ALMUSTAQBAL UNIVERSITY COLLEGE
Iraq - Babylon

RENEWABLE ENERGY TECHNOLOGY

Sustainable Path For a Carbon Free Future

Subject : Renewable Energy

Grade: 4th Class

Lecture :5

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SOLAR THERMAL TECHNOLOGIES

- Solar thermal is the oldest solar energy technology – has been used for centuries
- Solar thermal technologies can be divided in three types:
  - ✓ Passive solar building design
  - ✓ Thermal collectors for water heating, space heating and other uses
  - ✓ Solar thermal power plants

Solar Energy Collectors

Solar energy collectors are special kinds of heat exchangers that transform solar radiation energy to internal energy of the transport medium. This is a device that absorbs the incoming solar radiation, converts it into heat, and transfers the heat to a fluid (usually air, water, or oil) flowing through the collector.

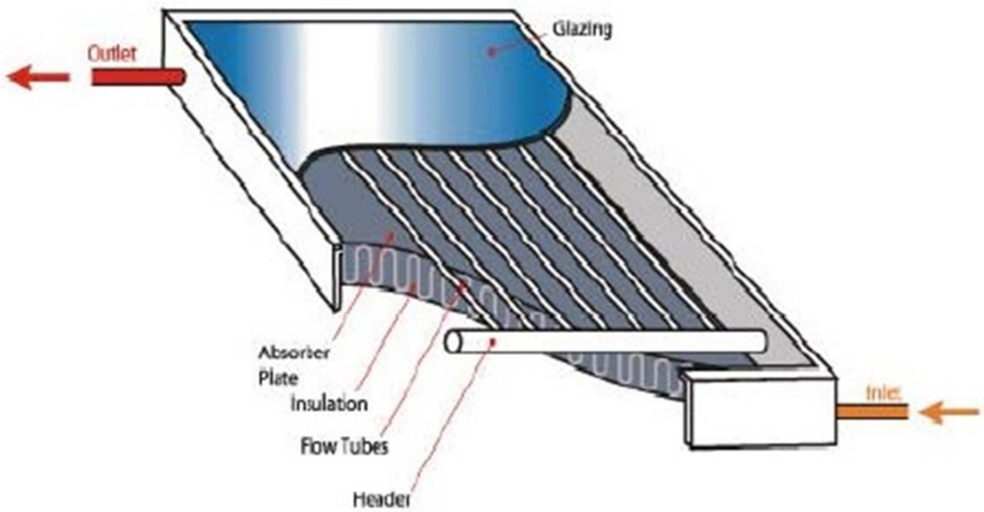
There are basically two types of solar collectors:

1. **Non-concentrating (or stationary)**
2. **Concentrating.**

A large number of solar collectors are available on the market. A comprehensive list is shown in Table 4.1

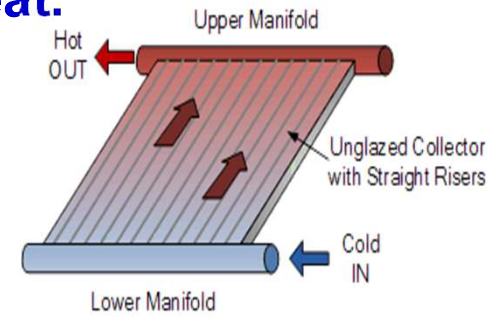
Solar Energy Collectors

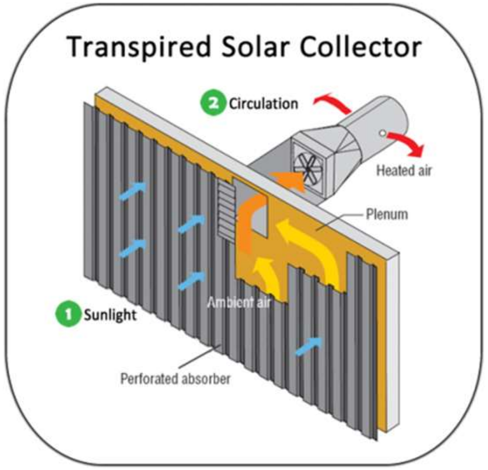
- Flat-plate solar collector absorbs sunlight and transfer the heat to water or a mixture of anti-freeze and water
- The hot fluid can be used directly or indirectly for hot water and space heating
- Generally used for low temperature applications like residential hot water heating



Solar Energy Collectors

- **Solar thermal collectors can be categorized by the temperature at which they efficiently deliver heat.**
  - **Low-temperature collectors:**
    - Unglazed mats for water heating.
    - Perforated plates for air preheating.
  - **Mid-temperature collectors:**
    - Glazed and insulated collectors.
  - **High-temperature collectors:**
    - Evacuated tubes.
    - Focusing collectors.





Solar Energy Collectors

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (°C)
Stationary	Flat-plate collector (FPC)	Flat	1	30–80
	Evacuated tube collector (ETC)	Flat	1	50–200
	Compound parabolic collector (CPC)	Tubular	1–5	60–240
Single-axis tracking			5–15	60–300
	Linear Fresnel reflector (LFR)	Tubular	10–40	60–250
	Cylindrical trough collector (CTC)	Tubular	15–50	60–300
	Parabolic trough collector (PTC)	Tubular	10–85	60–400
Two-axis tracking	Parabolic dish reflector (PDR)	Point	600–2000	100–1500
	Heliostat field collector (HFC)	Point	300–1500	150–2000

Note: Concentration ratio is defined as the aperture area divided by the receiver/absorber area of the collector.

3.1 Stationary collectors

Three main types of collectors fall into this category
1. Flat-plate collectors (FPCs).
2. Stationary compound parabolic collectors (CPCs).
3. Evacuated tube collectors (ETCs).

3.1.1 Flat-Plate Collectors (FPCs)

Flat-plate collectors (FPCs) are by far the most-used type of collector. Flat – plate collectors are usually employed for low-temperature applications, up to 80ºC, although some new types of collectors employing vacuum insulation or transparent insulation (TI) can achieve slightly higher values.

