constant Irradiance

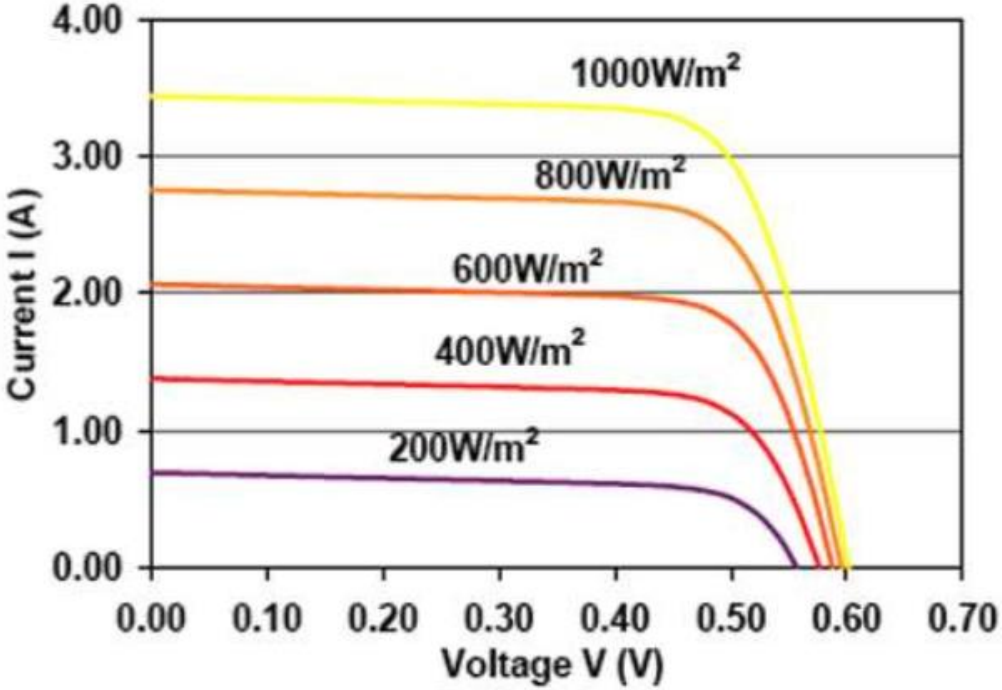


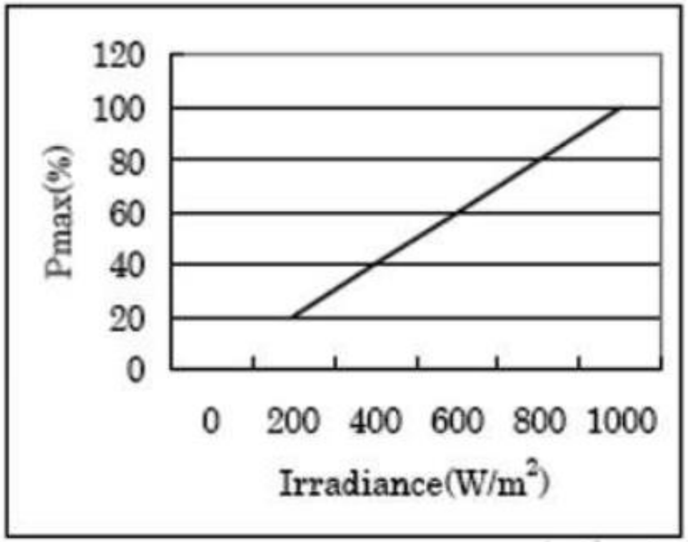


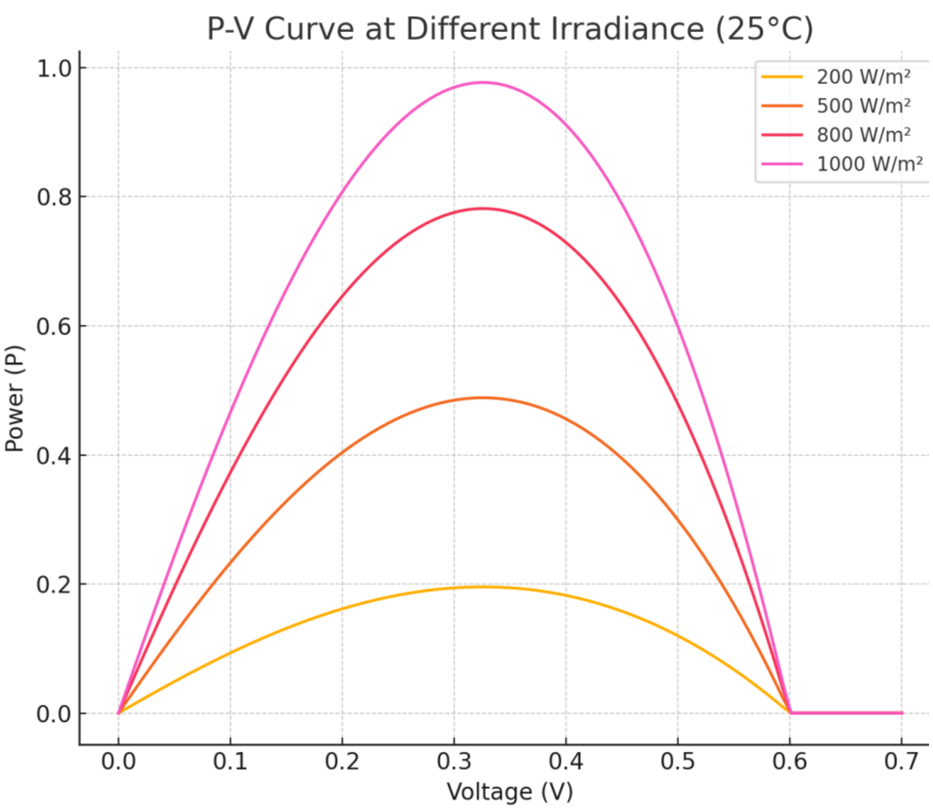

P-V Curve at Different Temperatures (1000 W/m²)
Power (P)
Voltage (V)
25°C
50°C
75°C
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


P-I Curve of Solar PV at Different Temperatures
Power (P)
Current (I)
25°C
50°C
75°C
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5

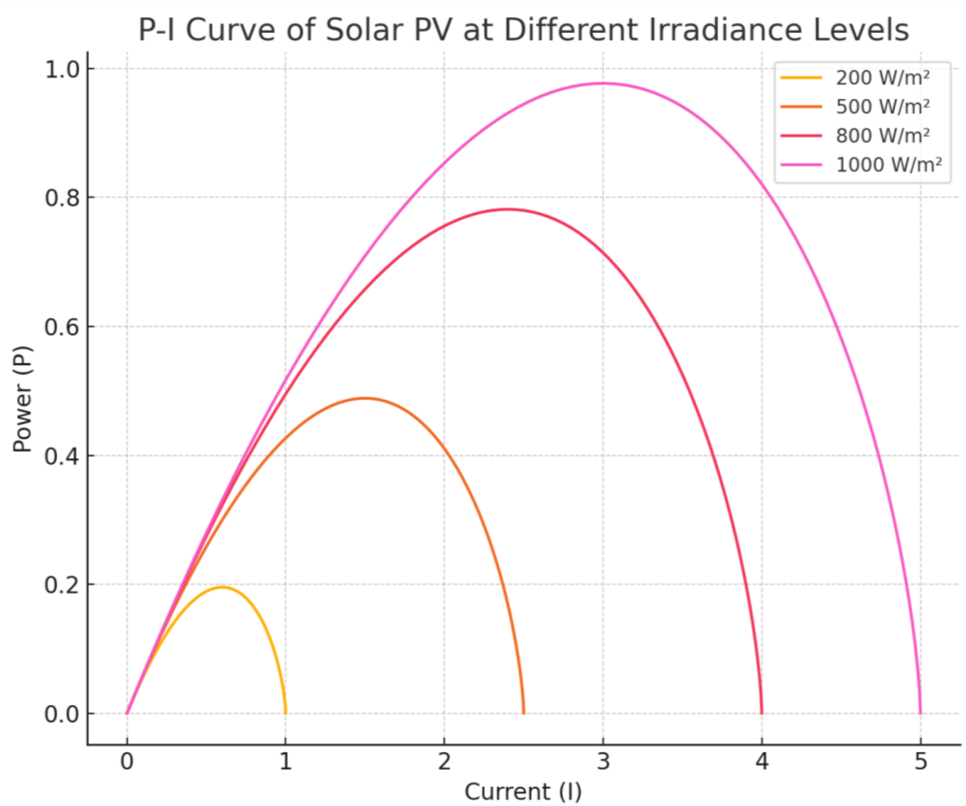
I-V and P-V Characteristics at Constant Cell Temperature







P-V Curve at Different Irradiance (25°C)
200 W/m²
500 W/m²
800 W/m²
1000 W/m²
Power (P)
Voltage (V)
0.0
0.2
0.4
0.6
0.8
1.0
0.1
0.3
0.5
0.7



P-I Curve of Solar PV at Different Irradiance Levels
200 W/m²
500 W/m²
800 W/m²
1000 W/m²
Power (P)
Current (I)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5

Solar Module or Solar Panel

- A single solar cell of size 4 sq. inch ($\cong$ 105 sq.cm) will produce around 3.05 A of I_{mp} and 3.36 A of I_{sc} at STC (Standard Temperature Conditions).
- Assuming V_{mp} to be 0.5 V, the maximum power generated by the cell would not exceed 1.52 W_p (Watt peak). This is too low power for any practical applications.
- In fact, increasing the size of the cell can increase the power, but there are practical limitations of cell size.
- Therefore, numbers of cells are connected in series and parallel to increase the current, operating voltage as well as the output power.
- When two cells are connected in series the voltage doubles (or the total output voltage is the product of voltage produced by individual cell and the numbers of cells connected in series). But the current through the series connected cells will be equal to the current produced by a single cell.

Example

- If 36 cells with V_{mp} = 0.5 V and Imp = 3 A are connected in series, then:
- The V_{mp} for 36 series connected cells = 0.5 V x 36 = 18 V, and
- Imp 36 series connected cells = current produced by the single cell = 3A
- The total power at MPP(Maximum Power Point) in this case would be :

$$P_{max} = V_{mp} \times I_{mp} = 18 \times 3 = 54 \text{ Wp.}$$

- If 36 cells with V_{mp} and Imp as in previous example are connected in parallel, then:
- V_{mp} for 36 parallel connected cells = V_{mp} of single cell = 0.5 V, and
- I_{mp} for 36 parallel connected cells = I_{mp} (of a single cell) x 36 = 3 x 36 = 108 A.
- The total maximum power in this case will be again,

$$P_{max} = 0.5 \text{ V} \times 108 \text{ A} = 54 \text{ Wp.}$$

Solar Array

- Solar array is a group of similar modules connected in series and parallel to increase the power delivered by the PV system.
- As in case of series and parallel connection of cells, Series connection of modules increases the final array voltage. In this case the current supplied by the array is equal to the current produced by a single module.
- Parallel connection of modules increases the output current keeping the voltage level at par with the voltage produced by the single module.
- In both cases the total power of the array will be equal to the product of power of single module times the number of modules used in connection.
- The array configuration (i.e. the number of modules connected in series or parallel) is dictated by the required system voltage.
- The peak reverse voltage that a module can withstand also governs the number of series connected modules in an array.
- The parameters of an array are same as that of a single cell or single module. The only difference is in their magnitudes.
- The input to configuring an array is the final required system voltage.
- For example, if the load is a 24 V DC pumps, only two modules of 12 V are to be connected in series to produce 24 V nominal outputs. Strings of two modules connected in series further can be connected in parallel to obtained required power levels. The figure 4.4.1 below is the suggestive array configuration for a 24 V DC system

Wiring line diagrams

A simple PV system/ Home system:

