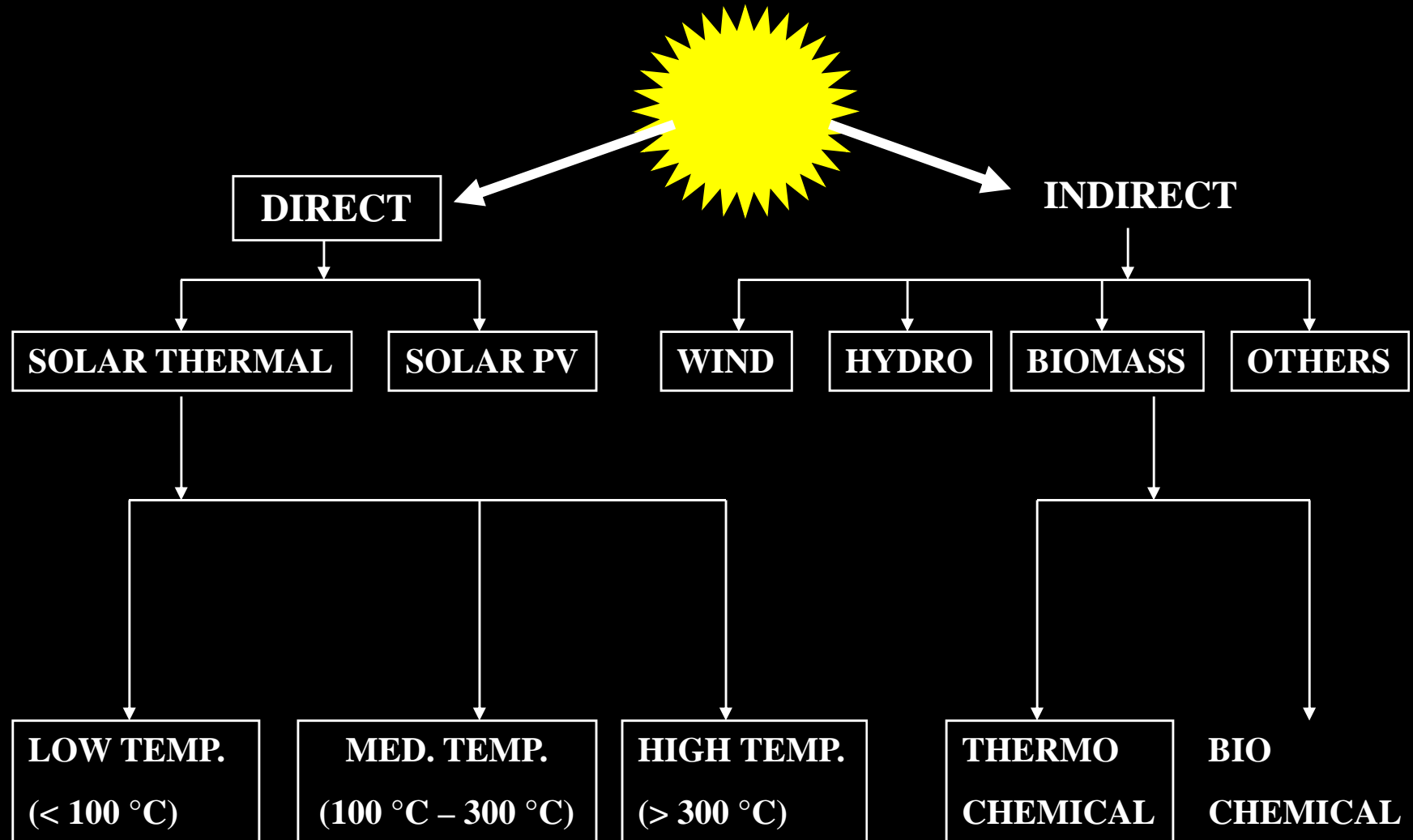


# Solar thermal application

27-03-2014

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# TRADITIONAL CLASSIFICATION OF RENEWABLES



# USES OF SOLAR ENERGY

- Heaters
  - Cars
  - Lights
  - Satellites
  - Dryers
  - Calculators
  - Commercial use
- Green houses
  - water pumps
  - Desalination
  - Chilling
  - Solar ponds
  - Thermal

On an office building , roof areas can be covered with solar panels .

- Remote buildings such as schools , communities can make use of solar energy.
- In developing countries , this solar panels are very much useful.
- Even on the highways , for every five kilometres ,solar telephones are used.

# Types of Applications

- Photovoltaic (PV)
  - Solar cell
- Solar thermal energy
  - Solar water heater
  - Solar thermal power
  - Solar cooling
  - Solar thermal ventilation

Application of Solar Energy



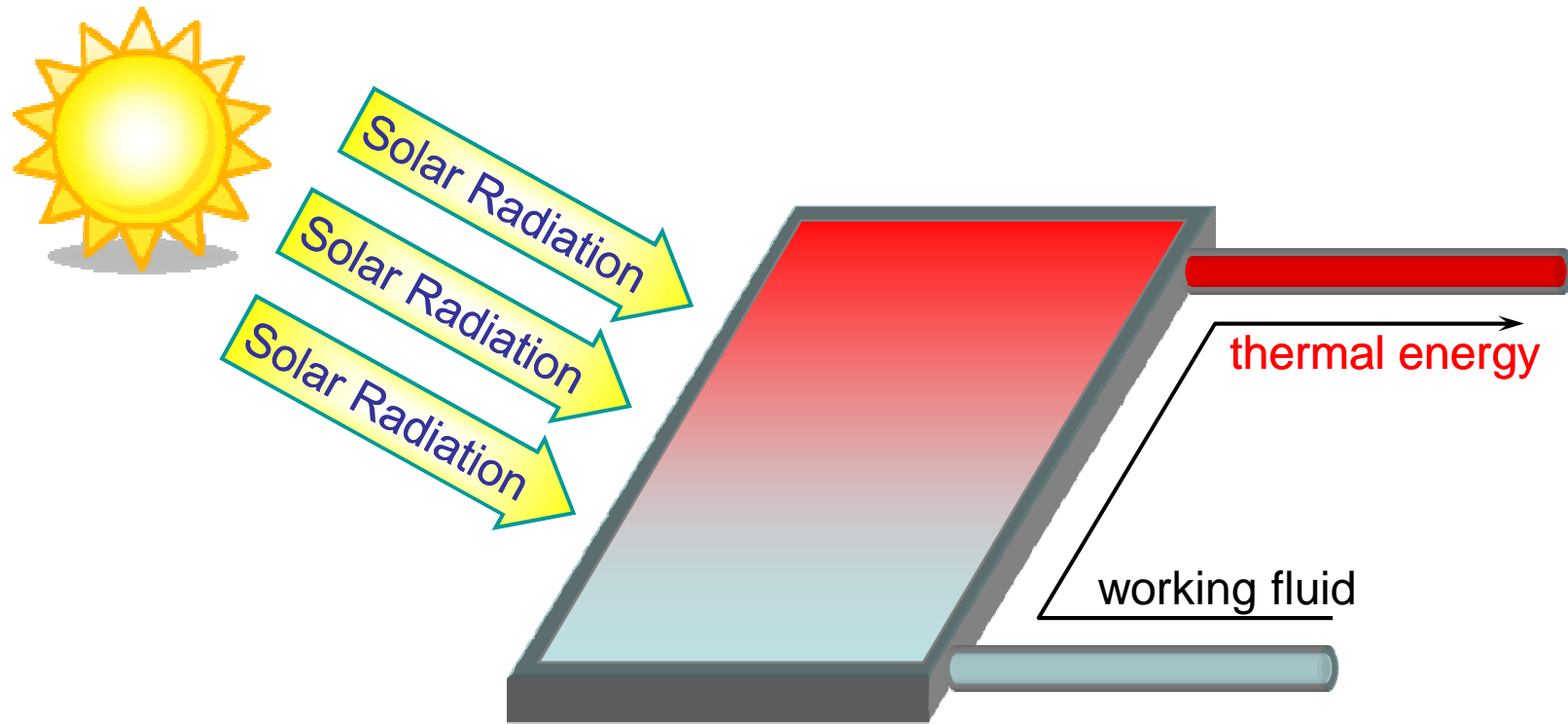
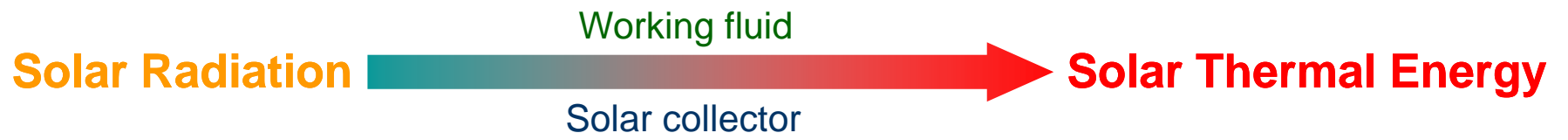
# Solar Energy Collectors