3.1.1 Flat-Plate Collectors (FPCs

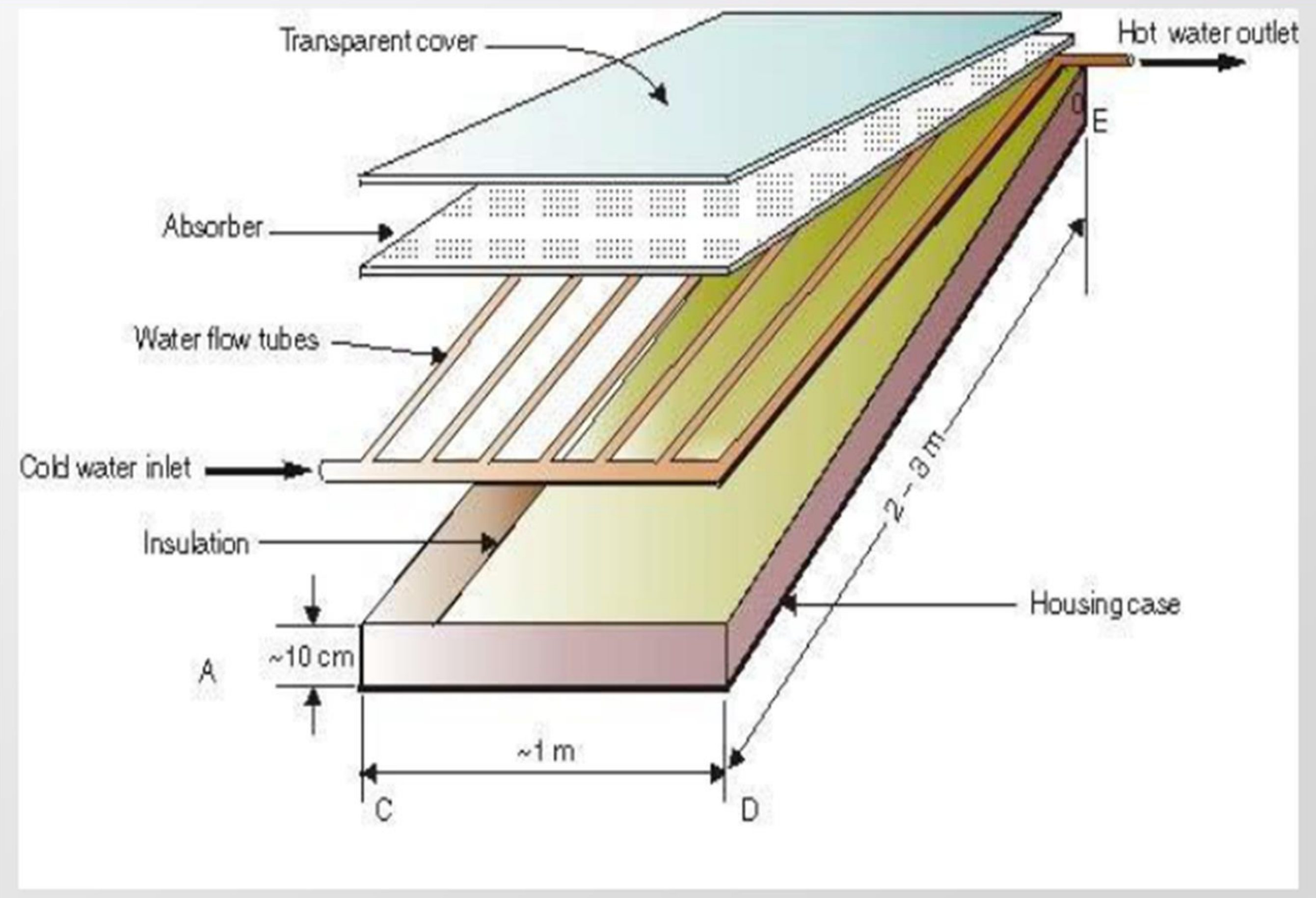


Figure 3.1 liquid flat-plate collector

3.1.1 Flat-Plate Collectors (FPCs

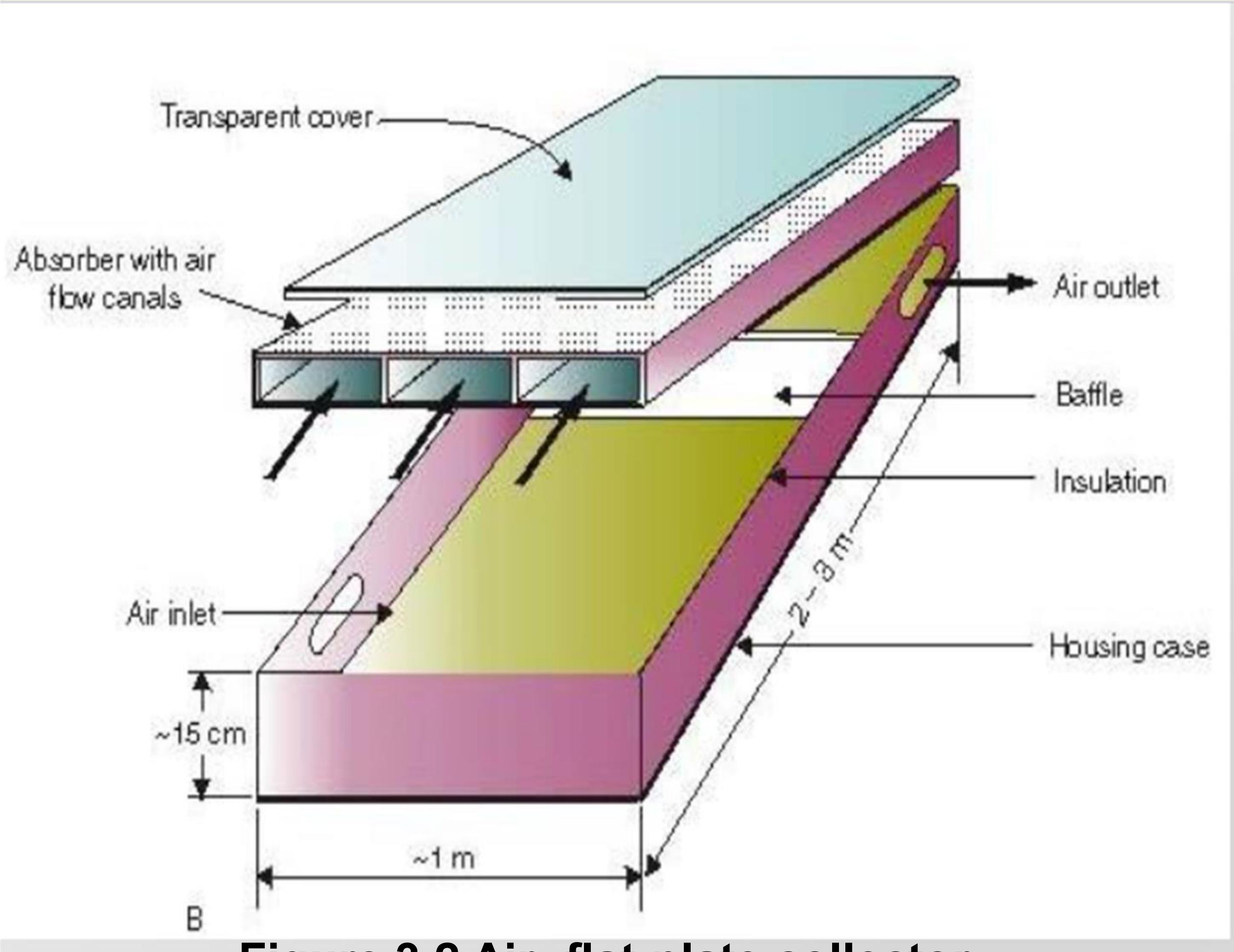
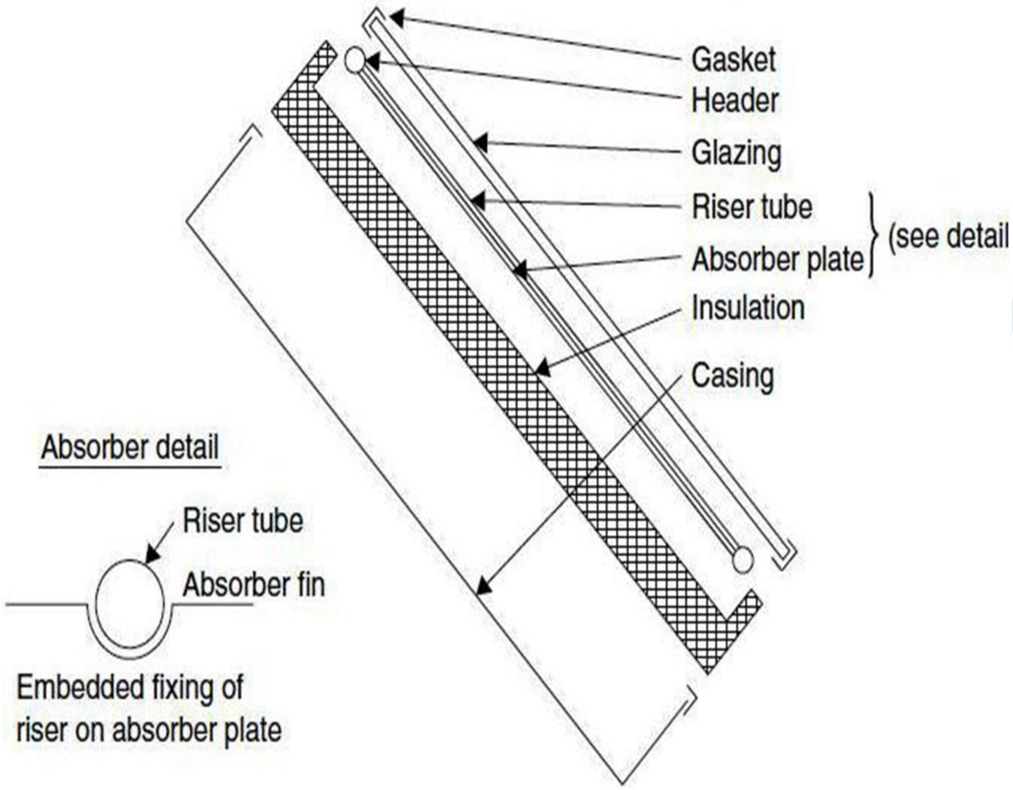


Figure 3.2 Air- flat-plate collector

3.1.1 Flat-Plate Collectors (FPCs



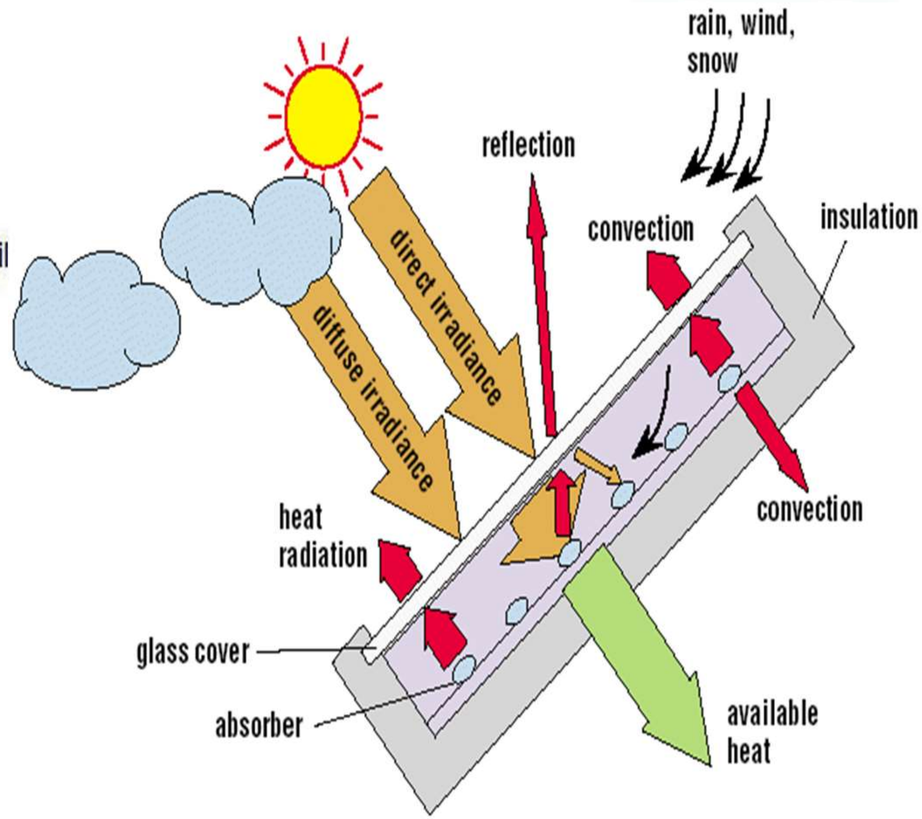


Figure 3.3 Exploded view of a flat-plate collector and absorber details

3.1.1 Flat-Plate Collectors (FPCs

Components of a typical flat plate collector

- **Absorber plate :** It is usually made of copper , steel or plastic . The surface is covered with a flat black material of high absorption .

- **Flow passage :** The flow passages conduct the working fluid through the collector . If the working fluid is a liquid , the flow passage is usually a tube that is attached to or is a part of absorber plate **.**

- **cover plate :** To reduce convective and radiative heat losses from the absorber , one or two transparent covers are generally placed above the absorber plate . They usually be made from glass or plastic .