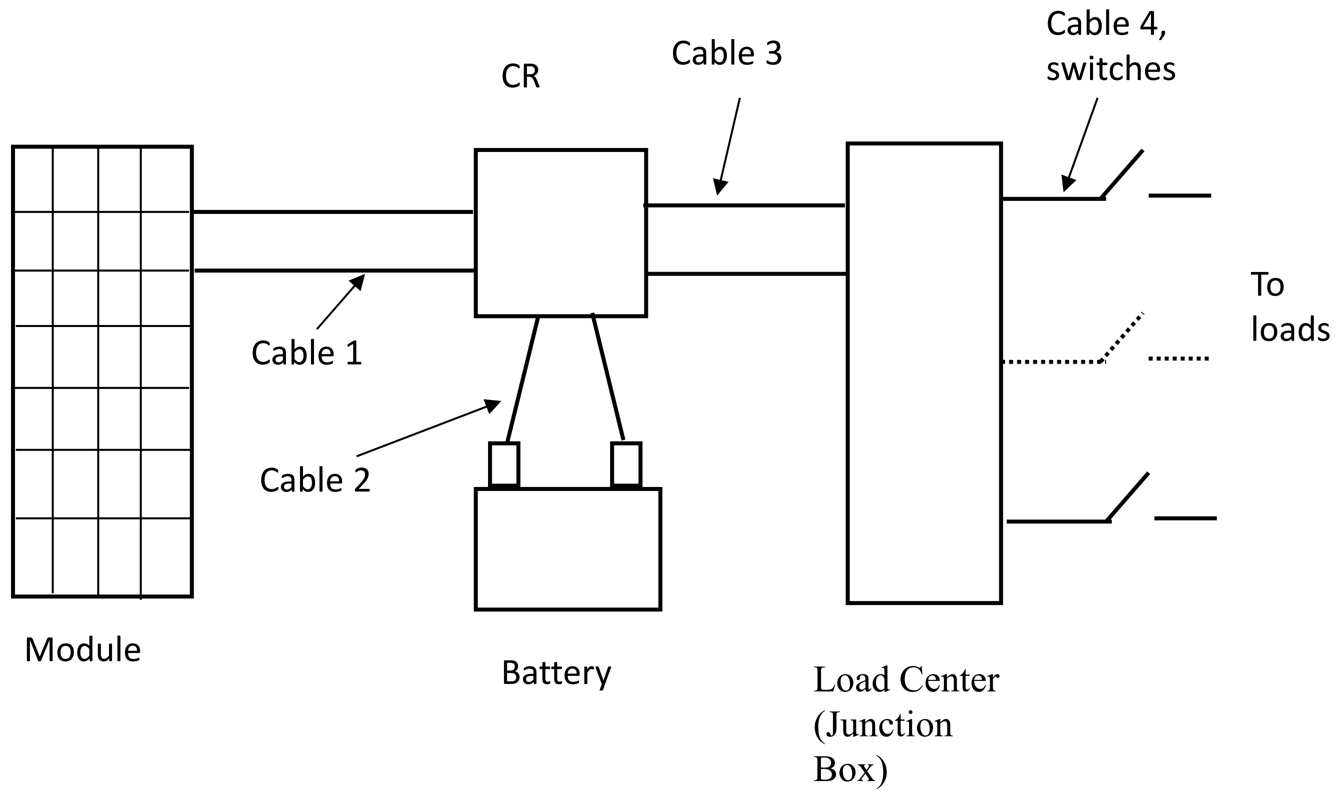


Fig. 6.8.1.1 Installation diagram for simple PV system

Start with simple block diagram

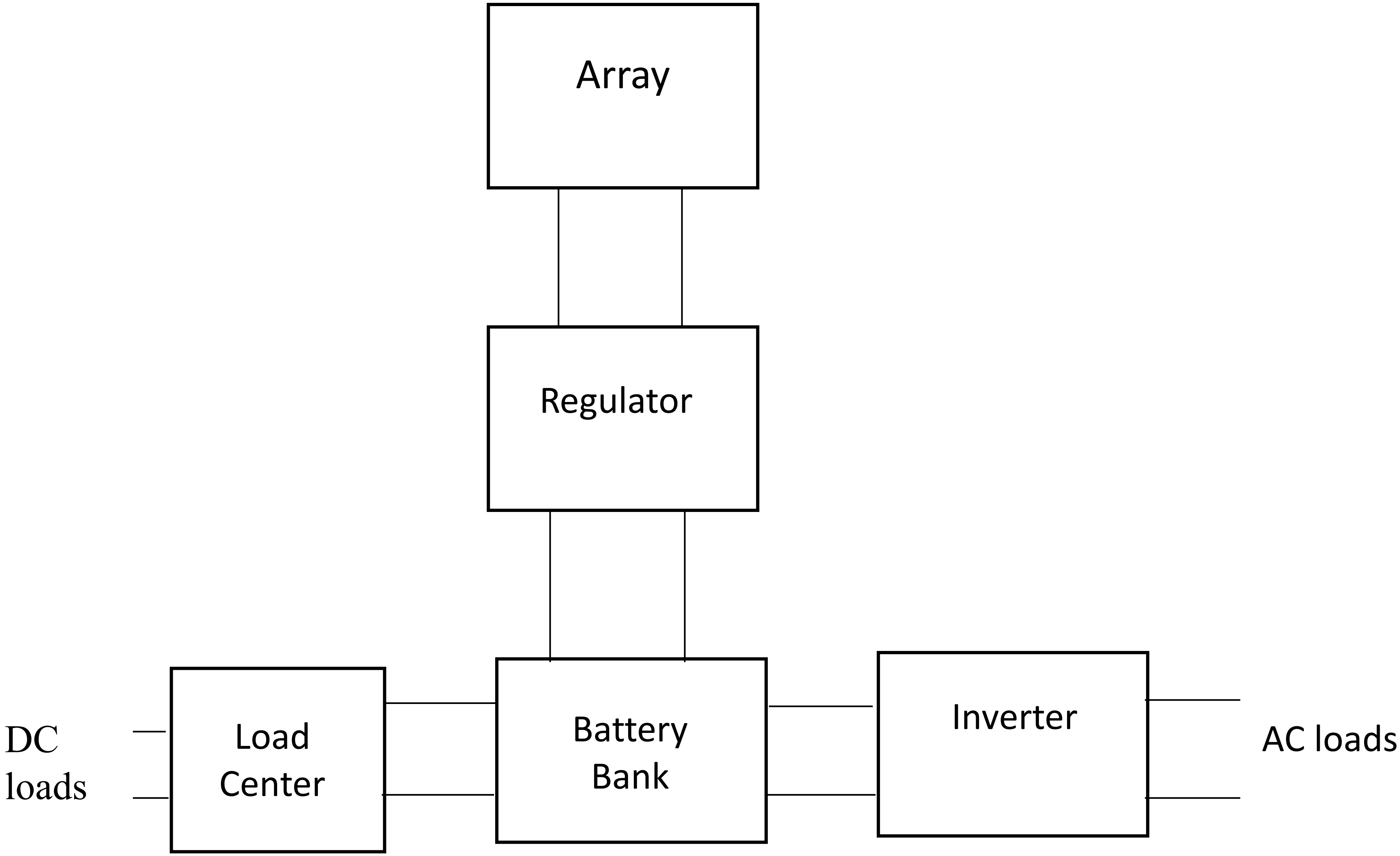
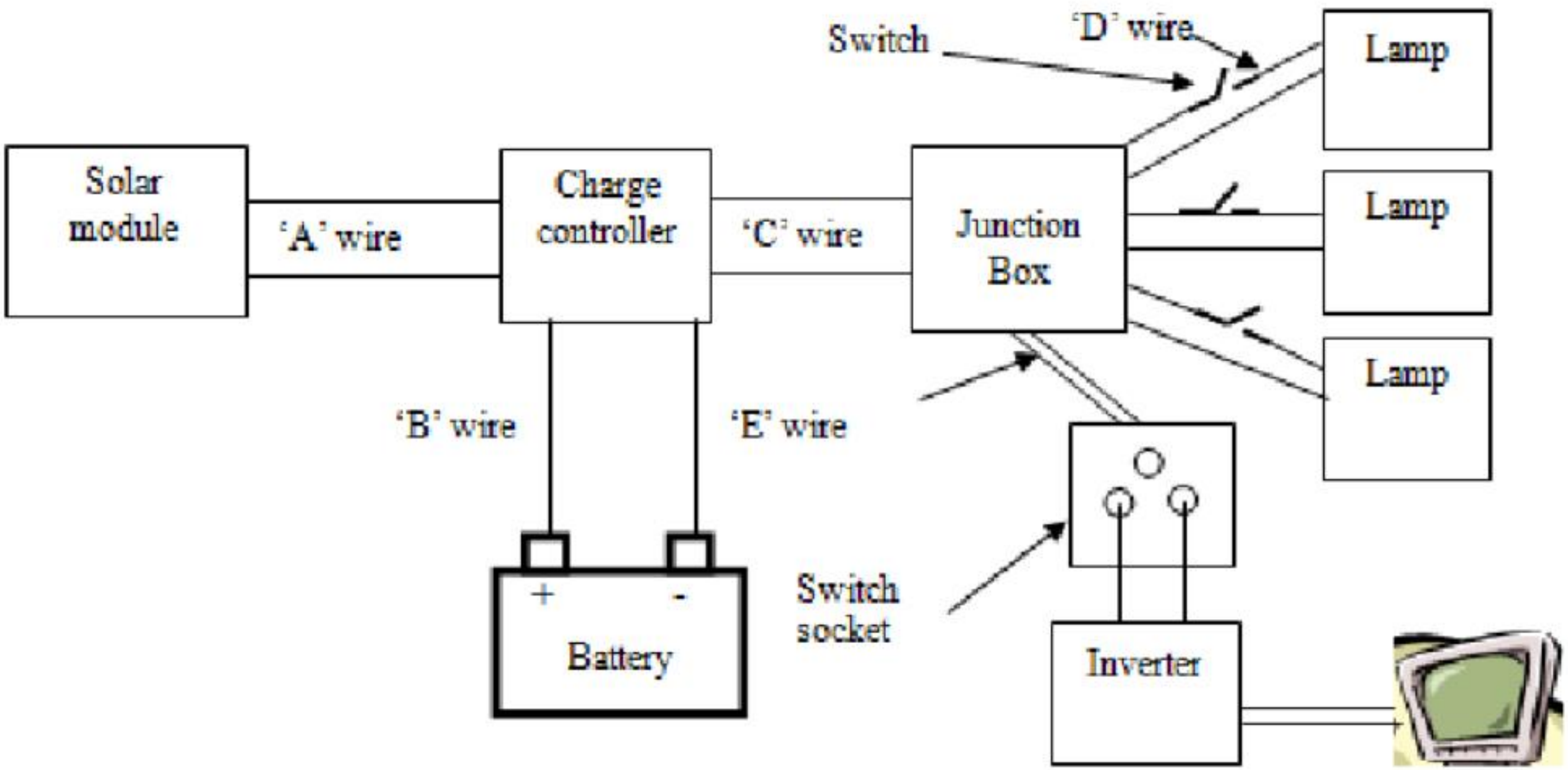
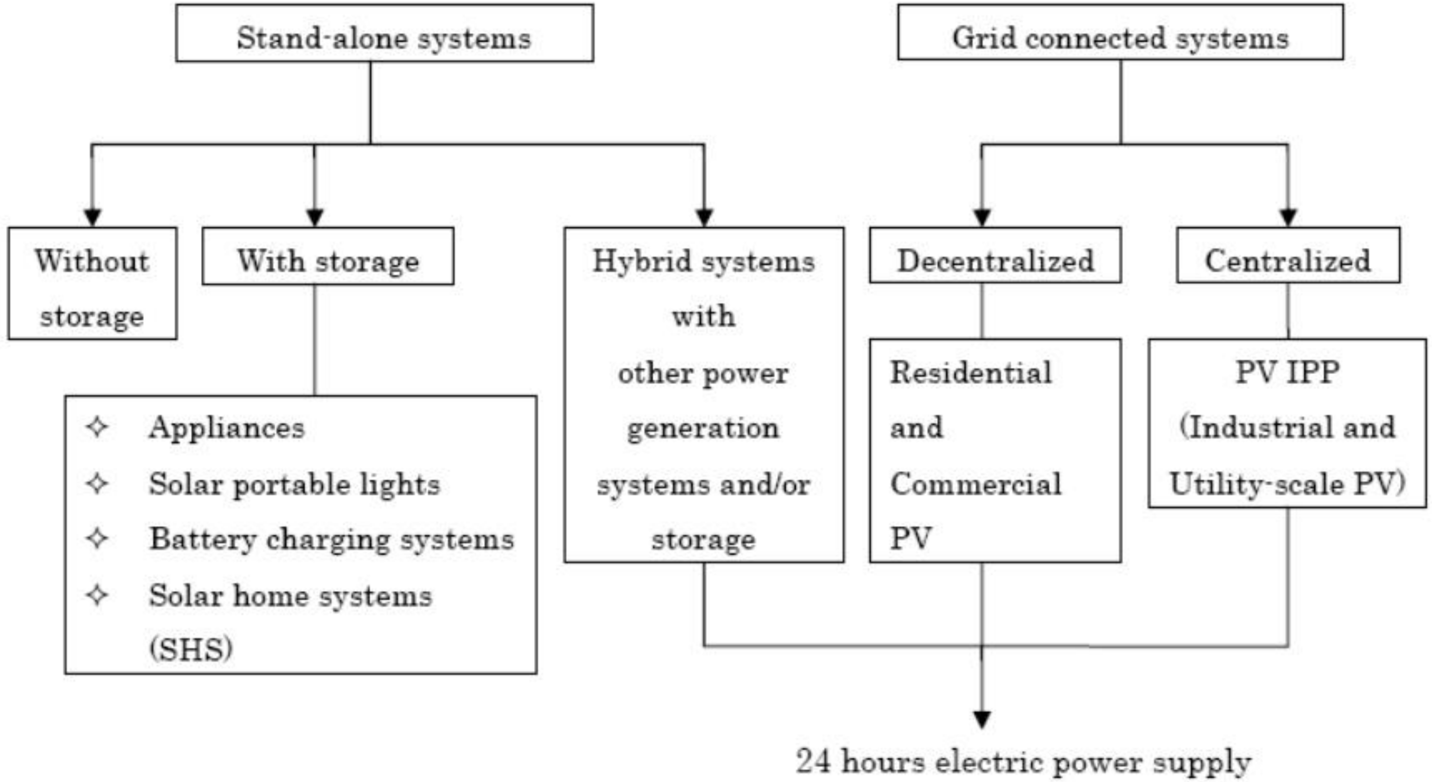