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# **Solar Collector**

- **Solar collector is a special type of heat exchanger**
- **A solar collector is a device designed to absorb incident solar radiation**
- **It transform solar radiation into heat**
- **It transfer that heat energy to a medium (water, solar fluid, or air) passing in contact with it.**
- **Then solar heat can be used for heating water, to back up heating systems or for heating swimming pools.**

- The heart of a solar collector is the absorber, which is usually composed of several narrow metal strips.
- The carrier fluid for heat transfer flows through a heat-carrying pipe, which is connected to the absorber strip.



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# Types of solar collector

- two types of solar collectors: non-concentrating or stationary and concentrating
- A non-concentrating collector has the same area for intercepting and absorbing solar radiation, whereas a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the sun's beam radiation to a smaller receiving area, thereby increasing the radiation flux. Concentrating collectors are suitable for high-temperature applications.

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
5–15			60–300	
Single-axis tracking	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
	Parabolic dish reflector (PDR)	Point	600–2000	100–1500
Two-axis tracking	Heliostat field collector (HFC)	Point	300–1500	150–2000

Low temperature

Medium temperature

High temperature

# Stationary Collectors

- 1. Flat-plate collectors (FPCs).
- 2. Stationary compound parabolic collectors (CPCs).
- 3. Evacuated tube collectors (ETCs).

# Flat plate collectors

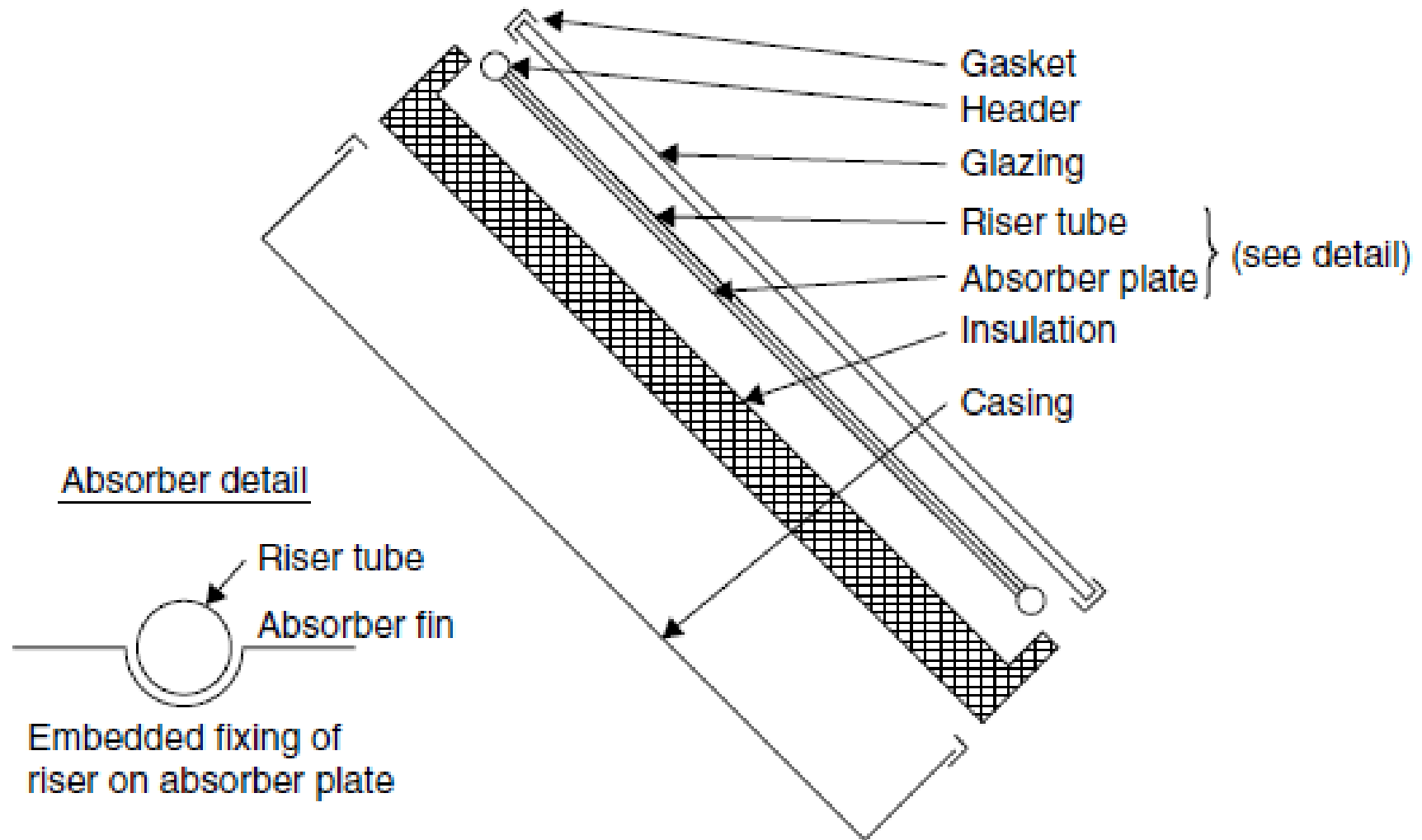
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# Principles