- **Insulation :** These are some materials such as fiberglass and they are placed at the back and sides of the collector to reduce heat losses **.**

3.1.1 Flat-Plate Collectors (FPCs

Components of a typical flat plate collector

- **Enclosure :** A box that the collector is enclosed in holds the components together, protect them from weather, facilitates installation of the collector on a roof or appropriate frame **.**

Figure 3.4 shows a number of absorber plate designs for solar water and air heaters that have been used with varying degrees of success. Figure 3.4a shows a bonded sheet design, in which the fluid passages are integral to the plate to ensure good thermal conduct between the metal and the fluid. Figures 3.4b and 3.4c show fluid heaters with tubes soldered, brazed, or otherwise fastened to upper or lower surfaces of sheets or strips of copper (see also the details in Figure 3.3). Copper tubes are used most often because of their superior resistance to corrosion.

3.1.1 Flat-Plate Collectors (FPCs

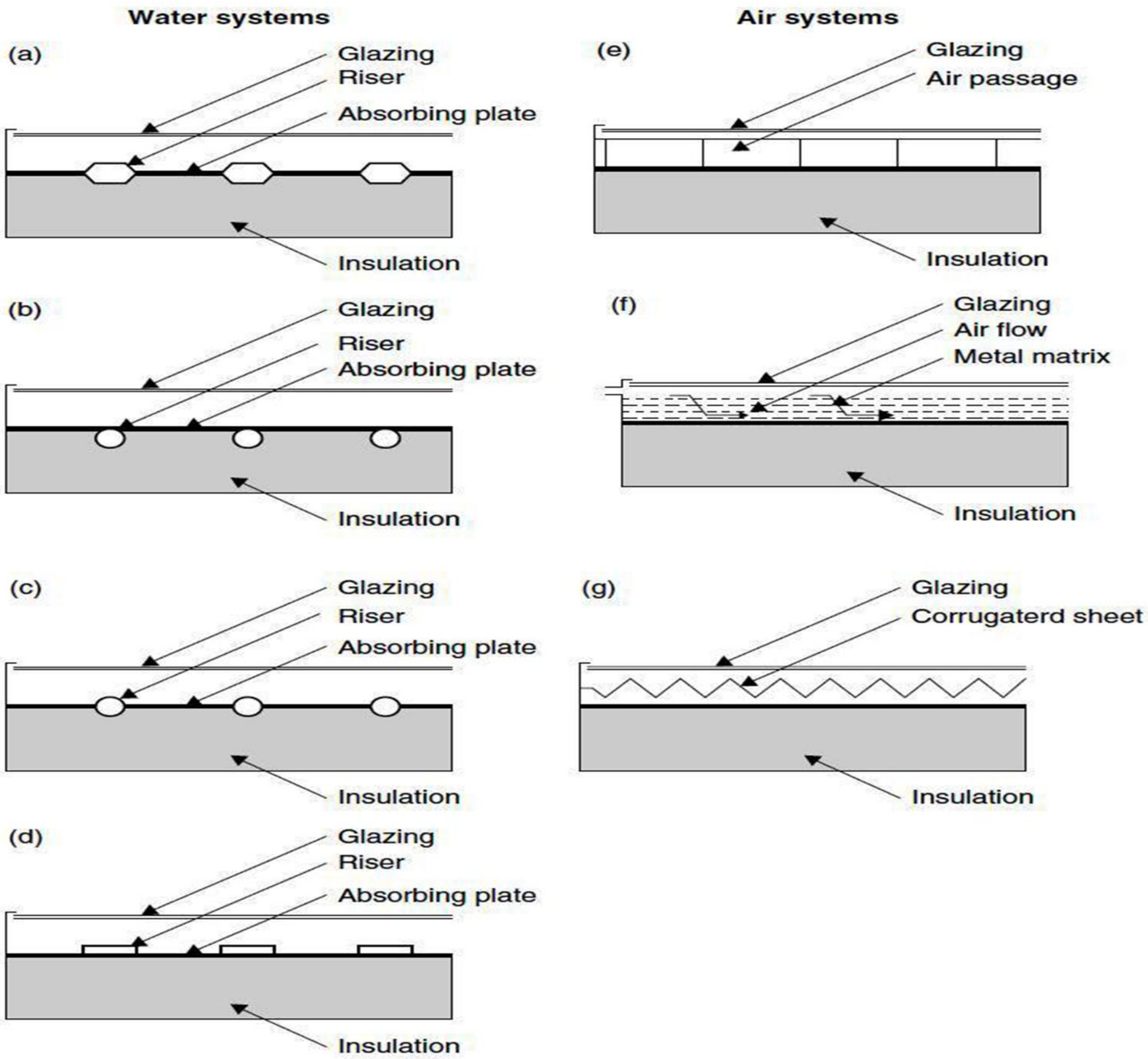
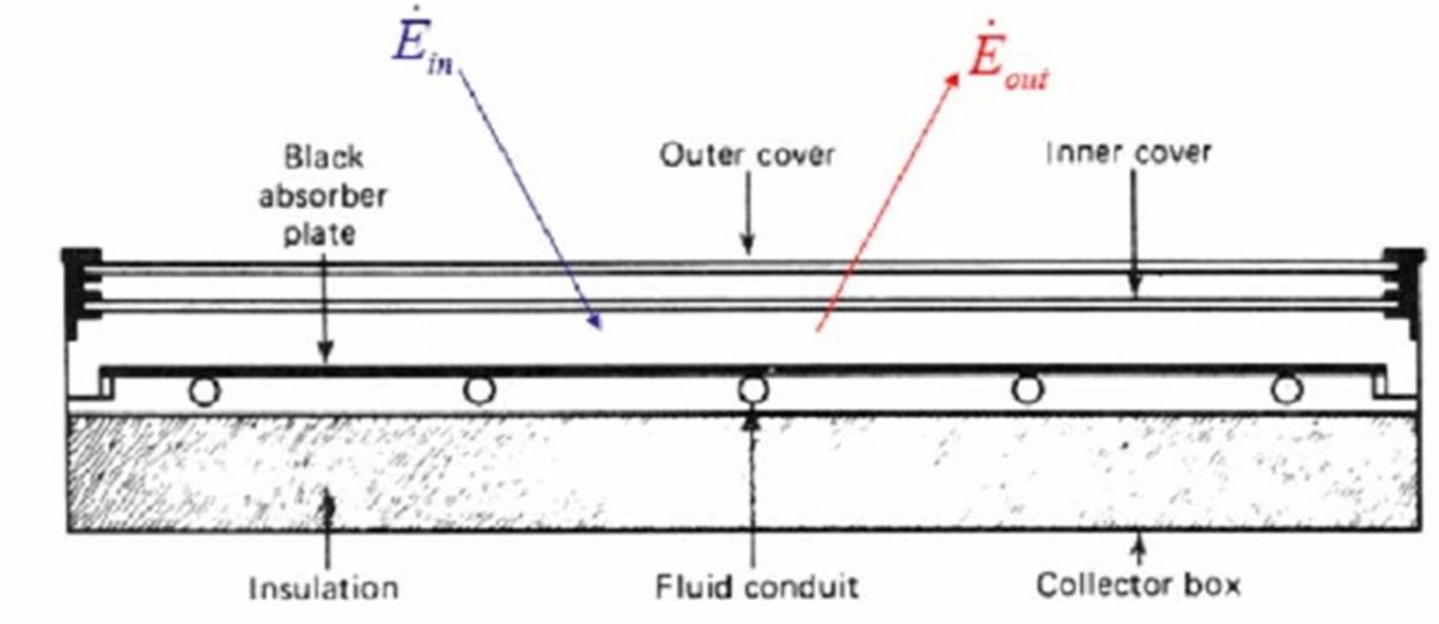