Fig. 6.8.1.2 Simple block diagram of larger system

A Solar PV system

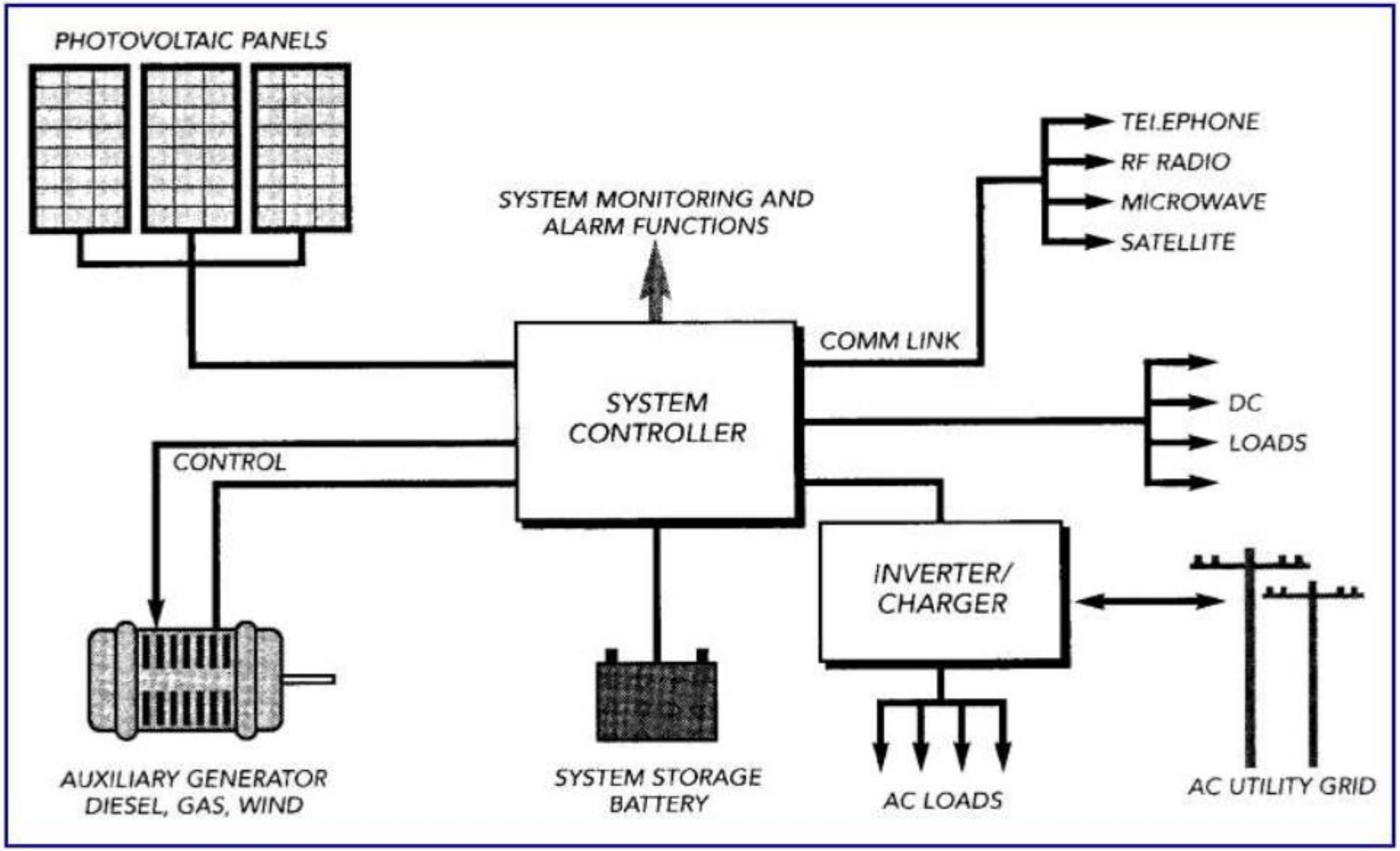


Application of Solar PV System

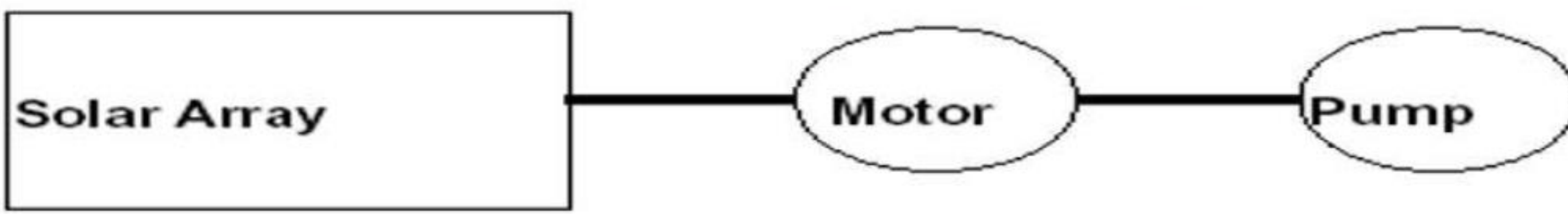


Solar PV stand-alone systems

PV SYSTEM BALANCE

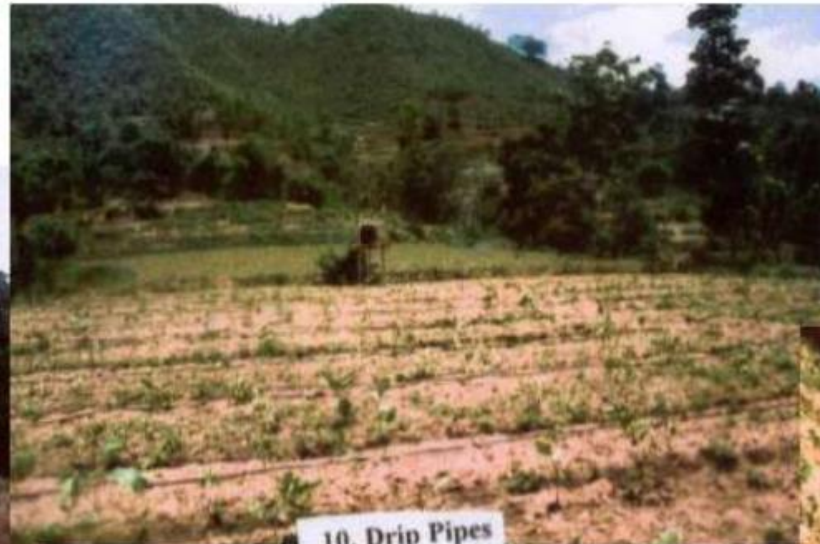


Application of Solar PV System



Solar PV Pumping

9. Dripping system



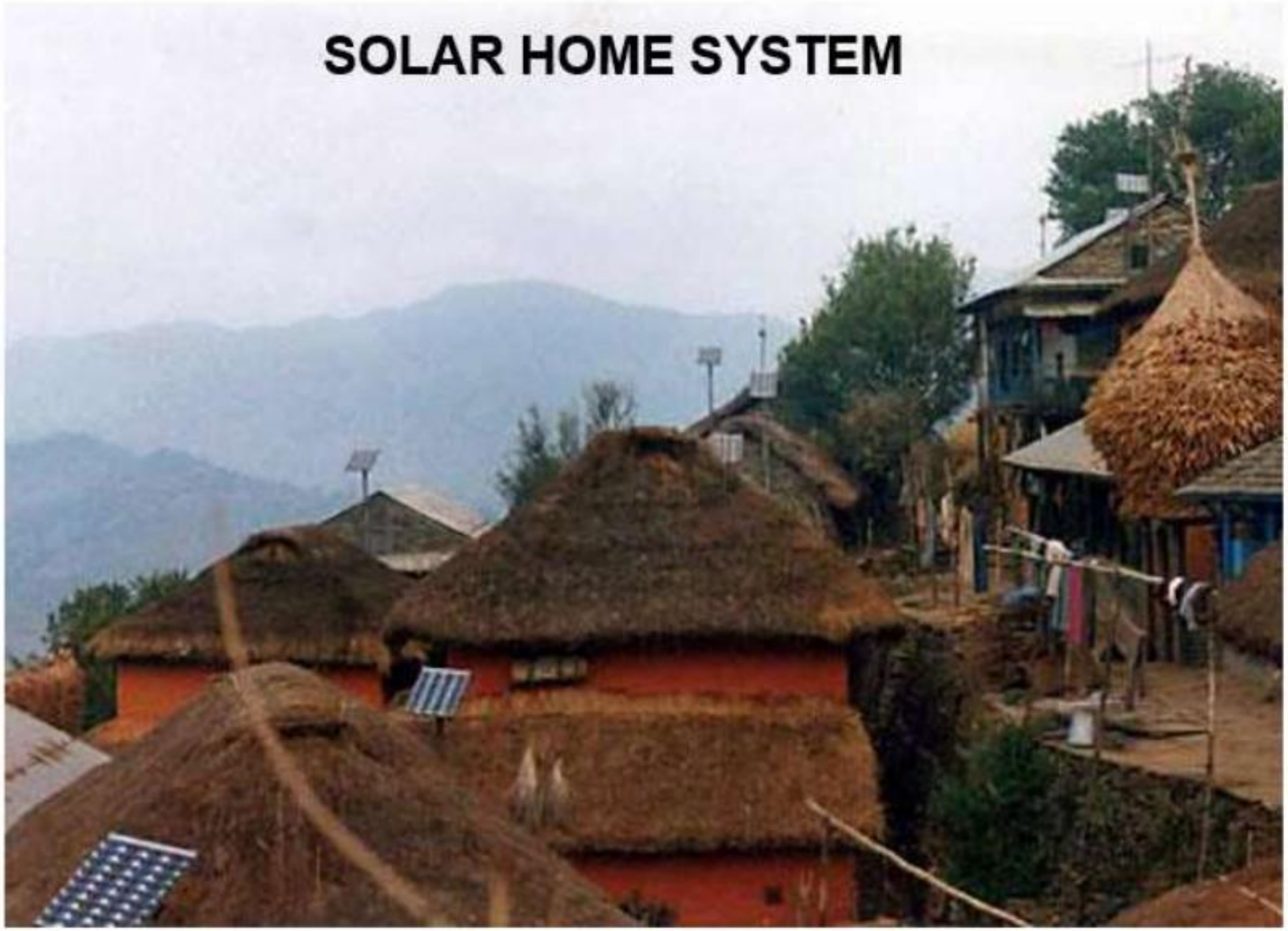
10. Drip Pipes

11. Plants being fed by drips

12. Vegetabe collection Centre at Salanghat Bazar which is at 10 min. Walk from the site of SPV WPS

SOLAR ELECTRICITY APPLICATION IN

SOLAR HOME SYSTEM



FIRST SOLAR PV VILLAGE IN NEPAL
Village : Pulimurang, Tanauhu
Date of installation: January 1994
Inaugurated by the then Prime Minister of Nepal on 14 May 1994

Solar PV Home System

TUKI

Child reading a book using TUKI

TUKI used as a reading lamp

SOLAR PV POWERING HEALTH CLINIC

IMPACTS OF PV BASED RURAL ELECTRIFICATION

Positive effects on

- ✓ Health and sanitation
- ✓ Child care
- ✓ Children education
- ✓ Cottage industry
- ✓ Household income
- ✓ Status of women
- ✓ Access to information
- ✓ Social interaction
- ✓ Rural telecommunication services
- ✓ Civil aviation services
- ✓ Drinking water supply

INCOME GENERATING ACTIVITIES THROUGH PV

- ✓ Rural Telecommunication Service
- ✓ Cordless Telephone System
- ✓ Photocopying machine
- ✓ Fax machine
- ✓ E-mail Services
- ✓ Mini battery charging stations
- ✓ Video Camera Charging
- ✓ Replacement of primary batteries
- ✓ Video shows
- ✓ Repair of electronic gadgets
- ✓ Private Health Clinic
- ✓ Late night shops along the highway
- ✓ Display boards along the highway

14. Small cottage industries
15. PV powered mills
16. Water pumping
17. Thanka painting
18. Increased agriculture production
19. Employment for SHS technicians
20. Adult education
21. PV in agroprocessing
22. Reverse migration
23. Hotel along the trekking routes
24. Water purification
25. Poultry Farming

SOLAR THERMAL ENERGY

Introduction

- **Solar thermal energy** (**STE**) is a technology for harnessing **solar energy** **for** **thermal energy** (**heat**)

- The basic purpose of a solar thermal energy system is to collect solar radiation and convert into useful thermal energy.

- The system performance depends on several factors, including availability of solar energy, the ambient air temperature, and especially the thermal characteristics of solar system itself.

Modes of heat flow

3 main modes of heat flow:

Conduction, Convection, Radiation

Conduction is the flow of heat by direct contact between warmer and cooler body.

Convection is the flow of heat carried by moving gas or liquid.

Warm air rises, gives up heat, cools, then falls.

Radiation is the flow of heat without need of an intervening medium.

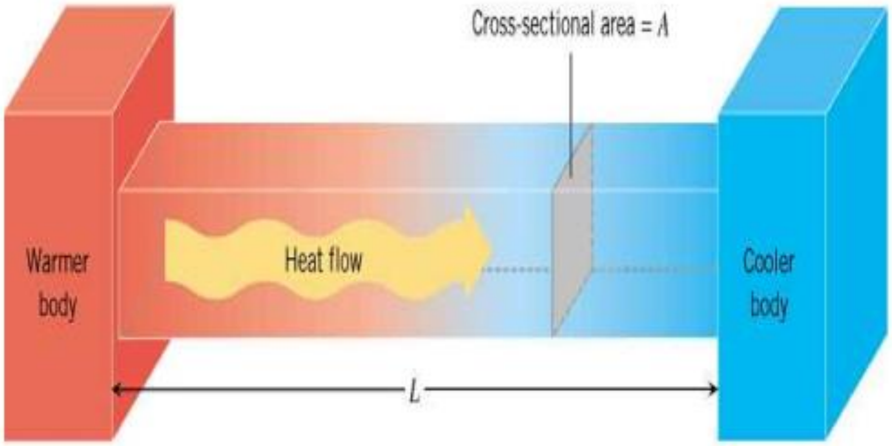
Typically by infrared radiation or light.

Heat Transfer

There are three ways in which heat can be transferred from one object to another:

- **Conduction** – when two objects are in physical contact.

$$Q = kA\left(\frac{\Delta T}{L}\right)t$$



k = thermal conductivity
Q = heat transferred
A = cross sectional area
t = duration of heat transfer
L = length
ΔT = temperature difference between two ends

Conduction(contd…)

- The heat transfer occurs by transmission of momentum of individual molecules
- Heat transfer occur when there is a temp gradient.
- The molecules at the hot end vibrate more rapidly than molecules at the cold end.
- This vibration is imparted to the neighboring molecules which vibrate faster and hence heat up.

Convection

- When heat flow is achieved by actual mixing of warmer portions with cooler portions of the same material, the process is known as convection.

- Two type
- 1. Forced convection
- 2. Natural convection.

$$h_1 = \frac{q}{A_1(t_1 - t_2)}$$

where h1 is surface coefficient

Radiation

- Its is the transfer of heat from one object to another by means of electro magnetic waves .
- Radiated heat transfer occurs in the space

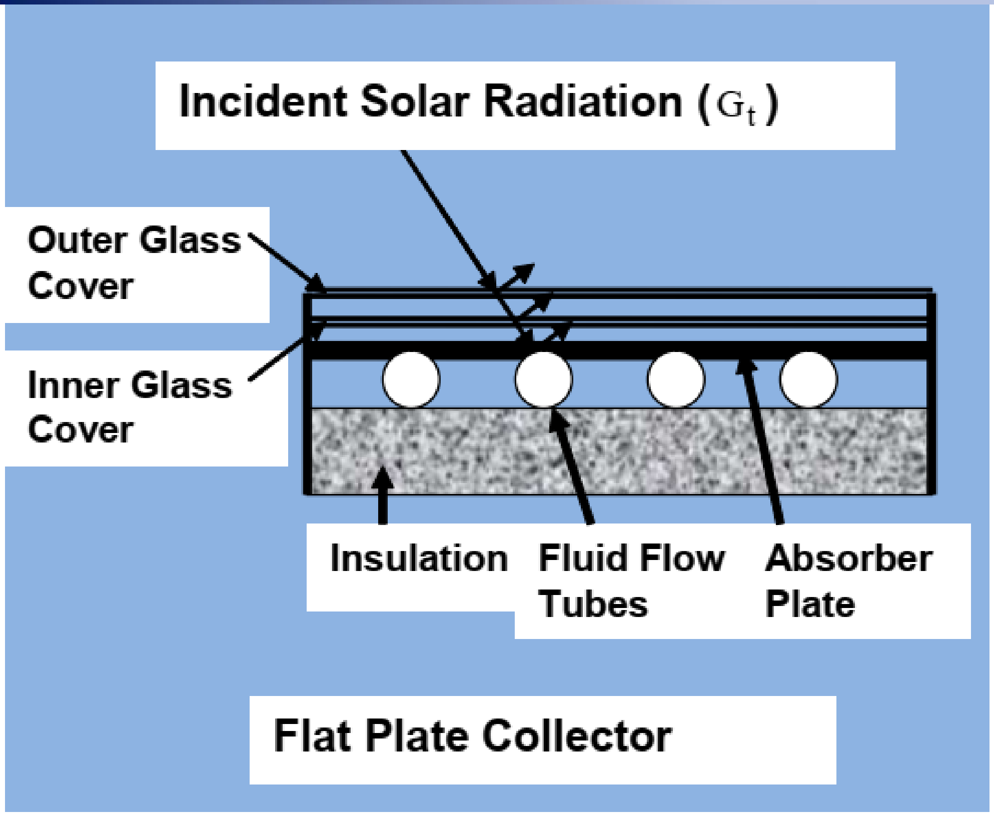
Solar collector

- The main part of the solar thermal energy system is solar collector.
- Device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector.
- Basically two types of solar collectors:
  - Non-concentrating or stationary
  - and concentrating.

- Three types of collectors fall in stationary category:

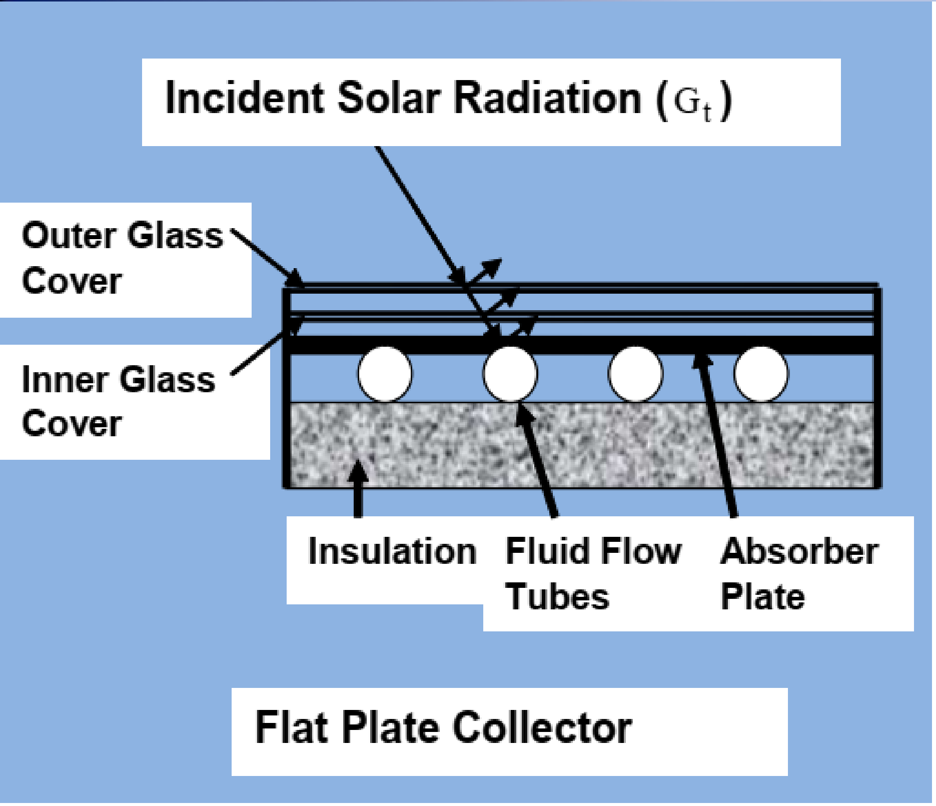
1. Flat plate collectors (FPC)
2. Stationary compound parabolic collectors (CPC)
3. Evacuated tube collectors (ETC)

Flat Plate Solar Collector



- Used for moderate temperature up to 100 C
- Uses both direct and diffuse radiation
- Normally do not need tracking of sun
- Use: water heating, building heating and air-conditioning, industrial process heating.
- Advantage: Mechanically simple