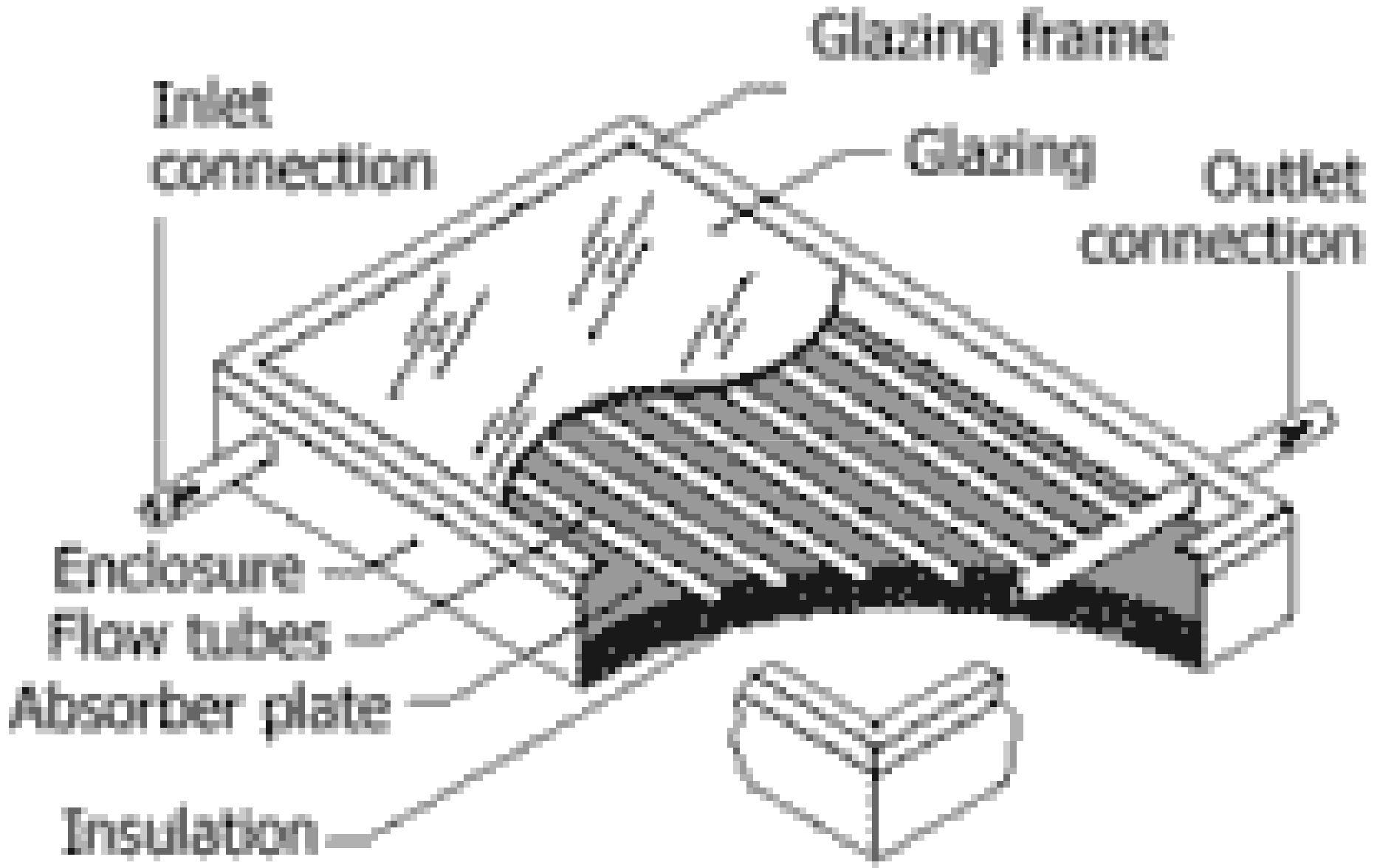
- When solar radiation passes through a transparent cover and impinges on the blackened absorber surface of high absorptivity, a large portion of this energy is absorbed by the plate and transferred to the transport medium in the fluid tubes, to be carried away for storage or use. The underside of the absorber plate and the two sides are well insulated to reduce conduction losses. The liquid tubes can be welded to the absorbing plate or they can be an integral part of the plate. The liquid tubes are connected at both ends by large-diameter header tubes. The header and riser collector is the typical design for flat-plate collectors.
- **The flux of incident radiation is at best approximately  $1100\text{W/m}^2$  and wave length varies from 0.29 to 2.5 micron meter.**

# Components of flat plate collectors

- 1. A transparent cover : one or more sheets of glass or radiation transmitting plastic film or sheet**
- 2. Tubes, fins, passages or channels: integral to collector absorber plate or connect to it**
- 3. Headers or manifolds. Pipes and ducts to admit and discharge the fluid.**
- 3. Absorber plate :normally metallic or with black surface**
- 4. Insulation: provided at the back and sides to minimize heat losses. i.e. mineral wool ,glass wool**
- 5. Casing: encloses the other components and protect them from weather**

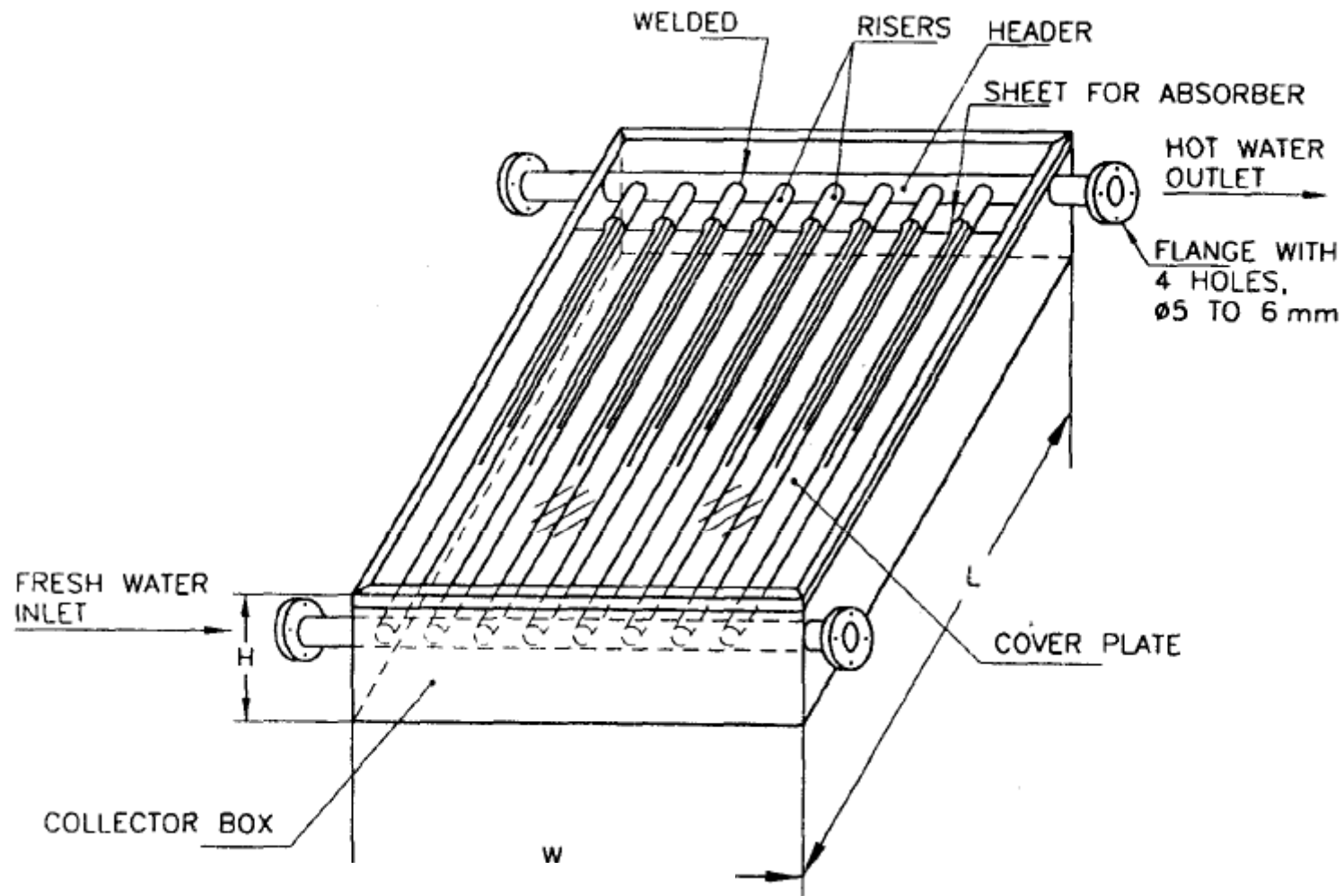


Exploded view of a flat-plate collector and absorber details.