Figure 3.4 Various types of flat-plate solar collector absorber configurations for water and air.

Flat Plate Solar Collectors Performance



$$\text{Collector efficiency}, \eta = \frac{\text{Useful energy gain}}{\text{Solar radiation incident on collector}} = \frac{Q_u}{A_c I_T}$$

A_c = Collector area

I_T = Incident solar radiation on collector (kW/m^2)

Flat Plate Solar Collectors Performance

$$Q_u = \dot{E}_{in} - \dot{E}_{out} = F_R A_c \left[\alpha \tau I_T - U_L (T_{f,o} - T_a) \right]$$

F_R = Collector efficiency factor

α = Absorptivity of collector

τ = Transmissivity of glass cover

U_L = Overall loss coefficient

$T_{f,o}$ = Temperature of fluid in the tubes

T_a = Ambient temperature

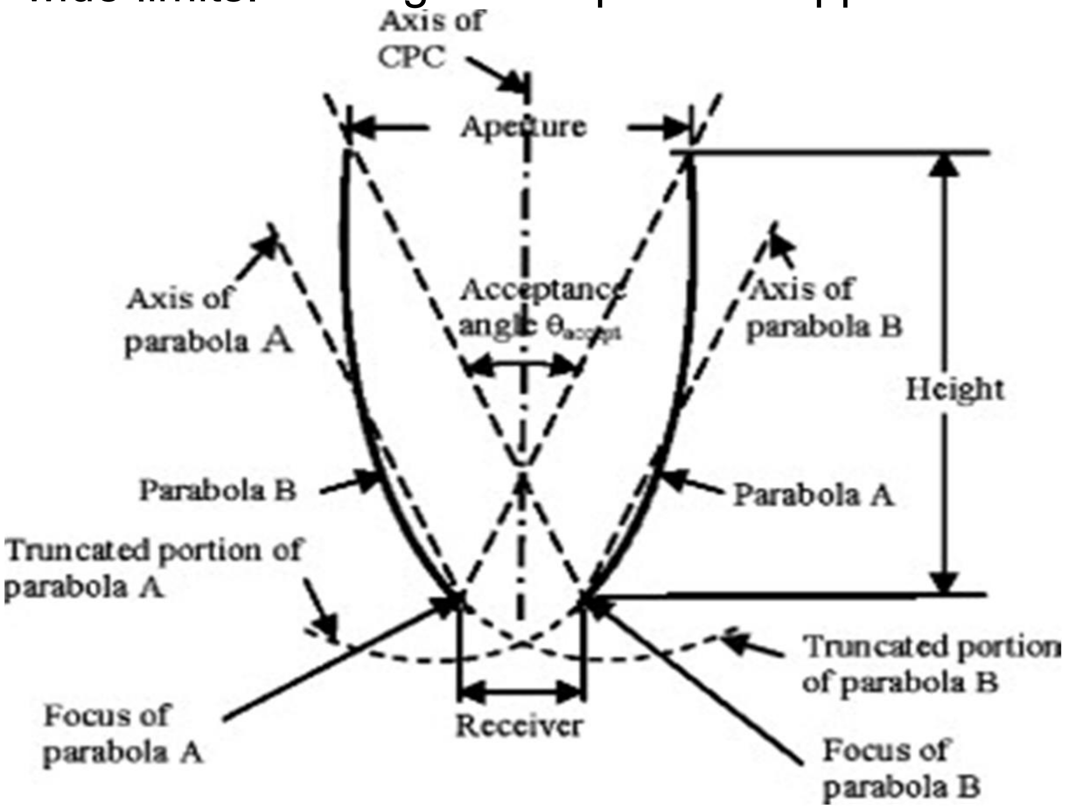
Flat Plate Solar Collectors Performance

$$\eta = \frac{Q_u}{A_c I_T} = \left[F_R(\tau\alpha) - F_R U_L \frac{\left(T_{f,o} - T_a\right)}{I_T} \right]$$

$$\text{Concentration Ratio} = \frac{\text{kW/m}^2 \text{ insolar radiation on surface}}{\text{kW/m}^2 \text{ on surface of focus of collector}}$$

3.1.2 Compound Parabolic Collectors (CPCs)

Compound parabolic collectors (CPCs) are non-imaging concentrators. They have the capability of reflecting to the absorber all of the incident radiation within wide limits. For higher-temperature applications a tracking CPC can be used