Flat Plate Solar Collector

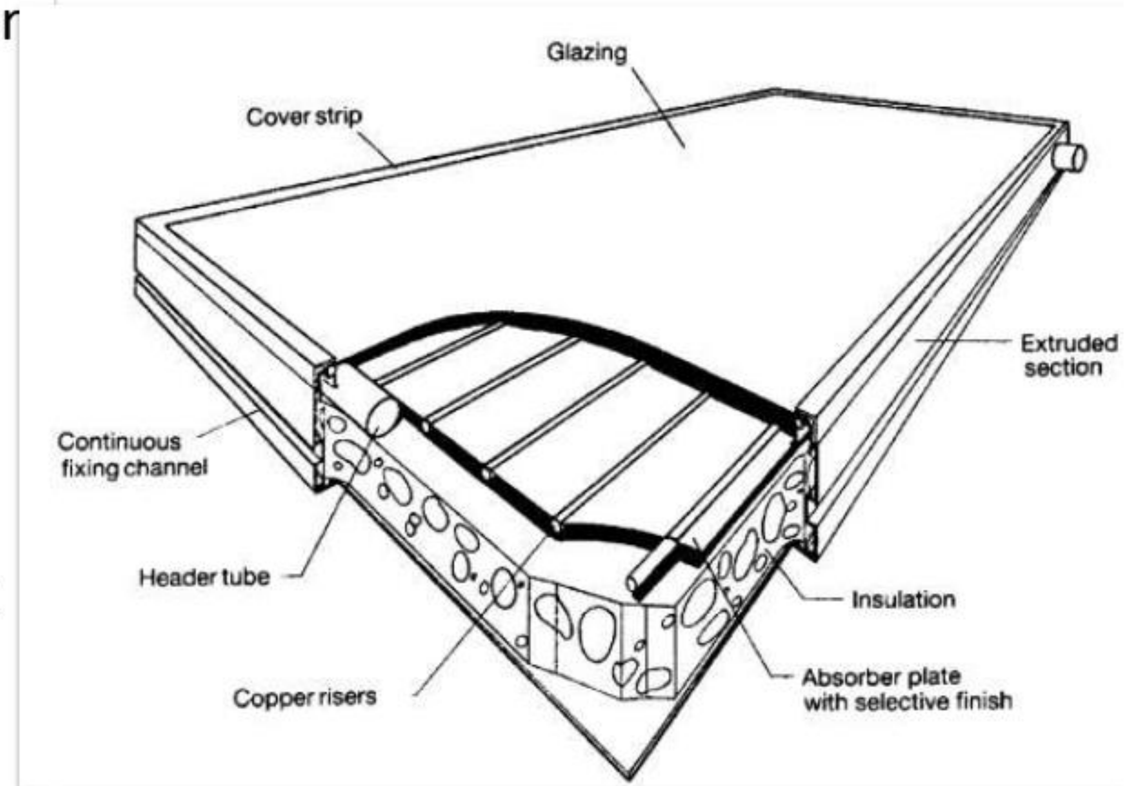


Consists of an **absorber plate, *cover glass, insulation*** **and *housing*.**

- The absorber plate is usually made of copper and coated to increase the absorption of solar radiation.
- The cover glass or glasses are used to reduce convection and re-radiation losses from the absorber.
- Insulation is used on the back edges of the absorber plate to reduce conduction heat losses.
- The housing holds the absorber with insulation on the back and edges, and cover plates.
- The working fluid (water, ethylene glycol, air etc.) is circulated in a serpentine fashion through the absorber plate to carry the solar energy to its point of use.

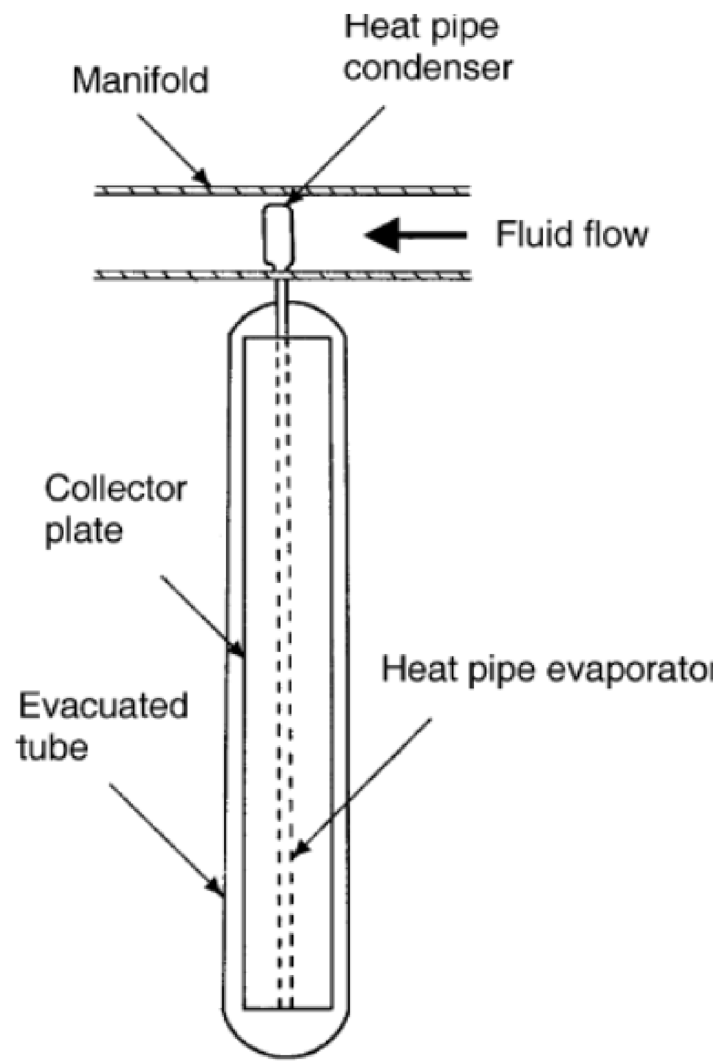
Flat-plate collectors

- solar radiation passes through a transparent cover
- Impinges on the blackened absorber surface of high absorptivity
- A large portion of this energy is absorbed by the plate and then transferred to the transport medium in the fluid tubes



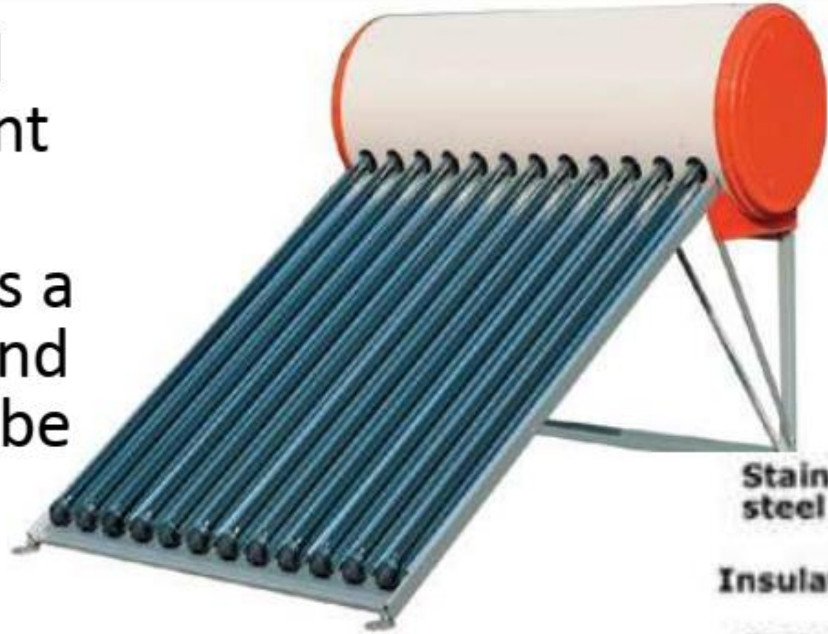
Evacuated tube collectors

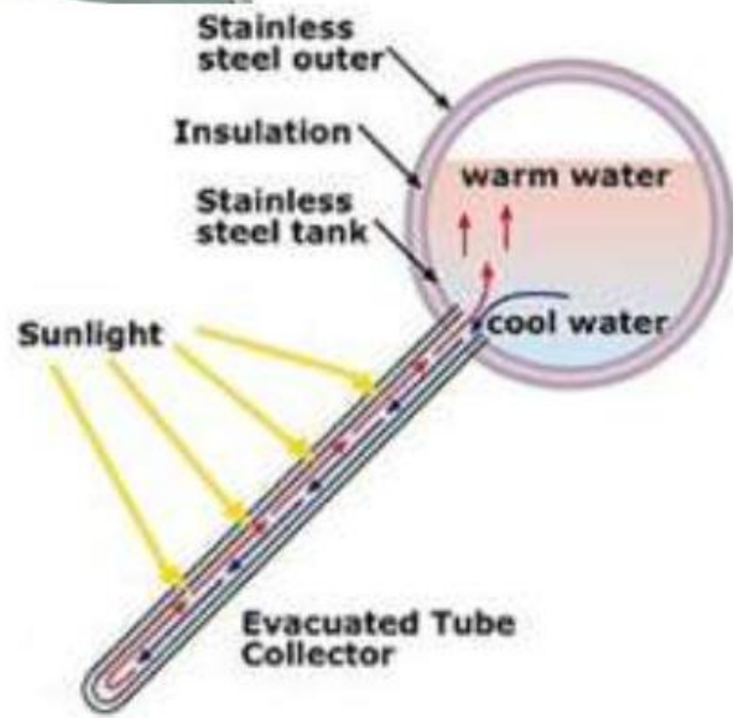
- Deterioration of internal materials resulting in reduced performance and system failure in cold climate of FPC
- A glass or metal tube containing the water or heat transfer fluid is surrounded by a larger glass tube. The space between them is a vacuum, so very little heat is lost from the fluid.
- As vacuum envelope reduces convection and conduction losses, so the collectors can operate at higher temperatures than FPC.



Evacuated Tube Solar Collectors

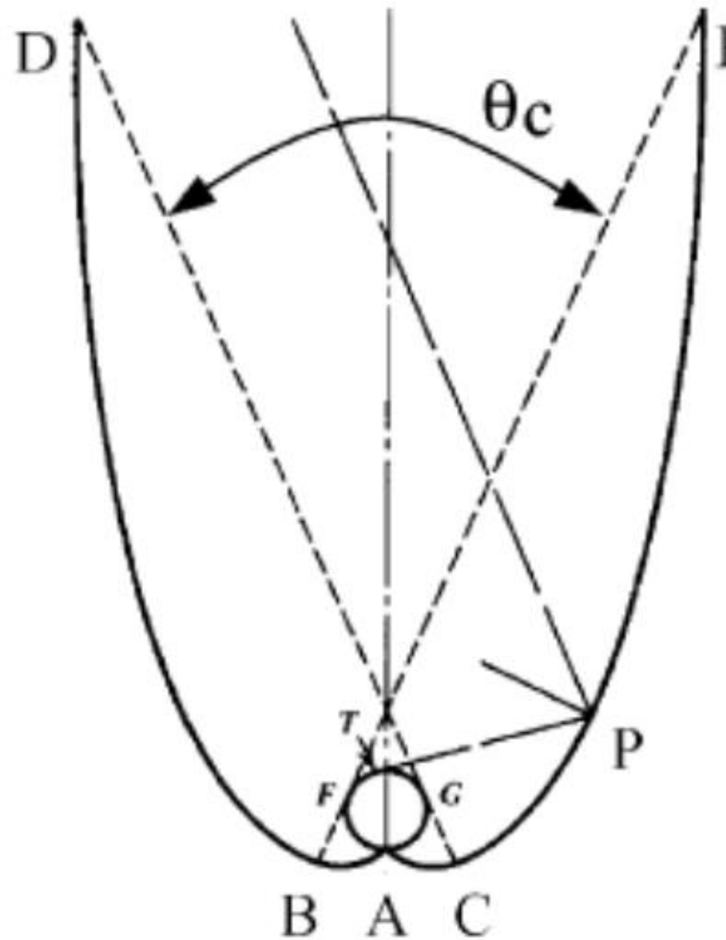
- It features parallel rows of transparent glass tubes.
- Each tube contains a glass outer tube and metal absorber tube attached to a fin.
- The fin’s coating absorbs solar energy but inhibits radiative heat loss.
- These collectors are used more frequently for commercial applications.





Compound Parabolic Collectors

- CPC are fixed collectors.
- Radiation within wide limits.
- Use of a trough with two sections of a parabola facing each other
- Compound parabolic concentrators can accept incoming radiation over a relatively wide range of angles, by using multiple internal reflections



. Schematic diagram of a compound parabolic collector.

Fixed Vs Tracking

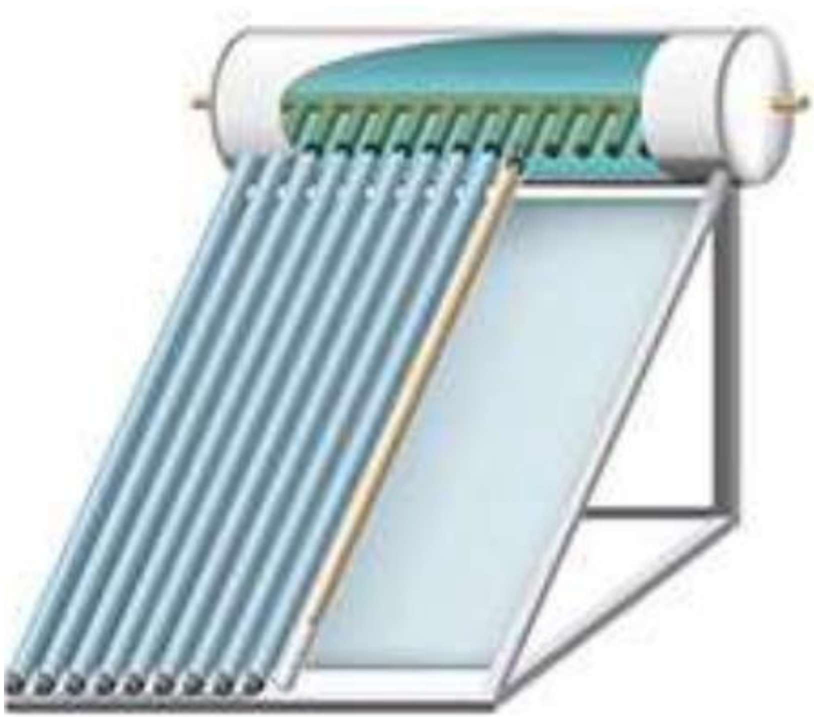
- A tracking collectors are controlled to follow the sun throughout the day.

- A tracking system is rather complicated and generally only used for special high-temperature applications.

- Fixed collectors are much simpler - their position or orientation, however, may be adjusted on a seasonal basis. They remain fixed over a day's time

- Fixed collector are less efficient than tracking collectors; nevertheless they are generally preferred as they are less costly to buy and maintain.