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Cross section of flat plate collectors



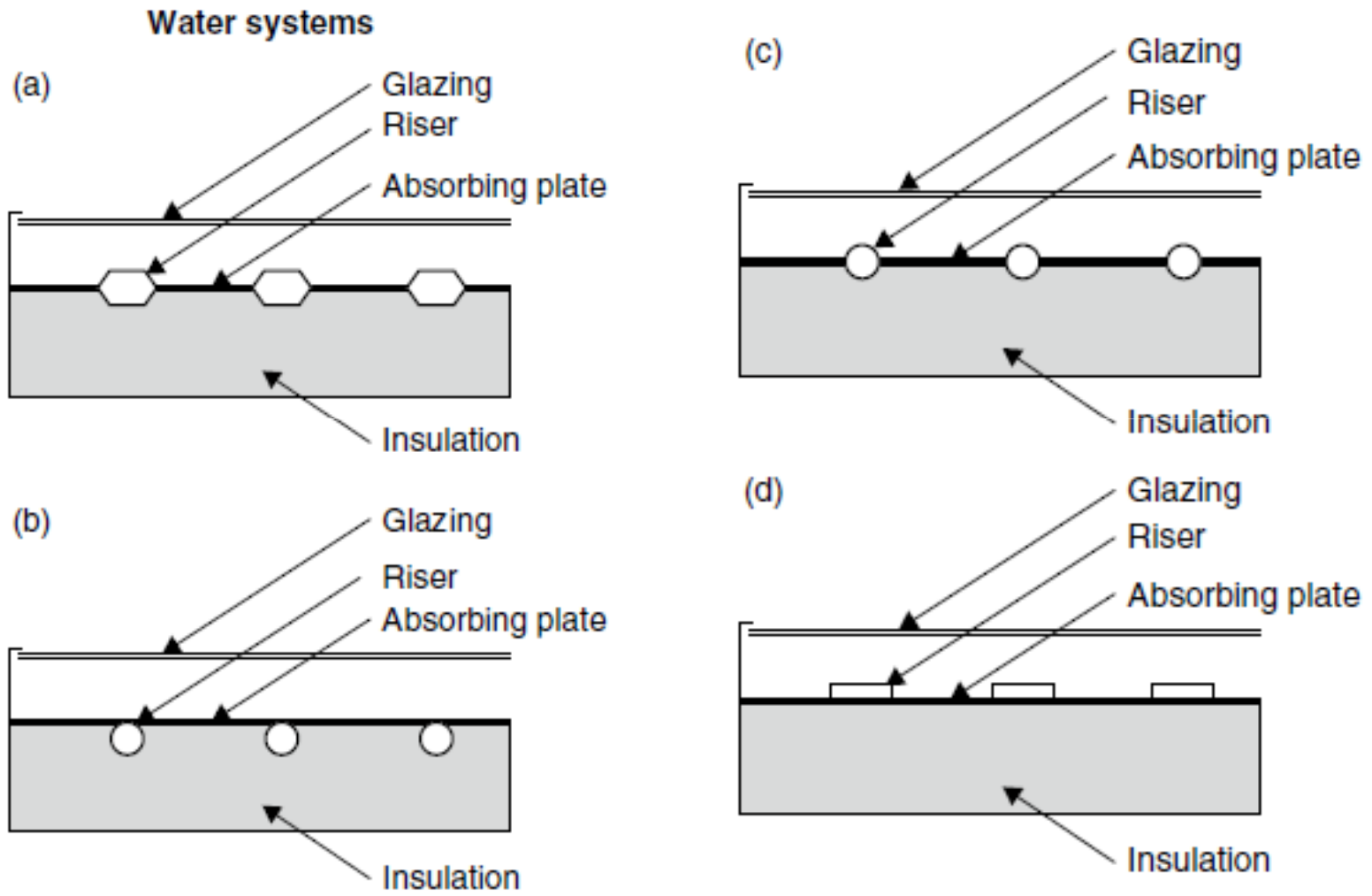


Size	Length(L)	Breadth(W)	Height(H)
a	1860 ± 10	1240 ± 10	100 ± 10
b	2120 ± 10	1040 ± 10	100 ± 10
c	2050 ± 10	930 ± 10	100 ± 10

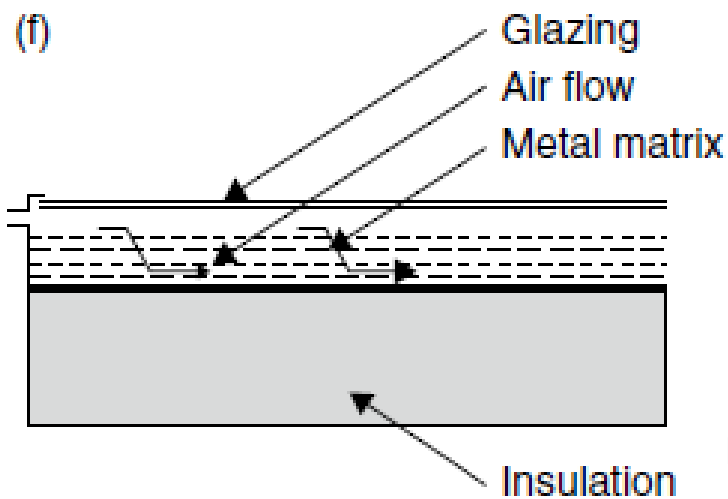
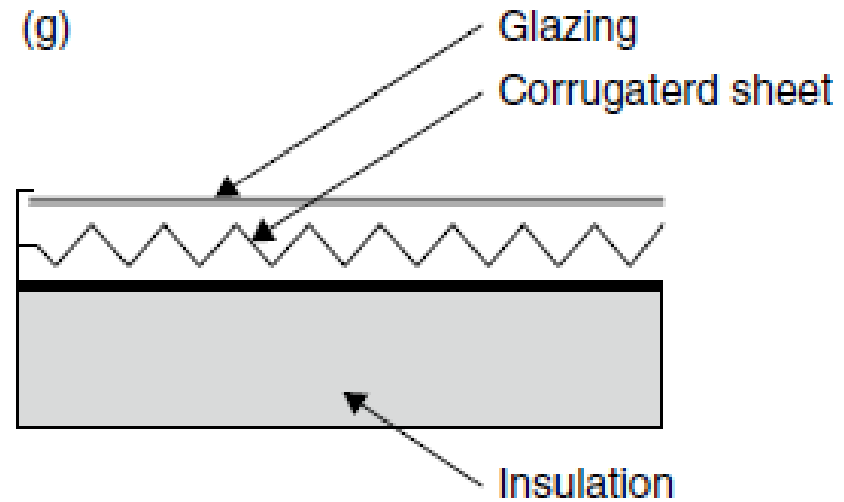
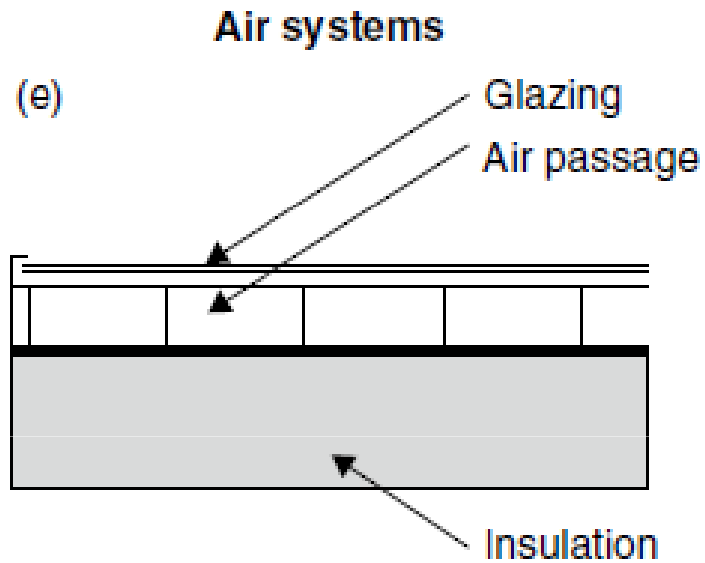
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All dimensions in millimetres.