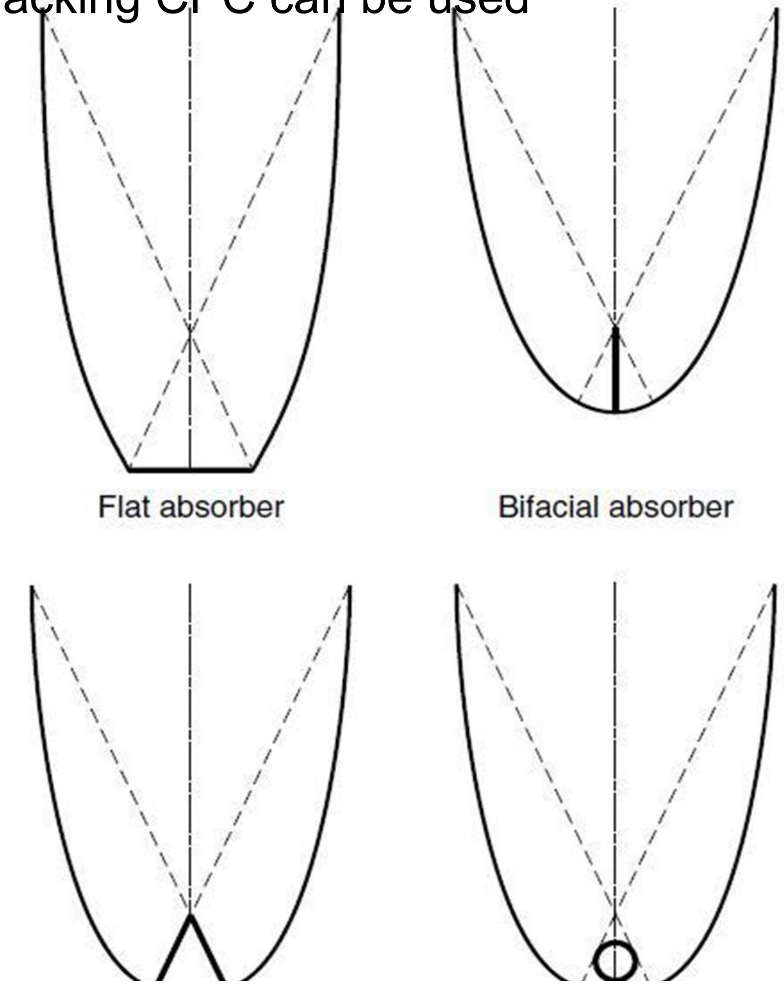


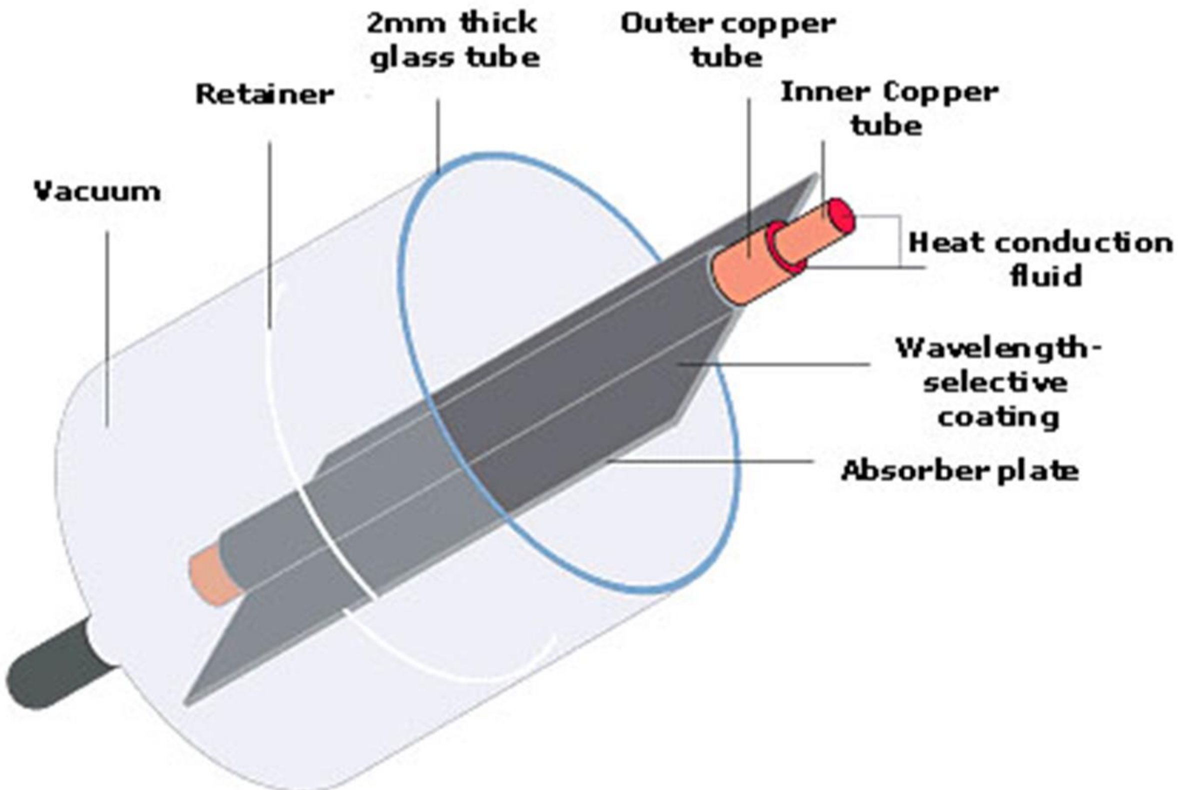
Figure 3.5 Various absorber types of CPCs

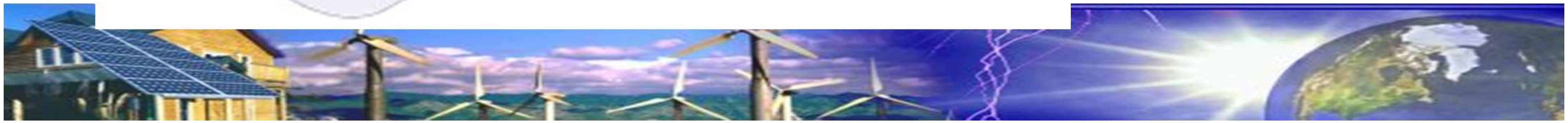
3.1.3 Evacuated Tube Solar Thermal Collectors

- Evacuated tube collectors use a “thermos bottle” type of collector that prevent freezing and can achieve higher temperatures
- Used when large volumes high temperature water are needed like commercial laundries, hotels and hospitals

3.1.3 Evacuated Tube Solar Thermal Collectors

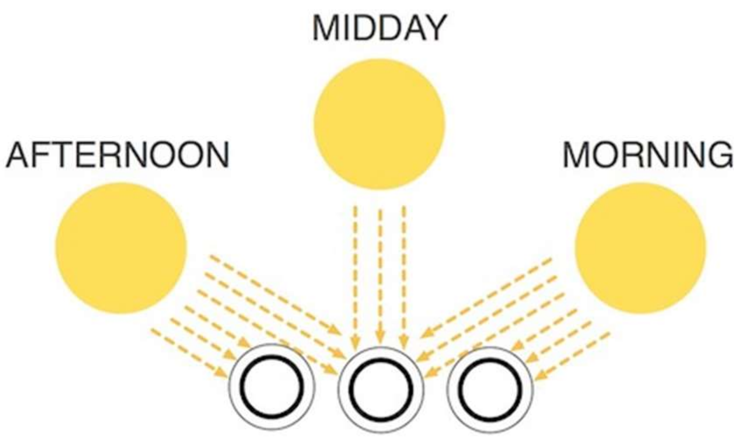
The vacuum space in the evacuated tube greatly reduces heat loss. This greatly increases the conversion efficiency at higher water temperatures or when the outside temperature is very cold.