Fixed collector



Tracking collector

SOLAR THERMAL APPLICATIONS

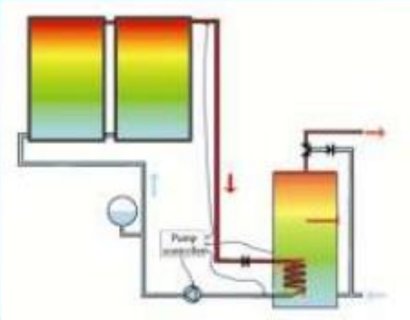
- Solar Water Heating
- Solar Drying
- Solar Cooking
- Solar Pond
- Solar Swimming Pool
- Solar Stills
- Solar Thermal Power Plant

Solar Water Heating System

- The solar water heating system offsets the use of natural gas, propane or electricity by preheating water before the conventional domestic hot water system.
- A solar water heating system is made up of several key components including:
  - Solar collectors
  - Thermal storage
  - System controls/controller
  - A back-up, conventional water heater

Solar Water Heating System Basics

- Solar water heating systems include storage
  tanks and solar collectors
- Most solar water heaters require a well-insulated storage tank.
- Solar storage tanks have an additional outlet and inlet connected to and from the solar collector.
- In two-tank systems, the solar water heater preheats water before it enters the conventional water heater.
- In one-tank systems, the back-up heater is combined
  with the solar storage in one tank

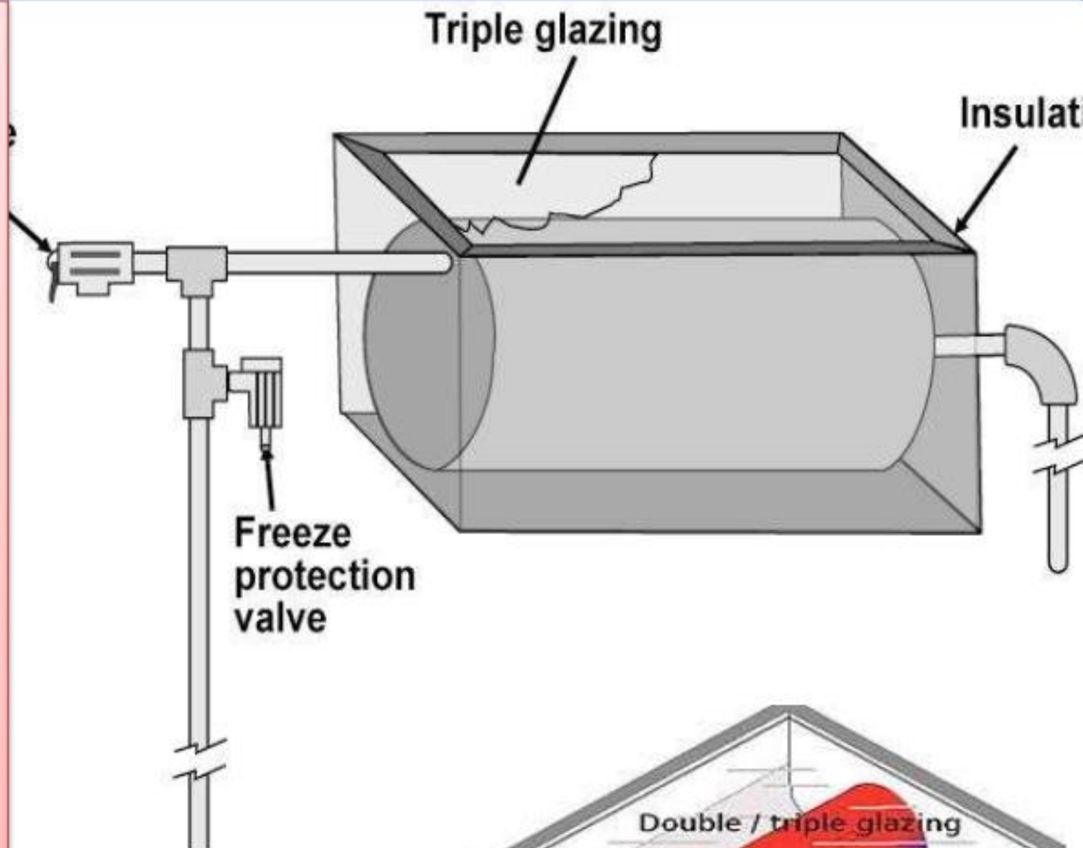


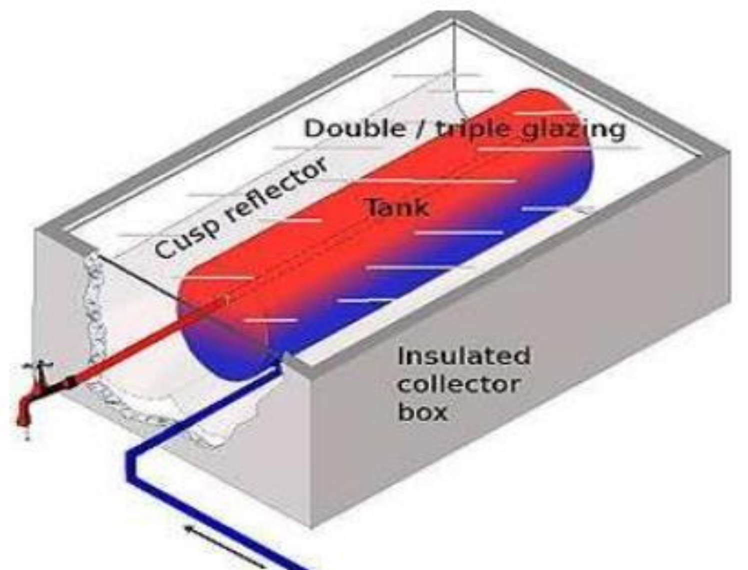
Solar Collectors

- Four types of solar collectors are used for residential applications:
  - Flat-plate collector
  - Integral collector-storage systems
  - Batch system
  - Evacuated-tube solar collectors

Batch solar water heater

- simplest of all solar water heating systems
- storage tanks coated with black, solar-absorbing material in an enclosure with glazing across the top and insulation around the other sides.
- When exposed to sun during the day, the tank transfers the heat it absorbs to the water it holds.
- The heated water can be drawn directly from the tank or it can replace hot water that is drawn from an interior tank inside the building.





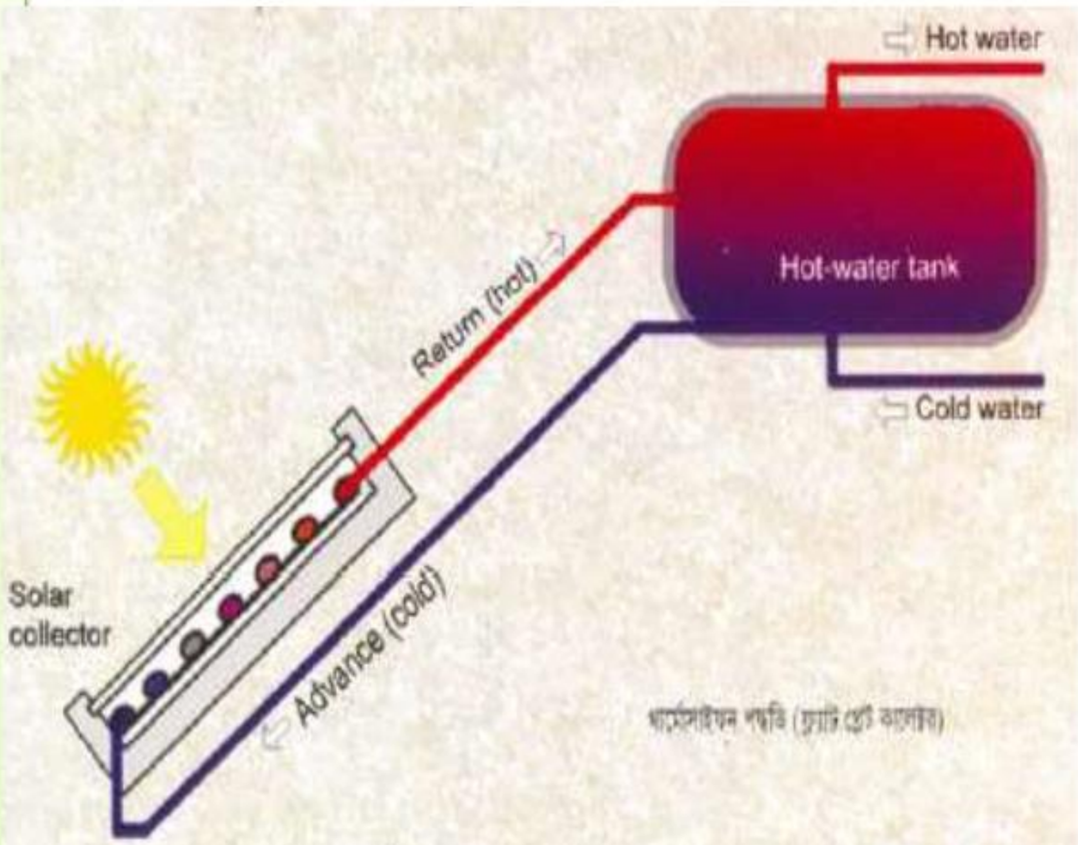
Active Solar Water Heating Systems

- There are two Solar Water Heating System types: *Active and Passive*

- There are two types of Active Solar Water Heating Systems:
  – Direct Circulation Systems
  – Indirect Circulation Systems

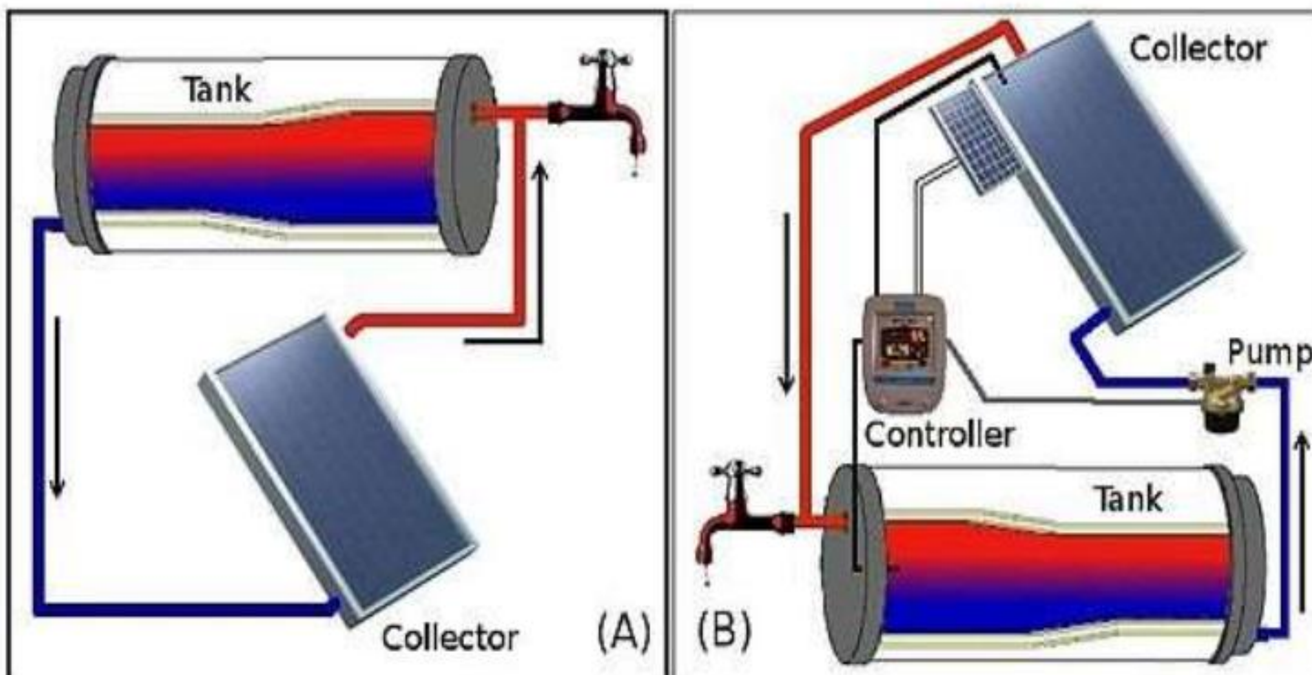
Thermo siphon System

- In thermo siphon system there is no need for a circulating pump and controller. Potable water flows directly to the tank on the roof.
- Solar heated water flows from the rooftop tank to the auxiliary tank installed at ground level whenever water is used with the building

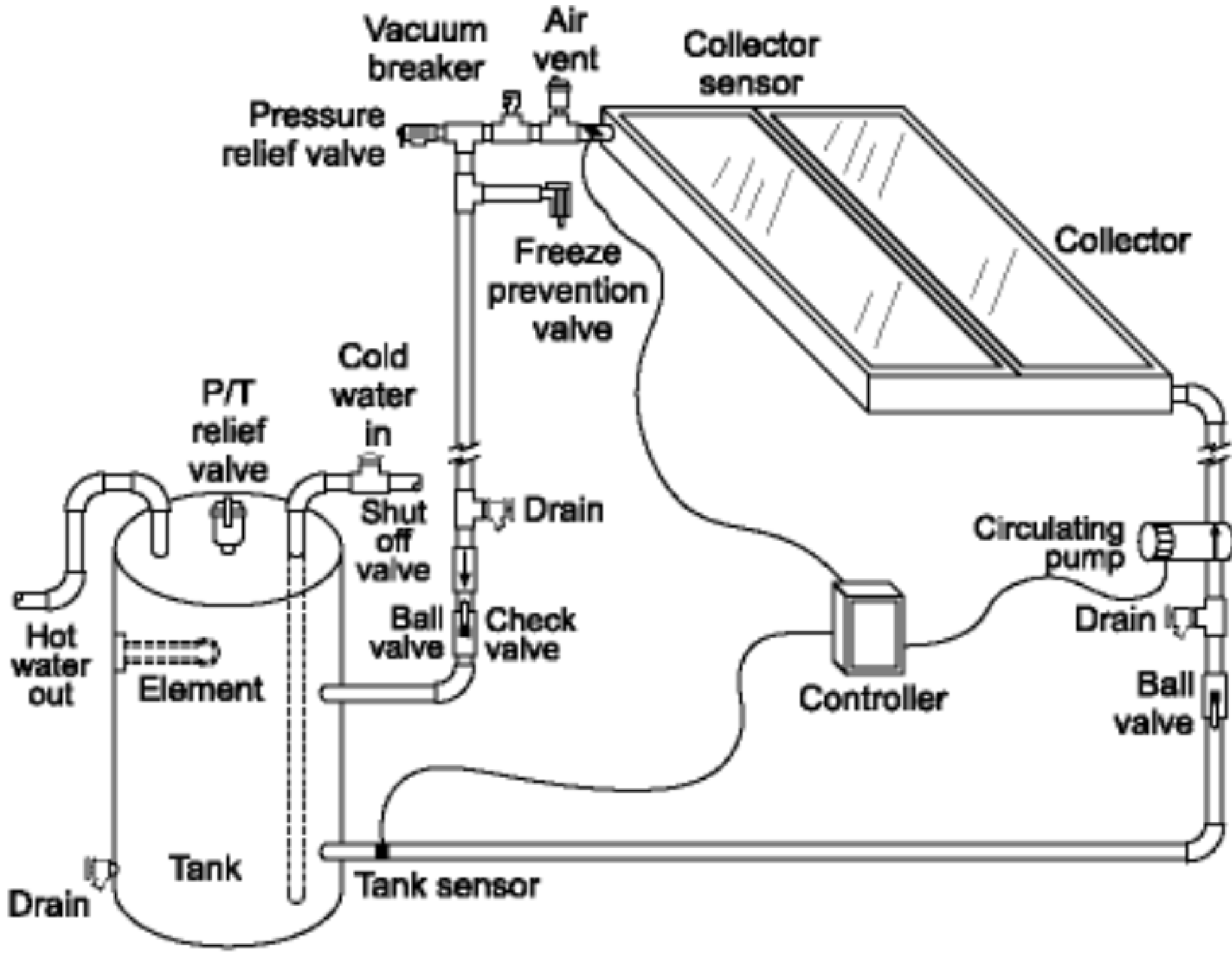


Passive (thermosiphon) solar water heaters on a rooftop in Jerusalem

Direct systems:
(A) Passive CHS system with tank above collector.
(B) Active system with pump and controller driven by a photovoltaic panel