# Water system



# Air system

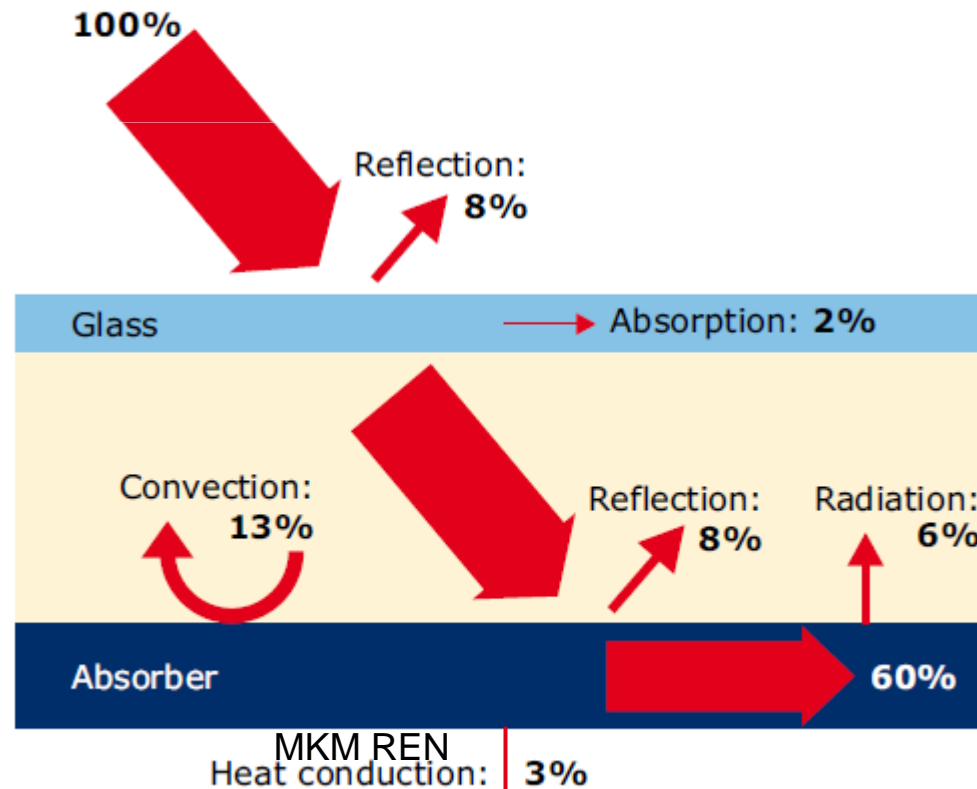


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# Flat-plate collector

Solar Thermal Energy

- Main losses of a basic flat-plate collector during angular operation



Weiss, Werner, and Matthias Rommel. *Process Heat Collectors*. Vol. 33, 2008.

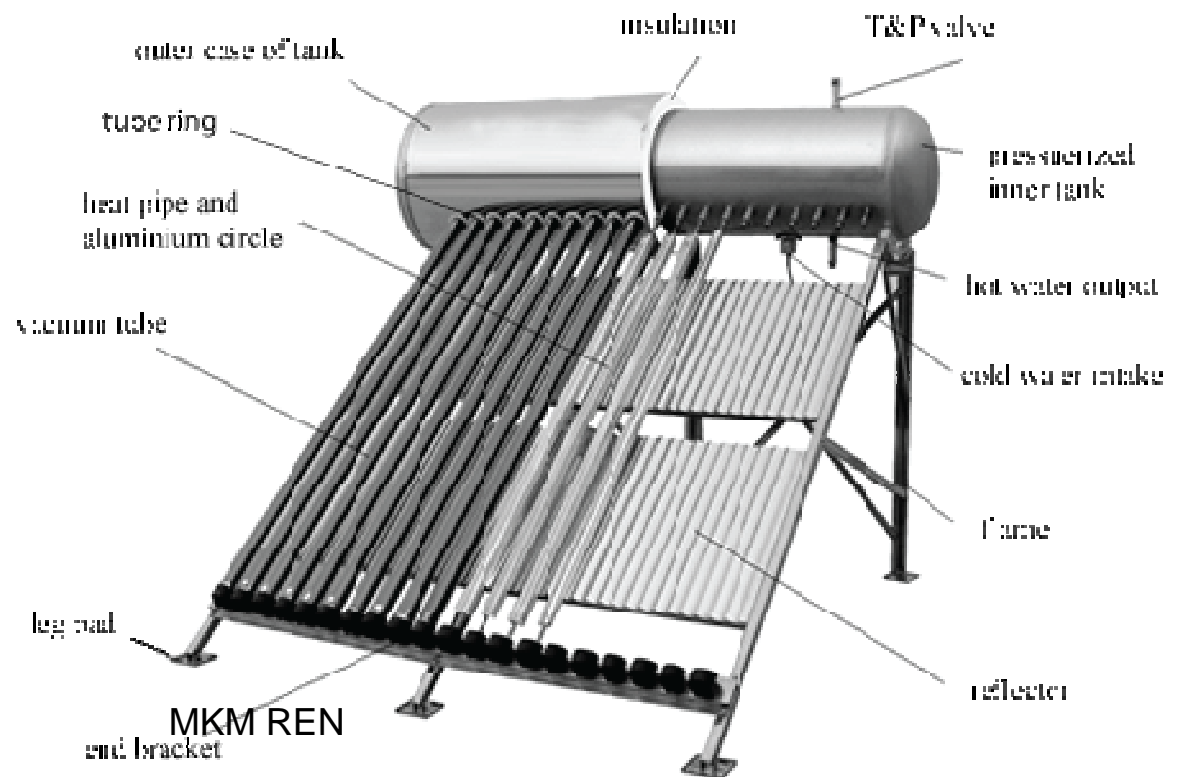
# Evacuated-tube collectors

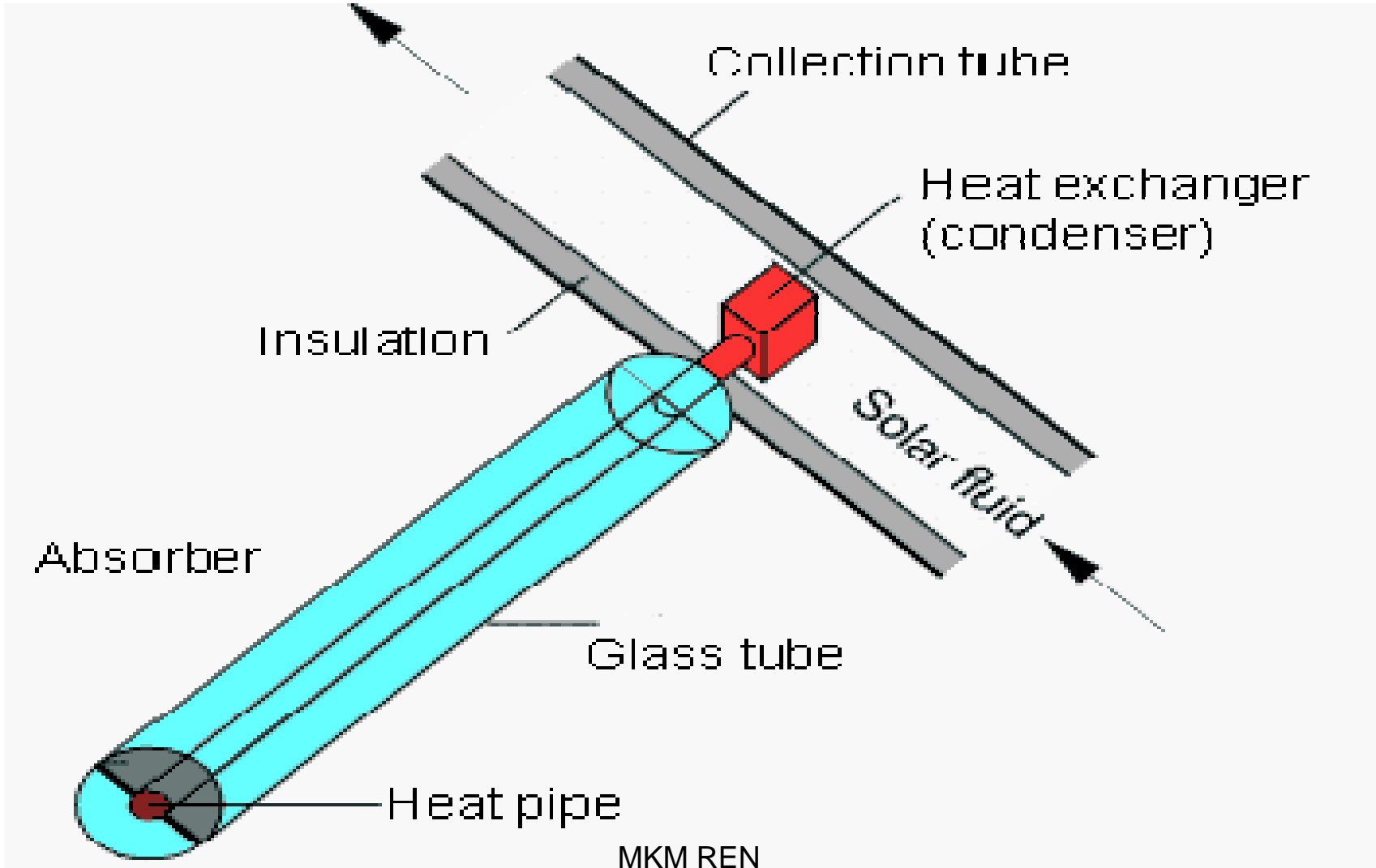
- In this type of vacuum collector, the absorber strip is located in an evacuated and pressure proof glass tube. The heat transfer fluid flows through the absorber directly in a U-tube or in countercurrent in a tube-in-tube system. Several single tubes, serially interconnected, or tubes connected to each other via manifold, make up the solar collector. A heat pipe collector incorporates a special fluid which begins to vaporize even at low temperatures. The steam rises in the individual heat pipes and warms up the carrier fluid in the main pipe by means of a heat exchanger. The condensed liquid then flows back into the base of the heat pipe.