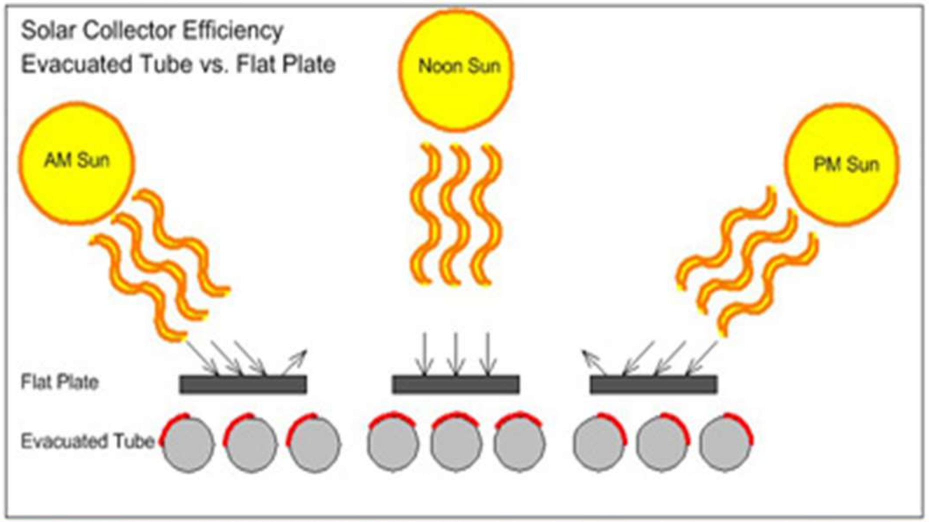




EVACUATED TUBE EFFICIENCY

- **Passive Tracking** : The round absorber surface of the evacuated tubes passively track the sun throughout the day, so no mechanical tracking device is required. This allows optimum surface area exposure from 7am to 5pm which covers the majority of the solar radiation each day.





3.2 Sun-tracking concentrating collectors

Concentrating, or focusing, collectors intercept direct radiation over a large area and focus it onto a small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorption surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that constantly orients the collectors toward the sun and keeps the absorber at the point of focus. Therefore; there are many types of concentrating collectors

3.2 Sun-tracking concentrating collectors

advantages	disadvantage
1- The working fluid can achieve higher temperatures in a concentrator system than a flat-plate system of the same solar energy-collecting surface. 2-It is possible to achieve a thermodynamic match between temperature level and task. 3- high thermal efficiency because of the small heat loss area. 4- Reflecting surfaces require less material and are structurally simpler than flat-plate collectors. 5- Owing to the relatively small area of receiver per unit of collected solar energy, selective surface treatment and vacuum insulation to reduce heat losses and improve the collector efficiency are economically viable.	1- Concentrator systems collect little diffuse radiation, depending on the concentration ratio. 2. Some form of tracking system is required to enable the collector to follow the sun. 3. Solar reflecting surfaces may lose their reflectance with time and may require periodic cleaning and refurbishing.

Types of concentrating collectors

There are four basic types of concentrating collectors:

- **Parabolic Trough Collectors (PTCs)**
- **Parabolic Dish Reflectors (PDRs)**
- **Heliostat Field Collectors (HFCs)**

3.2.1Parabolic trough system

- Parabolic troughs are devices that are shaped like the letter “u”. The troughs concentrate sunlight onto a receiver tube that is positioned along the focal line of the trough. Sometimes a transparent glass tube envelops the receiver tube to reduce heat loss.

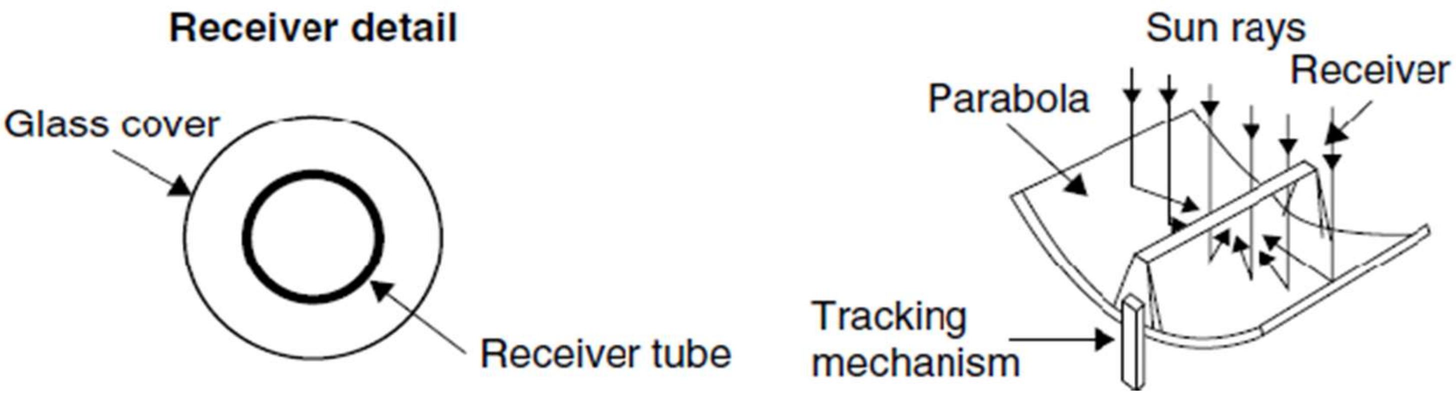


Figure 3.6 Schematic of Parabolic trough system .

3.2.1Parabolic trough system

- Parabolic troughs often use single-axis or dual-axis tracking.
- PTCs can effectively produce heat at temperatures between 50ºC and 400ºC
- Cost projections for trough technology are higher than those for power towers and dish/engine systems due in large part to the lower solar concentration and hence lower temperatures and efficiency.However with long operating experience, continued technology improvements, and operating and maintenance cost reductions, troughs are the least expensive, most reliable solar thermal power production technology for near-term .

3.2.2 Parabolic Dish Reflectors (PDRs)

- A parabolic dish collector is similar in appearance to a large satellite dish, but has mirror-like reflectors and an absorber at the focal point. It uses a dual axis sun tracker .