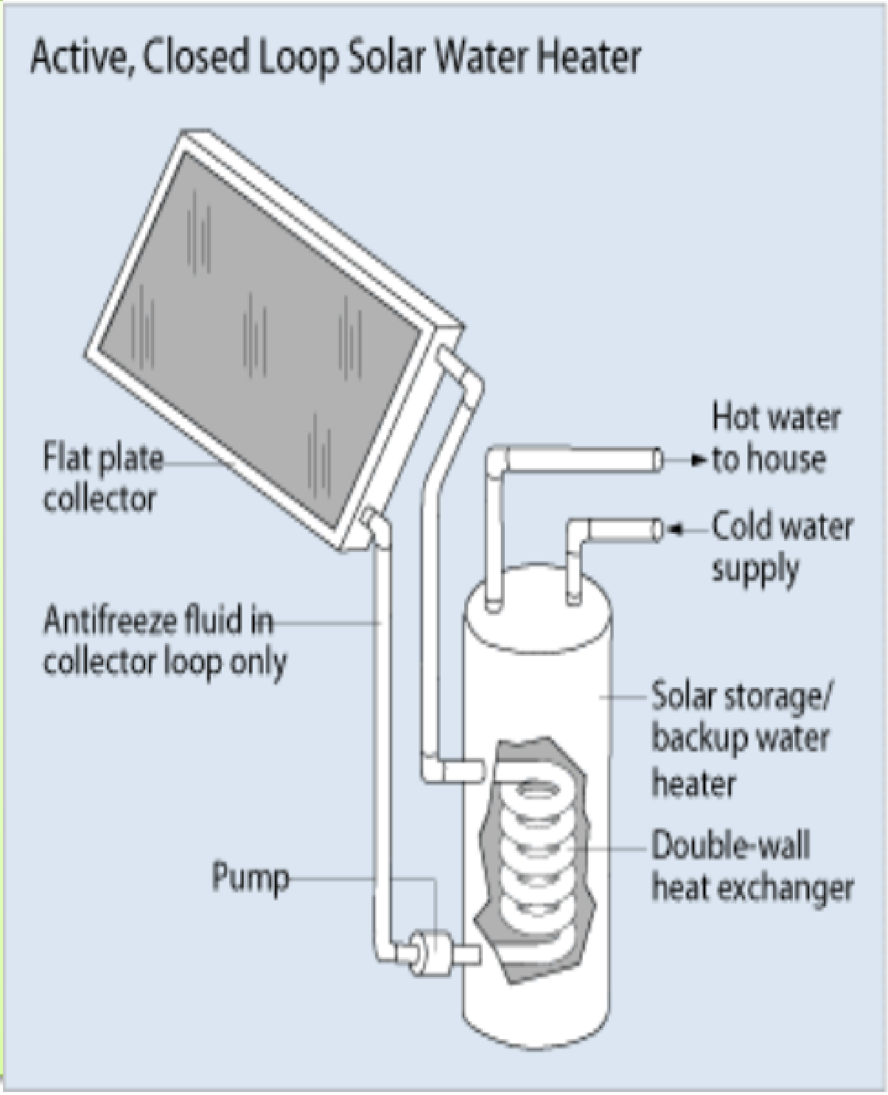
Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

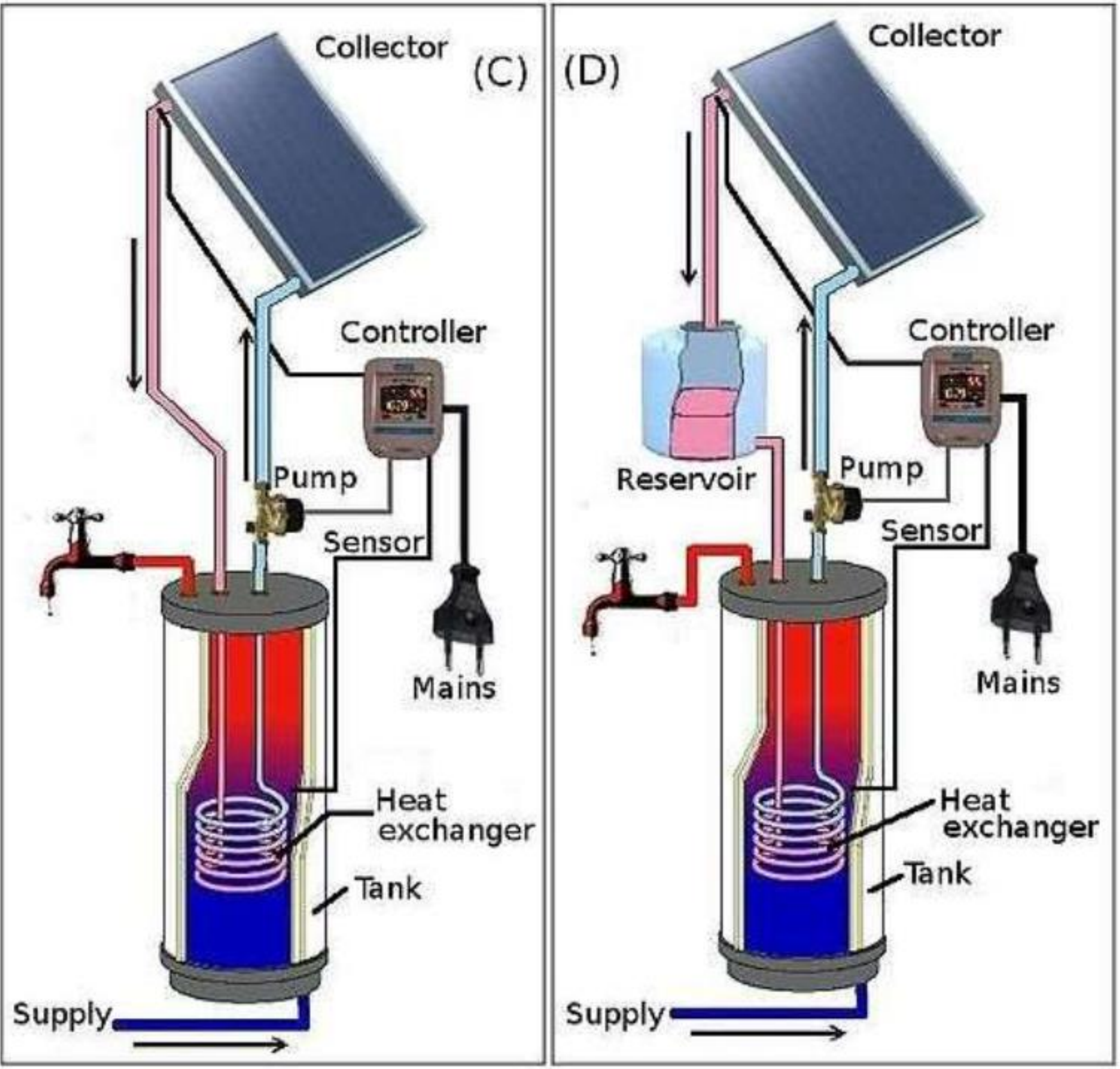


Direct Pumped System

Indirect Circulation Systems

- Pump circulates a non-freezing, heat transfer fluid through the collector(s) and a heat exchanger.
- This heats the water that then flows into the home.
- This type of system works well in climates prone to freezing temperatures.





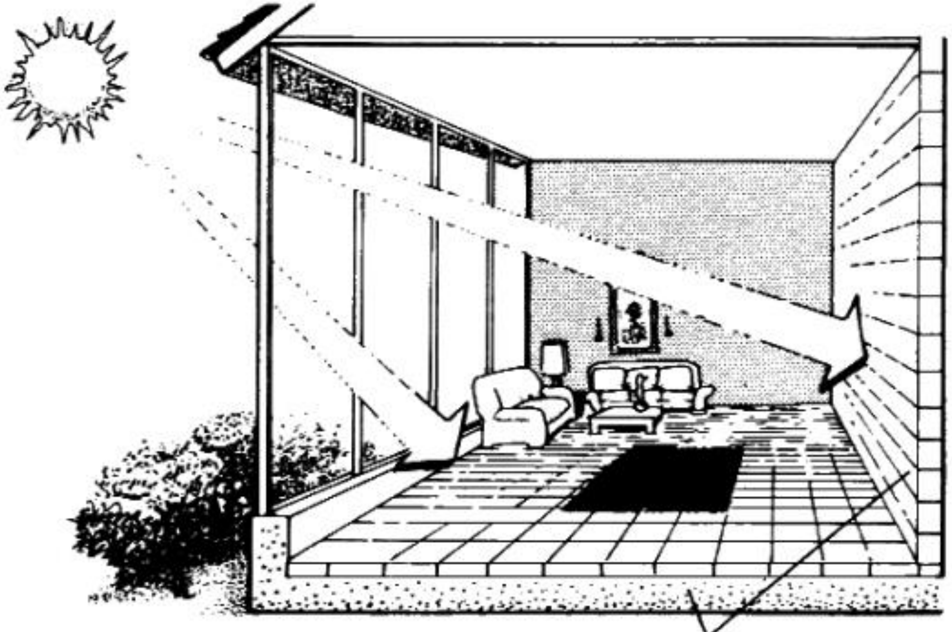
Indirect active systems: (C) Indirect system with heat exchanger in tank; (D) Drainback system with drainback reservoir. In these schematics the controller and pump are driven by mains electricity

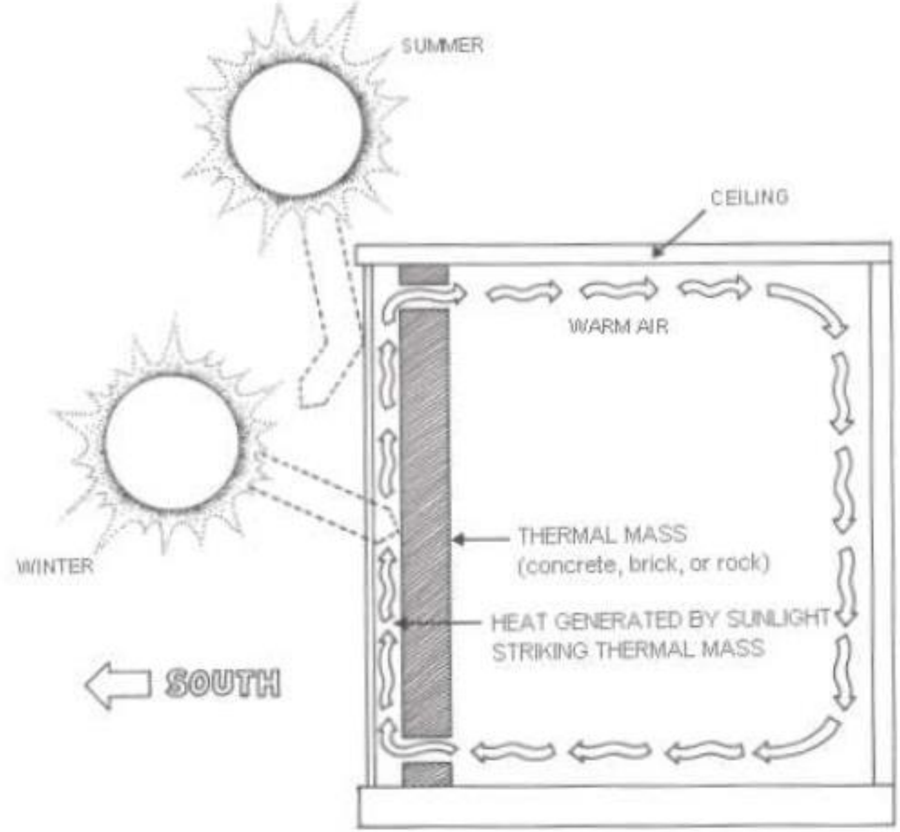
Selecting a Solar Water Heating System

- Investigate local codes, covenants, and regulations.
- Consider the economics of a solar water heating system.
- Evaluate the site's solar resource.
- Determine the correct system size.
- Estimate and compare system costs.

Application of active and passive solar thermal in building

- passive’ tends to be used when the Sun’s heat is first trapped in rooms or conservatories behind windows, even if controlled ventilation is used in the building.
- ‘Active’ tends to be used if the heat is first trapped in a purpose-built exterior collector.





Passively heated home in Colorado

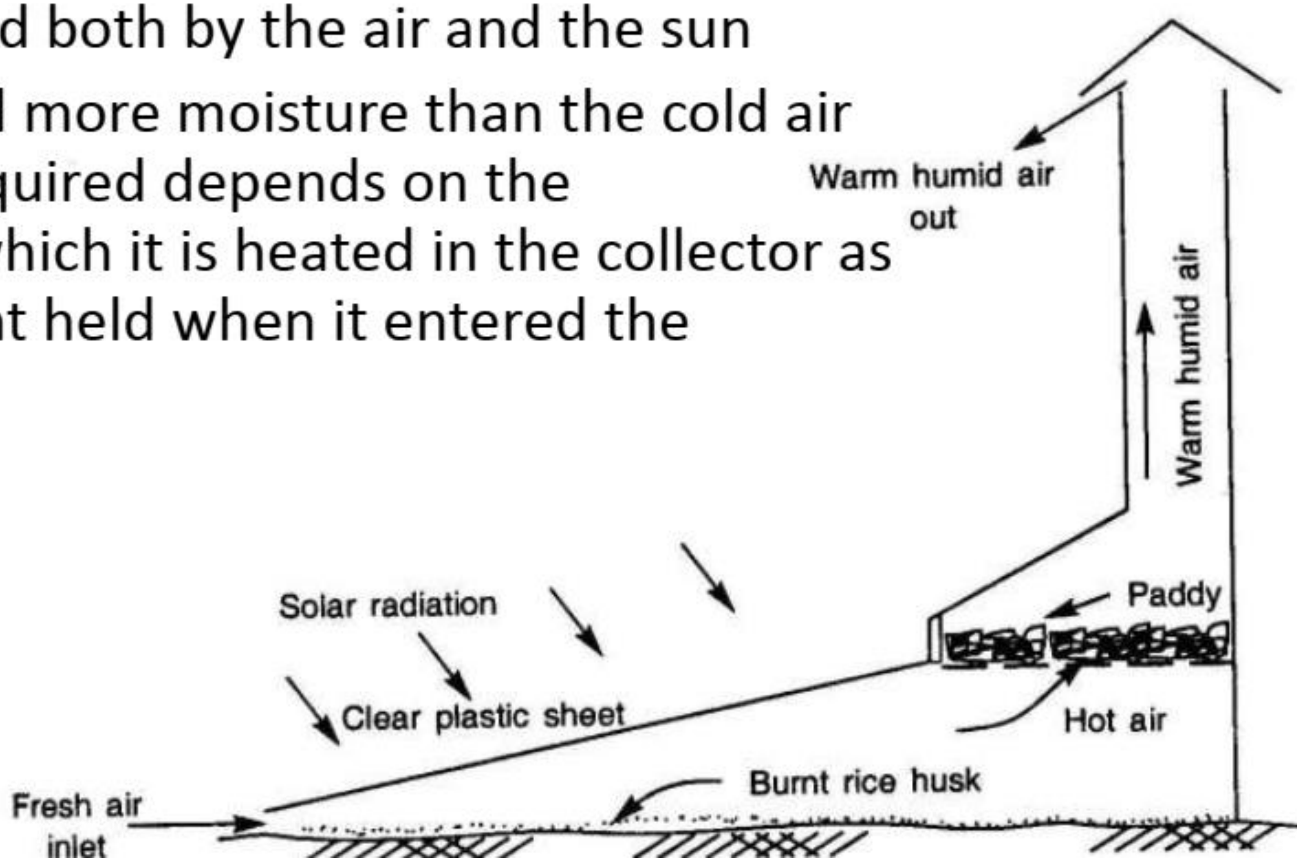
Solar Drying

Basics of Solar Drying

- Drying or dehydration of material means removal of moisture from the interior of the material to the surface and from the surface of the drying material.
- The drying of product is a complex heat and mass transfer process which depends on external parameters such as temperature, humidity and velocity of the air stream; drying material properties like surface characteristics (rough or smooth surface), chemical composition (sugar, starches, etc) physical structure (porosity. density. etc.); size and shape of the product.

Working principle

- Air is drawn through the dryer by natural circulation
- It is passed through the collector and then partially cooled as it picks up moisture from the input material
- The input is heated both by the air and the sun
- Warm air can hold more moisture than the cold air so the amount required depends on the temperature to which it is heated in the collector as well as the amount held when it entered the collector.