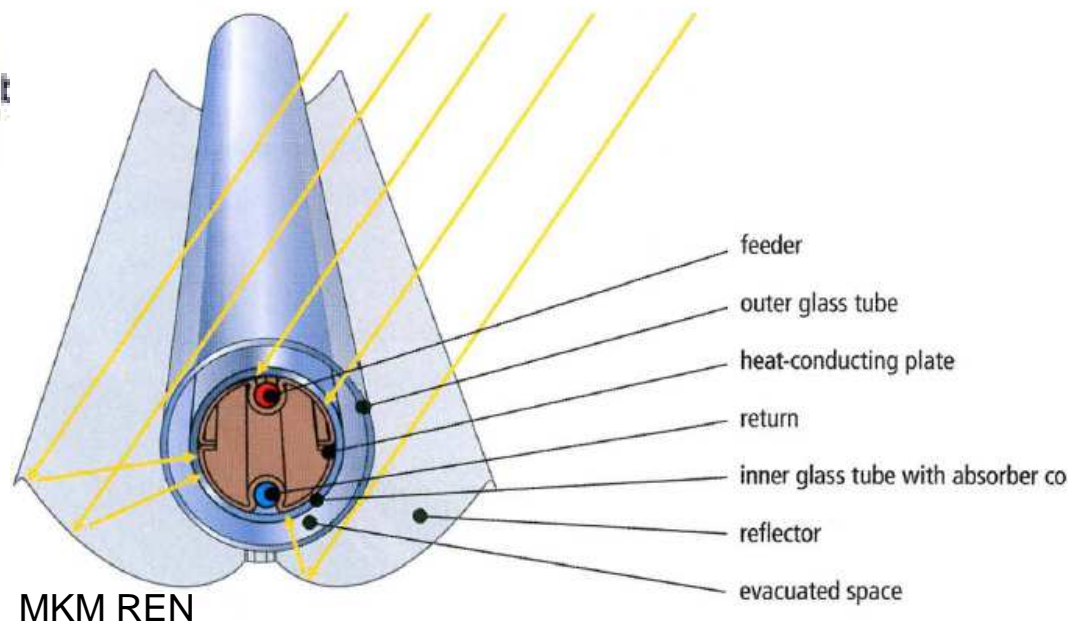
# Evacuated tube collector

Solar Thermal Energy

- A collector consists of a row of parallel glass tubes.
- A vacuum inside every single tube extremely reduces conduction losses and eliminates convection losses.