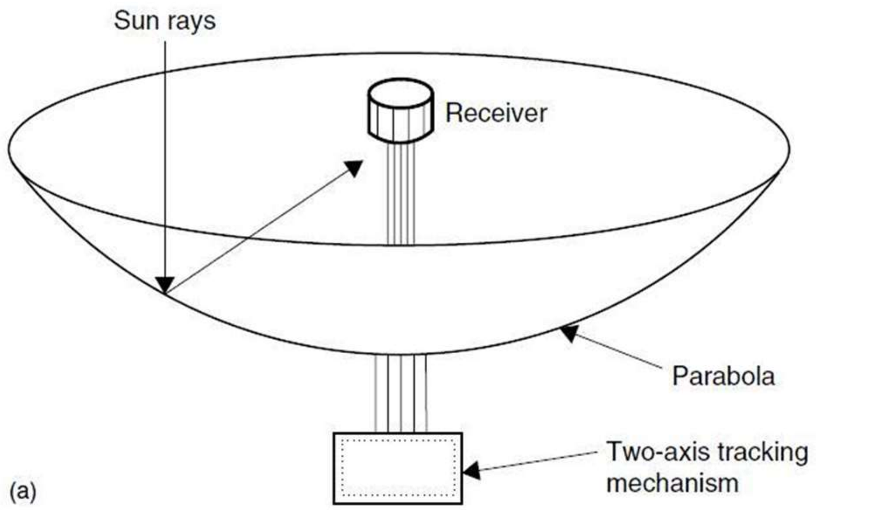


Figure 3.7 Crossection of parabolic dish

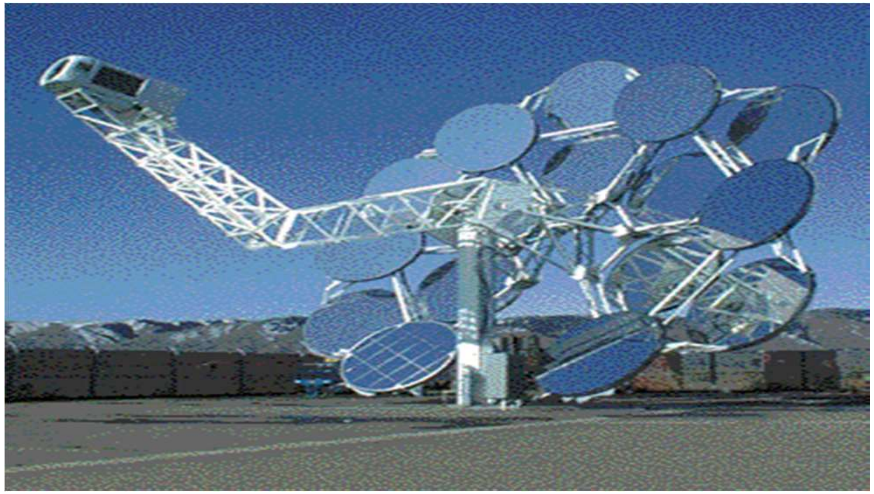


Figure 3.8 Parabolic dish collector with a mirror-like reflectors and an absorber at the focal point.

3.2.3 Heliostat Field Collectors (HFCs)

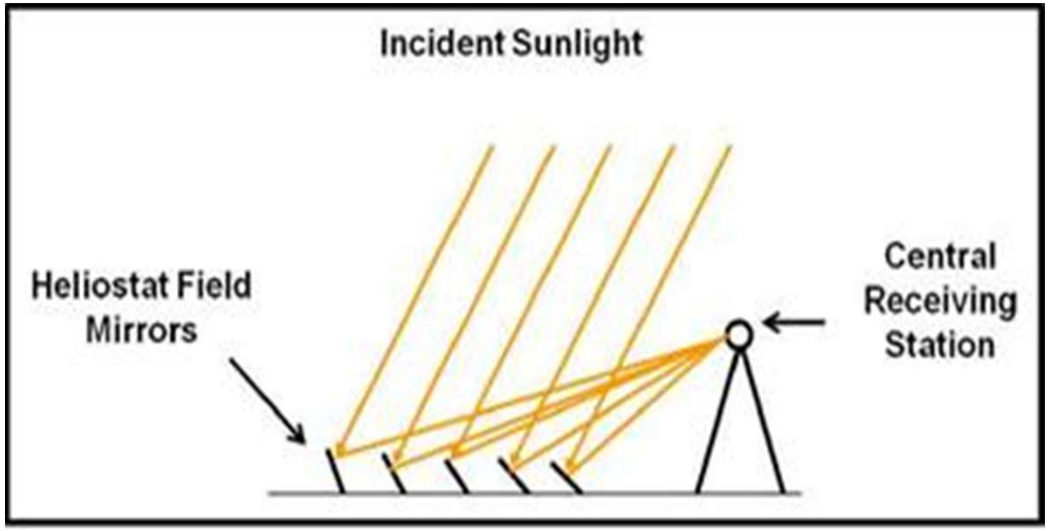
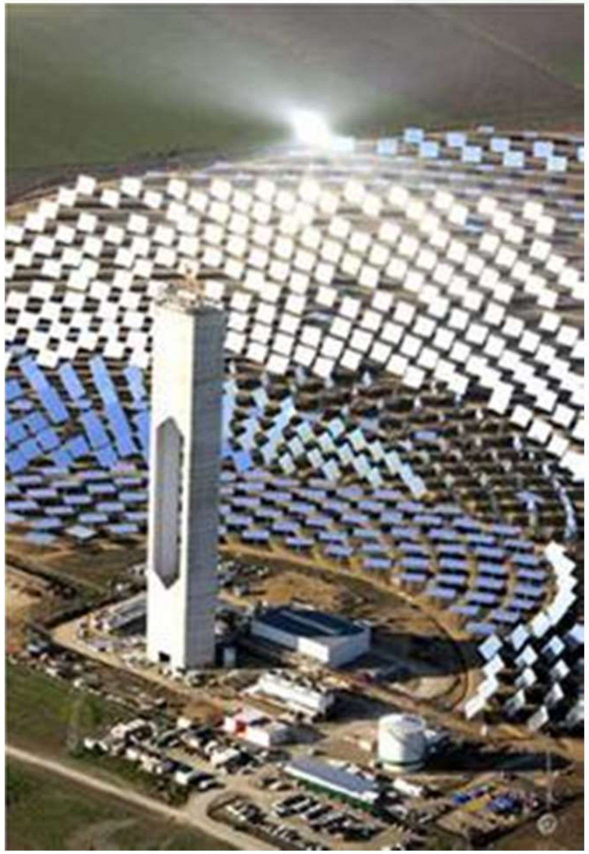


Figure 6-9. Solar Tower Sketch



3.2.3 Heliostat Field Collectors (HFCs)

Central receivers have several advantages:

1. They collect solar energy optically and transfer it to a single receiver, thus minimizing thermal energy transport requirements.
2. They typically achieve concentration ratios of 300 to 1500 and so are highly efficient, both in collecting energy and in converting it to electricity.
3. They can conveniently store thermal energy.
4. They are quite large (generally more than 10 MW) and thus benefit from economies of scale.

Do You Have Any Questions?