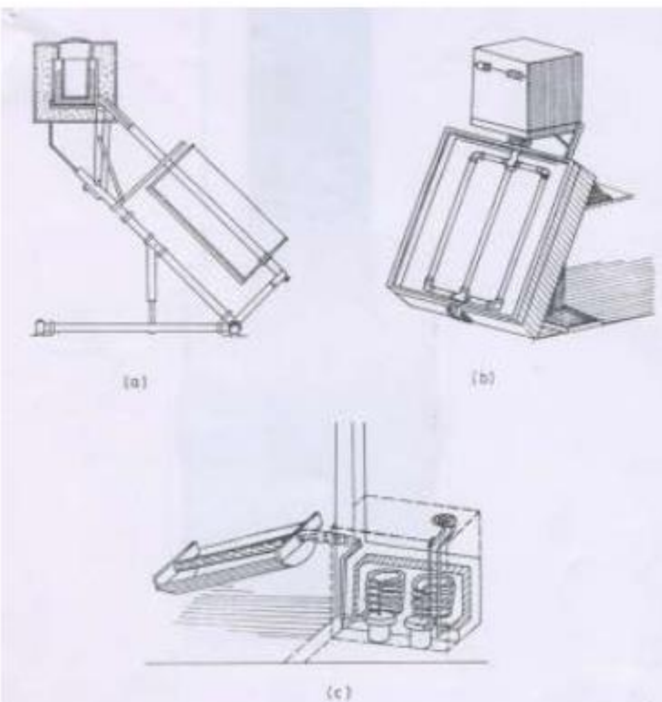


Solar cooking

Indirect or Box type Solar Cooker

•An insulated hot box (square, rectangular, cylindrical) painted black from inside and insulated from all sides except window side which is double glazed is used.

•Single plane or multiple plane reflectors are used. Some times these are also known as oven type solar cookers. These can be electrical cum solar cookers and some cookers utilize a kind of latent heat storage material.



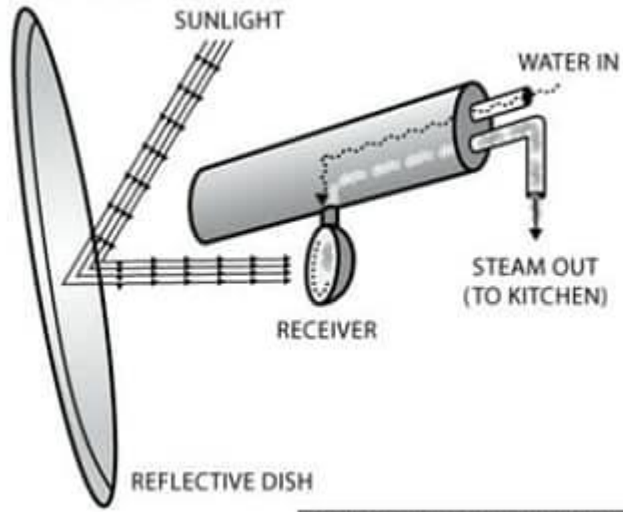
Cont..

- solar energy concentrator (parabolic, spherical, cylindrical, fresnel) is used to direct the sun rays and focus the solar radiation on a focal point or area where a cooking pot or frying pan is placed.
- In these cookers the convection heat loss from cooking vessel is large and the cooker utilizes only the direct solar radiation.

Case Study

Solar Cooking in Tirupathi (TTD)

Case Study



Solar Cooking in Tirupathi (TTD)

WORLD’S LARGEST SOLAR STEAM COOKING SYSTEM AT TIRUPATI

Solar Water Heater in Kagbeni, Mustang.

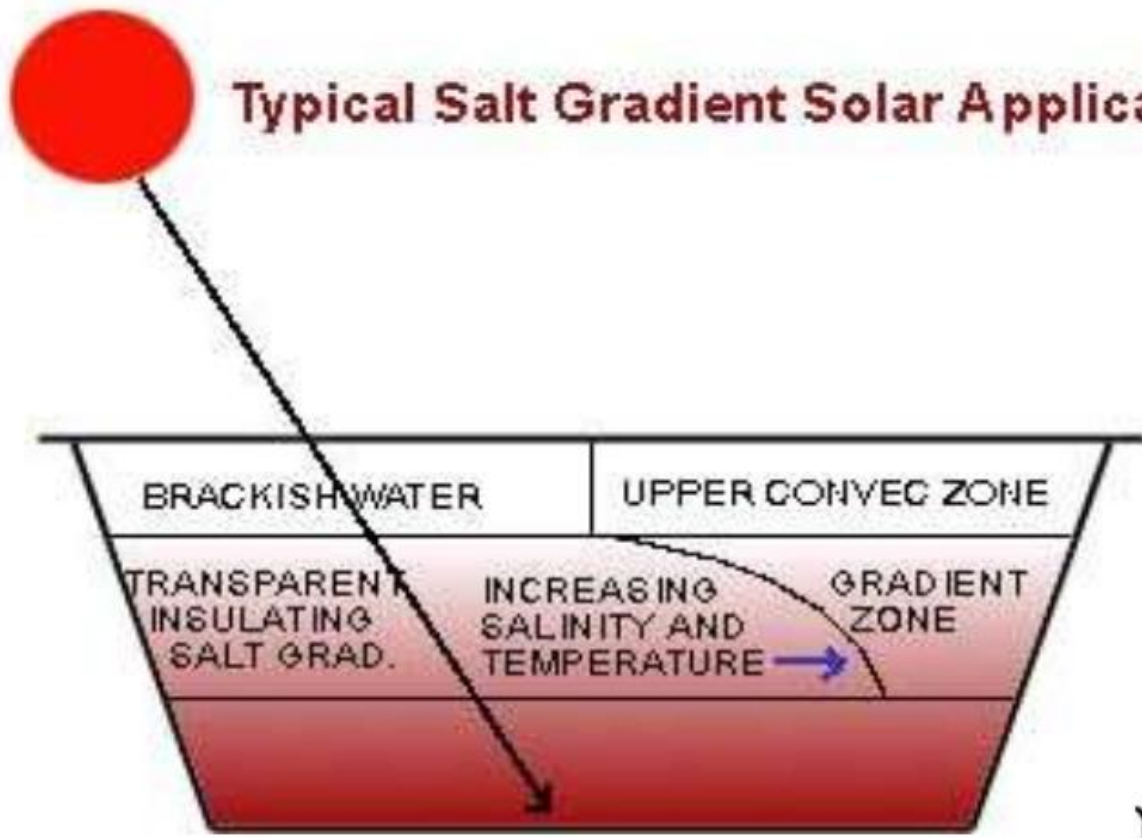
Solar Parabolic Cooker, Nepal
source :Rural Integrated Development Service (RIDS) - Nepal

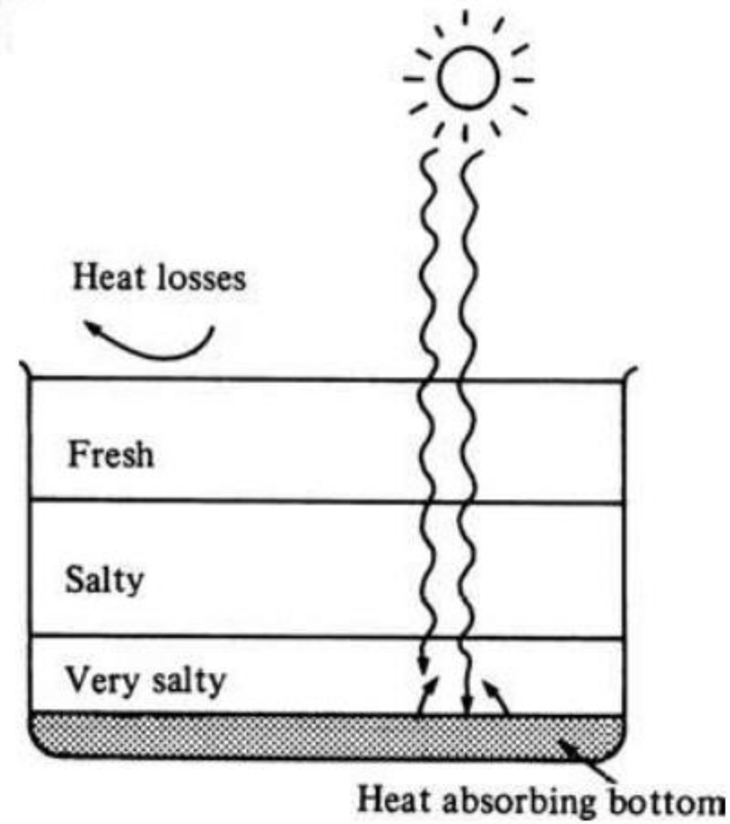
Solar drier drying cabinet with 6 drying trays

Solar pond

- A solar pond is a body of water that collects and stores solar energy.
- Solar energy warm a body of water (that is exposed to the sun), but the water loses its heat unless some method is used to trap it.
- A solar pond consists of three main layers.
  - The top layer is near ambient temperature and has a low salt content.
  - The bottom layer is hot – typically 160–212°F (71–100°C) – and is very salty.
  - The important gradient zone separates these two. The gradient zone acts as a transparent insulator, permitting sunlight to be trapped in the hot bottom layer (from which useful heat is withdrawn).

Typical Salt Gradient Solar Application





Working principle

- The solar pond works on a very simple principle.
- Water warmed by the sun expands and rises as it becomes less dense. Once it reaches the surface, the water loses its heat to the airthrough convection, or evaporates, taking heat with it. In an ordinary pond, heat loss into the atmosphere. The net result is that the pond water remains at the atmospheric temperature.
- The colder water, which is heavier, moves down to replace the warm water, creating a natural convective circulation that mixes the water and dissipates the heat.
- The design of solar ponds reduces either convection or evaporation in order to store the heat collected by the pond. They can operate in almost any climate
- The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise. Thus store the heat it absorbs.

APPLICATIONS

- **Salt production (for enhanced evaporation or purification of salt, that is production of 'vacuum quality' salt)**
- **Aquaculture, using saline or fresh water (to grow, for example, fish or brine shrimp)**
- **Dairy industry (for example, to preheat feed water to boilers)**
- **Fruit and vegetable canning industry**
  - **Fruit and vegetable drying (for example, vine fruit drying)**
  - **Grain industry (for grain drying)**
- **Water supply (for desalination)**

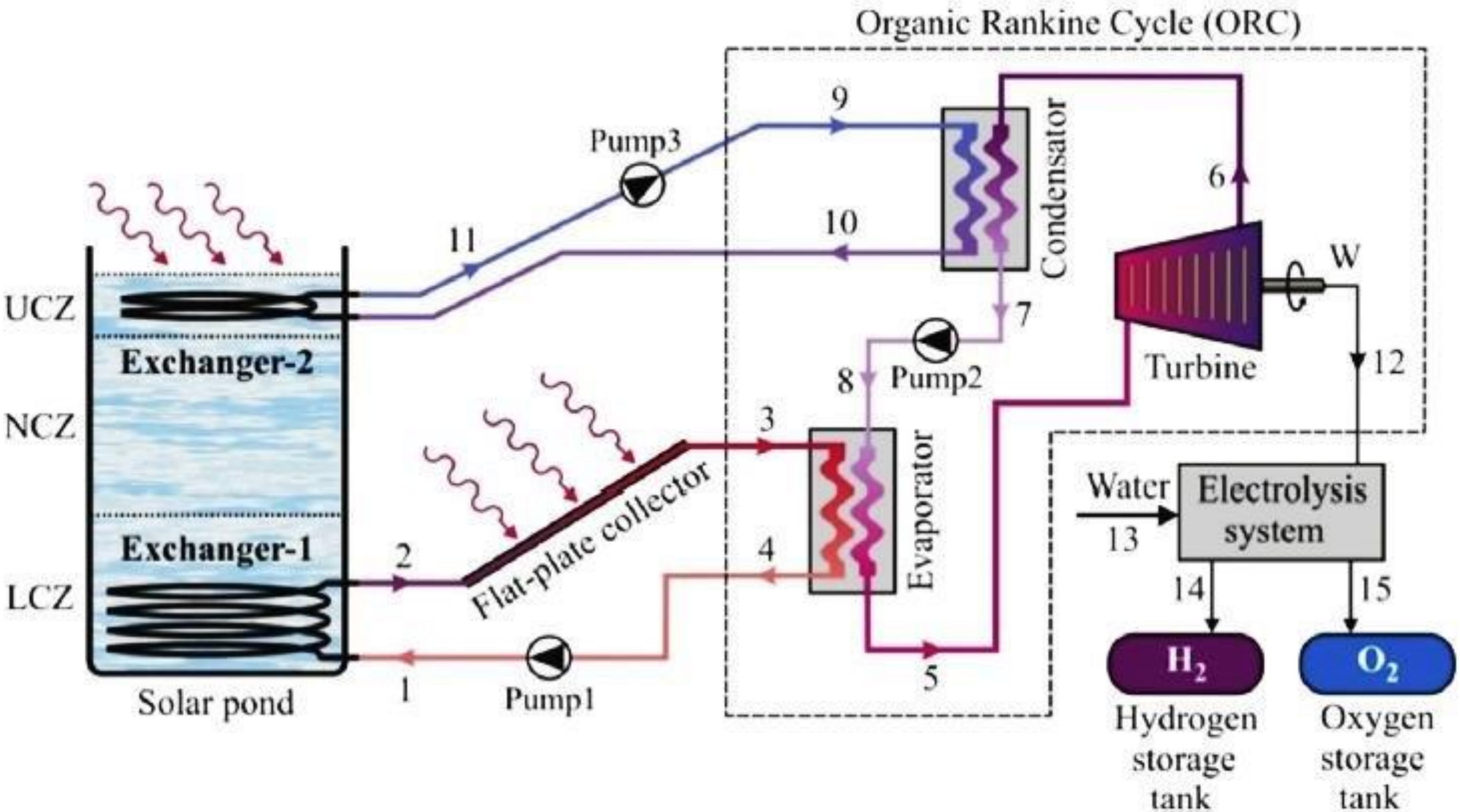
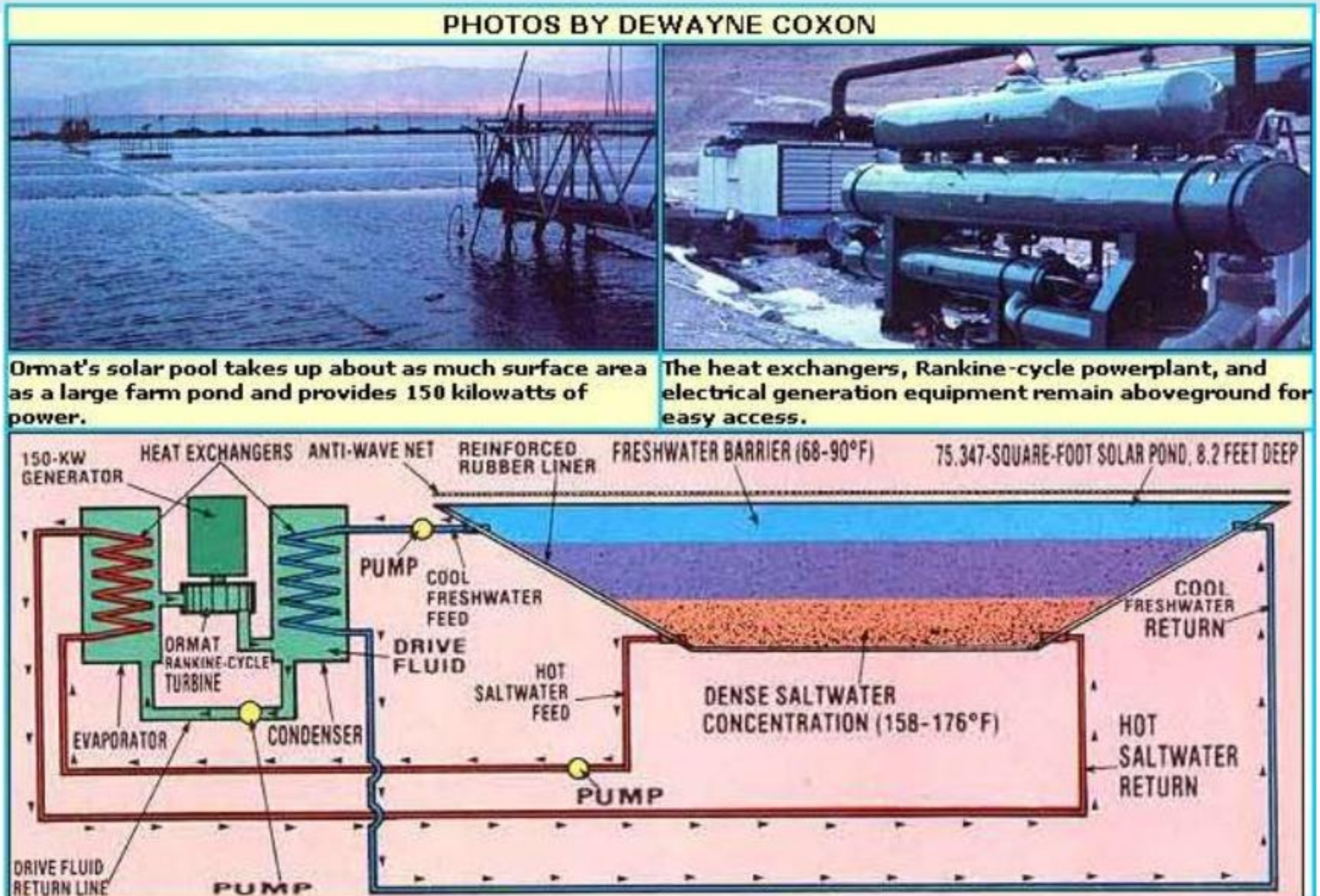