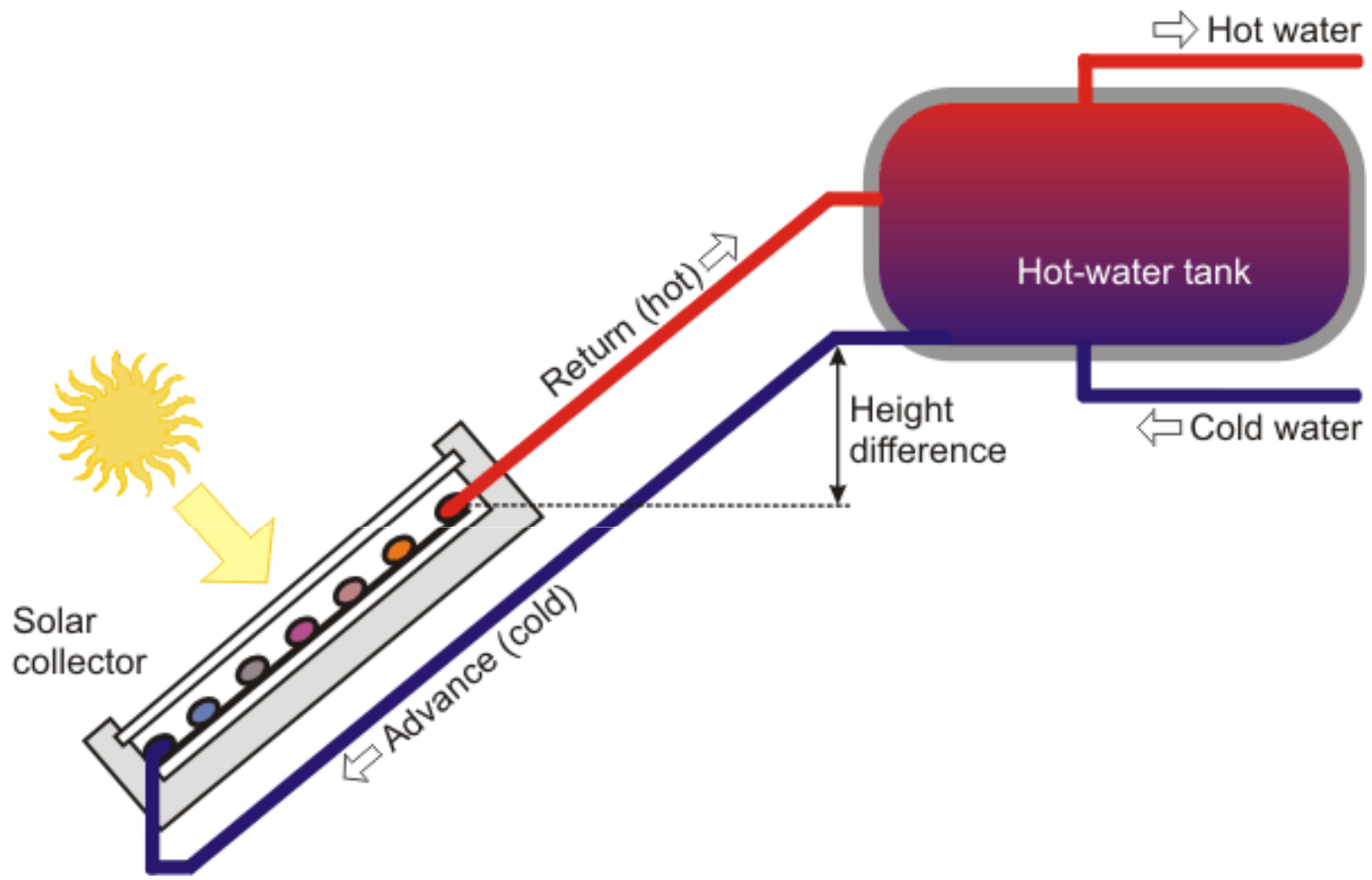




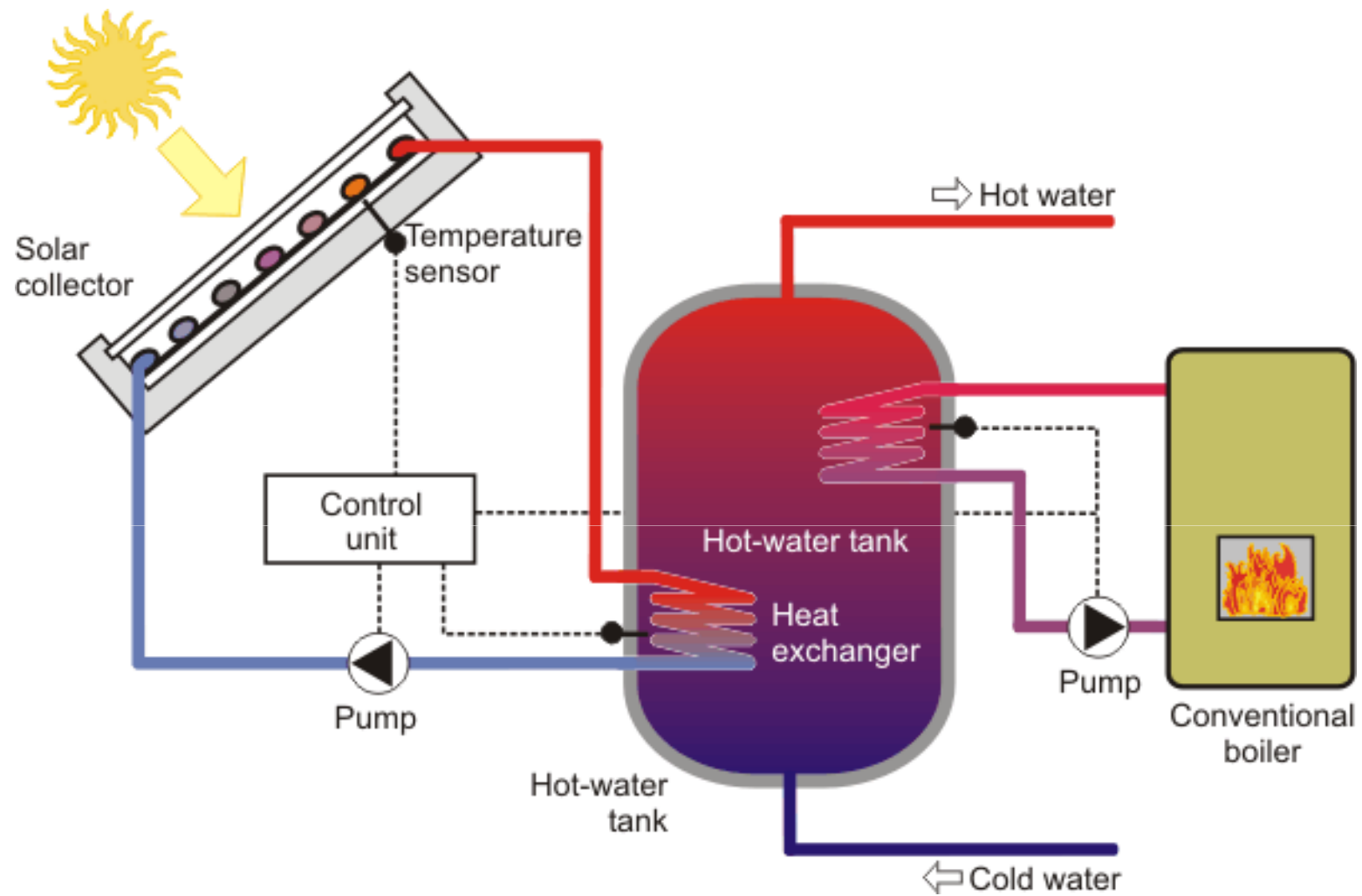
- The pipes must be angled at a specific degree above horizontal so that the process of vaporizing and condensing functions. There are two types of collector connection to the solar circulation system. Either the heat exchanger extends directly into the manifold ("wet connection") or it is connected to the manifold by a heat-conducting material ("dry connection"). A "dry connection" allows to exchange individual tubes without emptying the entire system of its fluid. Evacuated tubes offer the advantage that they work efficiently with high absorber temperatures and with low radiation. Higher temperatures also may be obtained for applications such as hot water heating, steam production, and air conditioning.

# How much energy does a solar collector provide?

- The efficiency of a solar collector is defined as the quotient of usable thermal energy versus received solar energy. Besides thermal loss there always is optical loss as well. The conversion factor or optical efficiency  $\eta_0$  indicates the percentage of the solar rays penetrating the transparent cover of the collector (transmission) and the percentage being absorbed. Basically, it is the product of the rate of transmission of the cover and the absorption rate of the absorber.



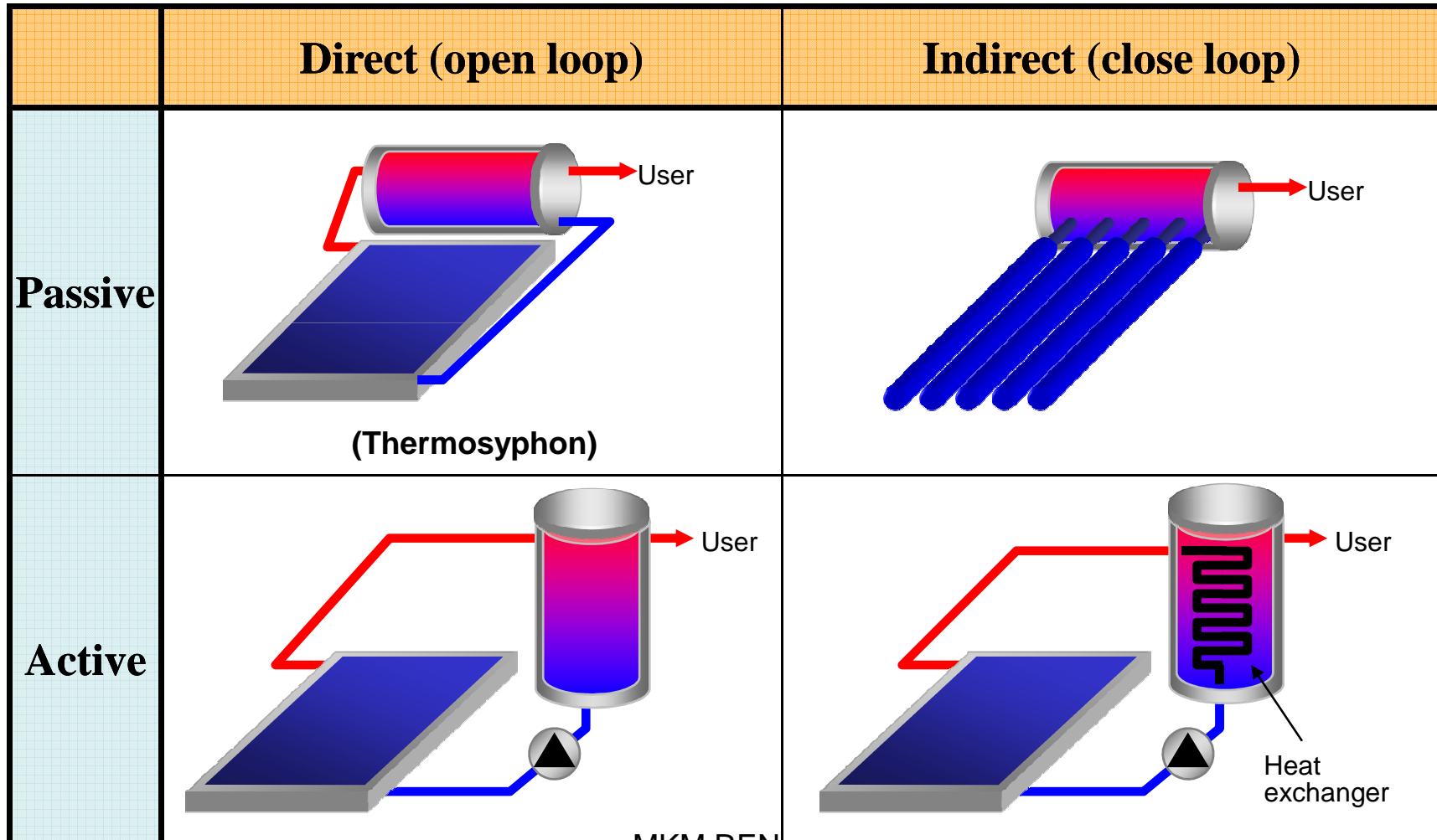
A thermosyphon system



A double-cycle system with forced circulation with a conventional boiler for back-up heating