Fig: Electricity Generation Using Solar Pond

There are two main categories of solar ponds:

- nonconvecting ponds, which reduce heat loss by preventing convection from occurring within the pond;
- and convecting ponds, which reduce heat loss by hindering evaporation with a cover over the surface of the pond



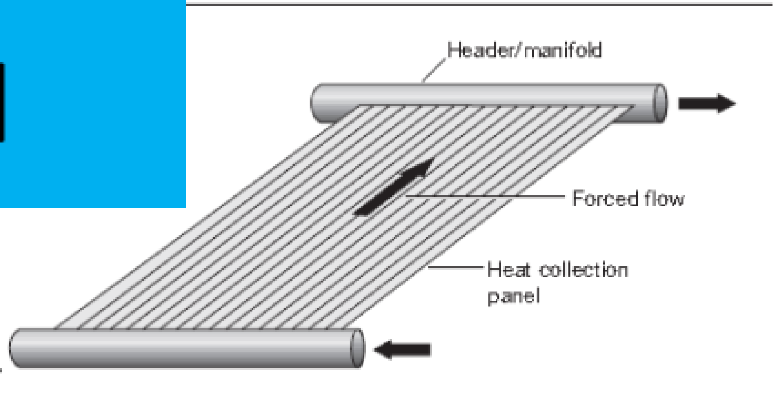
Ormat's solar pool takes up about as much surface area as a large farm pond and provides 150 kilowatts of power.

The heat exchangers, Rankine-cycle powerplant, and electrical generation equipment remain aboveground for easy access.

Bhuj solar pond, Gujarat

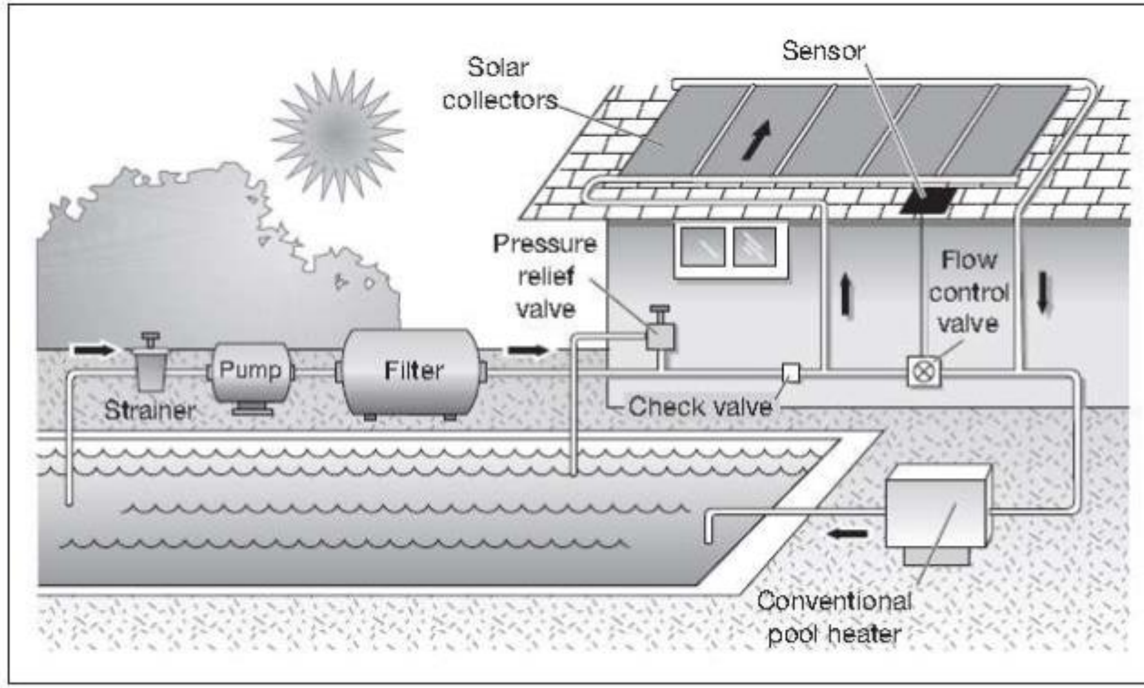
El paso, Texas ,US

solar swimming pool

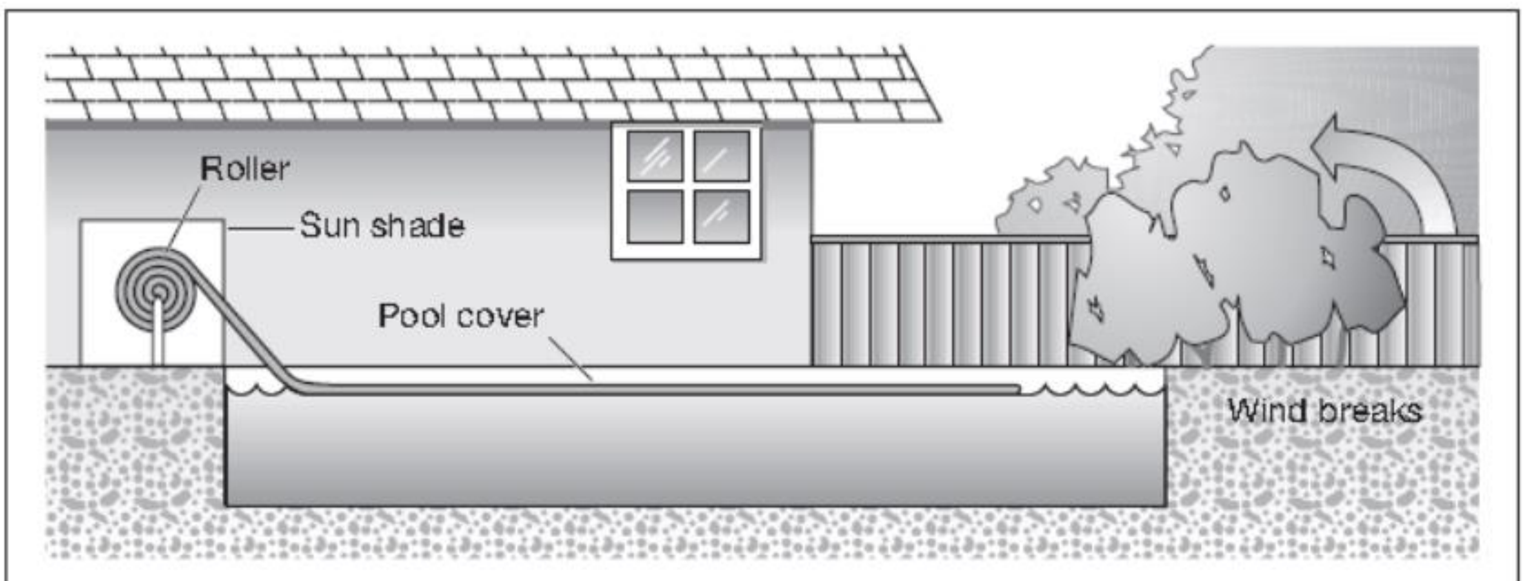


PICAL POOL COLLECTOR *Square footage depends on several factors,*
:h as the size of the pool and the desired water temperature.

- A typical solar pool heater consists of a collector made of plastic panels.
- The panels have tubes (called headers) on the top and bottom of the panel
- The headers are connected by many small tubes through which water flows and gets heated by the sun.
- The size of a collector needed for a swimming pool depends on several factors including the size of the pool, climate, desired water temperature wind conditions, how shaded the pool is and how often the pool will be used.
- Normally, the total area (square footage) of the solar collector will be at least half of the pool surface area.
- Collectors should face south and be tilted at an angle equal to the latitude of the pool's location minus 10 to 15 degrees.
- Pool collectors can either be mounted on the roof of a building or mounted on a frame on the ground near the pool.



SOLAR WATER HEATER SYSTEM *Solar collectors become part of the existing system.*



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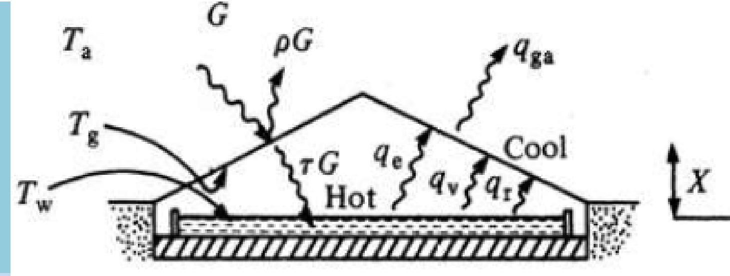
Solar still

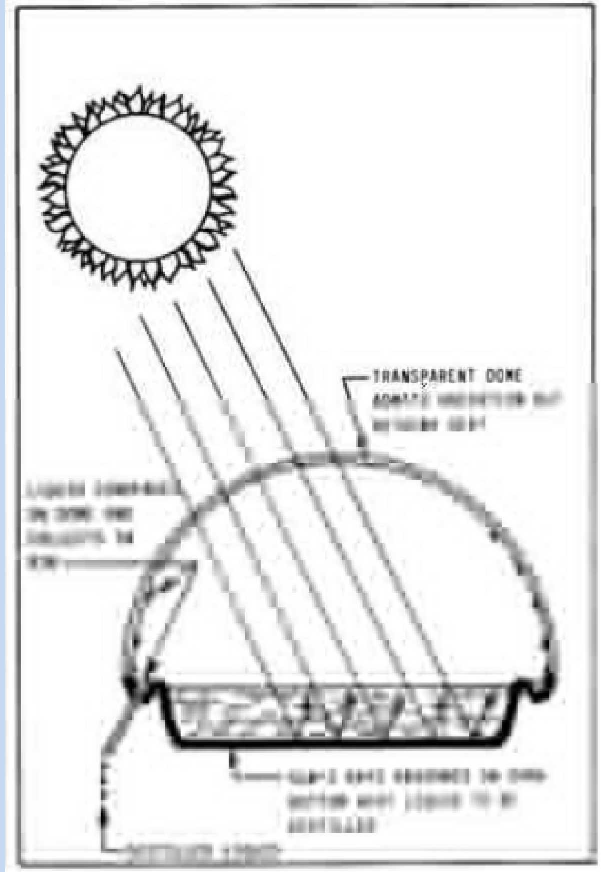


- To distill fresh water from sea water.
- Can easily distill alcohol

- It consists of internally blackened basin containing a shallow depth of impure water.
- A transparent, vapour-tight cover completely encloses the space above the basin.
- The cover is sloped towards the collection channel.

Working principle

- The sun's rays pass freely through the transparent dome and are absorbed by the dark bottom of the still
- The Liquid in the bottom of the still is heated.
- The water vapour diffuses and moves convectively upwards, where it condenses on the cooler cover.
- The condensed drops of water then slide down the cover into the catchment trough.
- The distilled liquid collects in the trough around the rim and is collected through the attached tube.

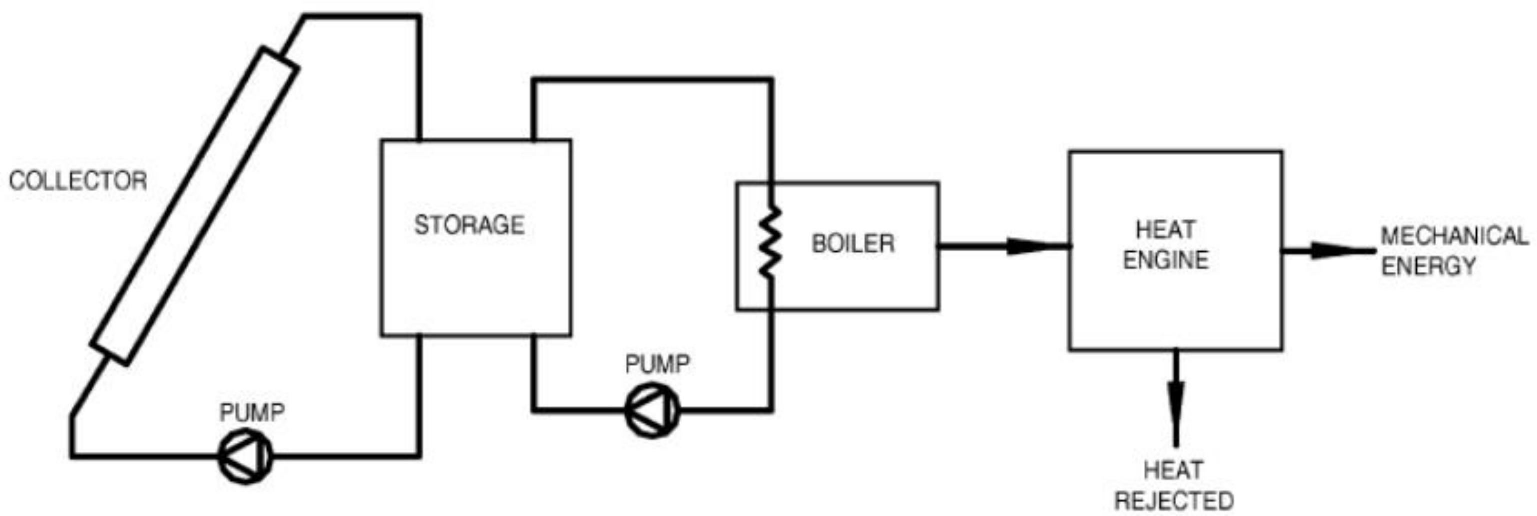


Solar thermal power systems

- Conversion of solar to mechanical and electrical energy has been the objective of experiments for more than a century
- The idea is to use concentrating collectors to produce and supply steam to heat engines
- This section is concerned with generation of mechanical and electrical energy from solar energy by processes based mainly on concentrating collectors and heat engines.

Cont...

The basic process for conversion of solar to mechanical energy is shown schematically. Energy is collected by concentrating collectors, stored and used to operate a heat engine.



Schematic of a solar-thermal conversion system.

High Altitude Solar Hot Water System, Nepal

Power tower in Barstow, California

Power tower

Indian CSP project development

California

Application of Solar Energy

- Solar photovoltaic cells
- Heating and cooling of residential building.
- Solar water heating
- Solar drying of agricultural and animal products
- Solar distillation on a small community scale.
- Salt production by evaporation of seawater or inland brines.
- Solar cookers
- Solar engines for water pumping

Application of Solar Energy contd…

- Food refrigeration
- Bio conversion and wind energy, which are indirect sources of solar energy
- Solar furnace
- Solar electric power generation
- Solar pond
- Steam generation heated by rotating reflectors
- Reflectors with lenses and pipes for fluid circulations