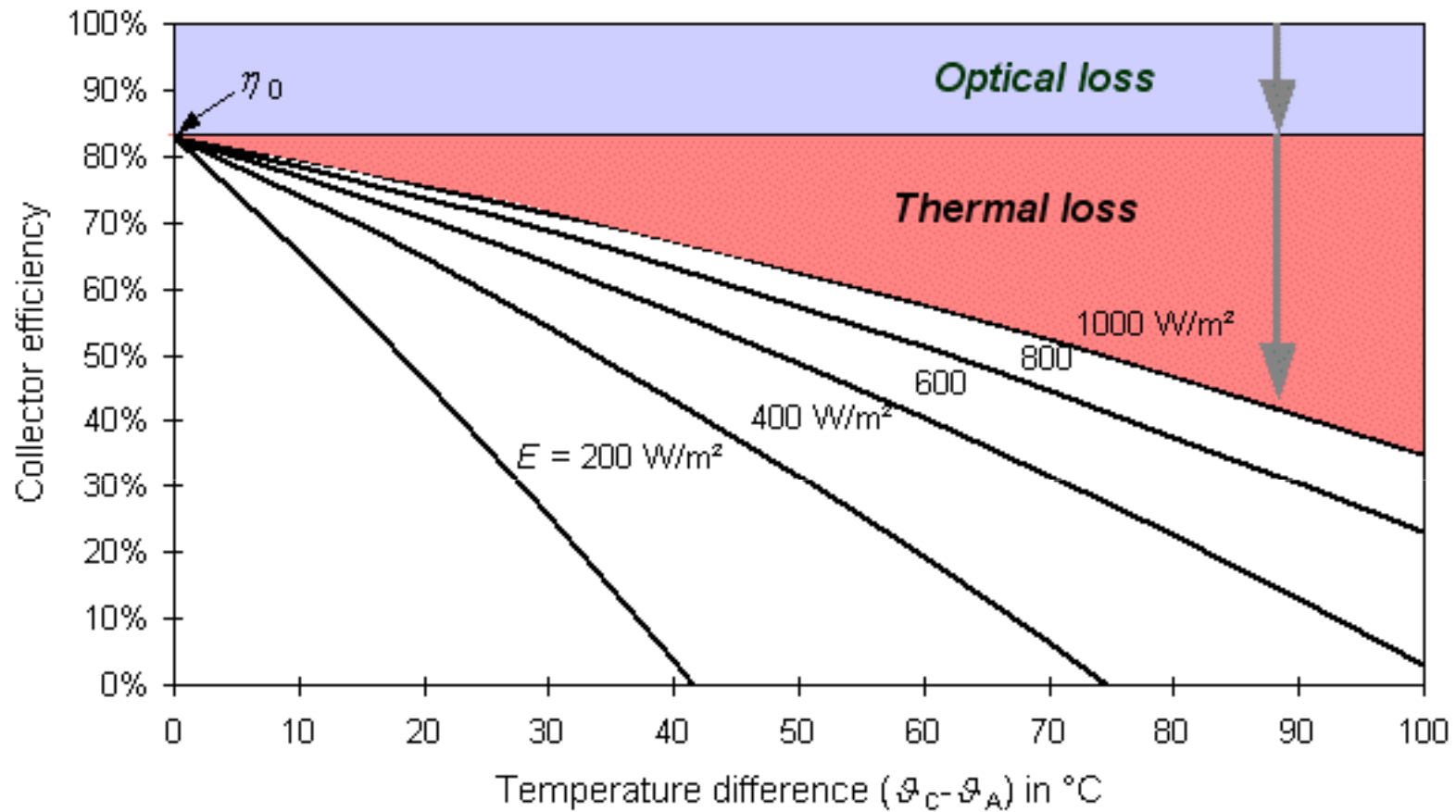
# Solar Water Heater

Solar Thermal Energy



$$Q_u = A_c [HR(\tau * \alpha) - U_L(t_p - t_a)]$$

- $Q_u$  =useful energy delivered by collector, Watts/hr
- $A_c$  collector area, $m^2$  , $H$ =rate of incident beam or diffused radiation on unit area of surface of any orientation  $w/m^2$
- $\tau$ , transitivity and  $\alpha$  ,absorptive
- $U_L$  =over all heat loss coefficient , $W/m^2 \text{ } ^\circ C$
- $t_p$  =average temperature of the upper surface of the absorber plate,  $^\circ C$
- $t_a$  =atmospheric temperatures,  $^\circ C$

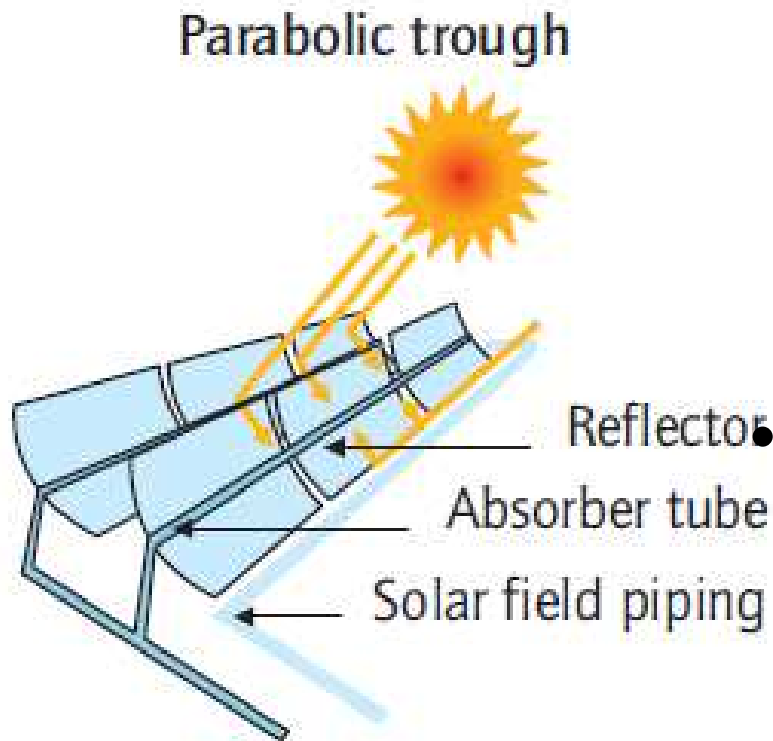


Collector efficiencies at different irradiances and temperature differences

# Compound Parabolic Collectors (CPCs)

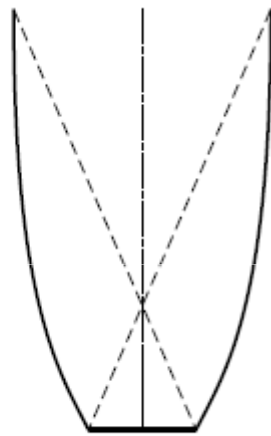
- Compound parabolic concentrators can accept incoming radiation over a relatively wide range of angles.
- By using multiple internal reflections, any radiation entering the aperture within the collector acceptance angle finds its way to the absorber surface located at the bottom of the collector.



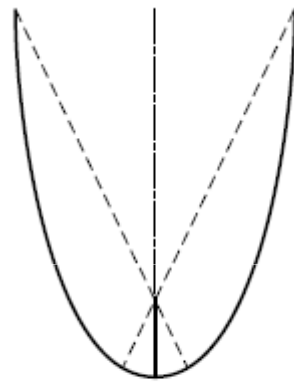


- Consist of parallel rows of mirrors (reflectors) curved in one dimension to focus the sun's rays.

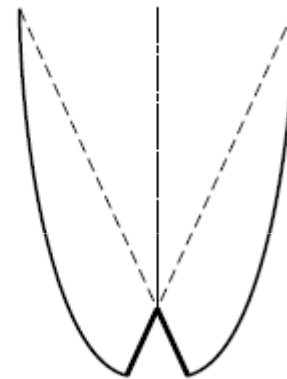
• All parabolic trough plants currently in commercial operation rely on synthetic oil as the fluid that transfers heat from collector pipes to heat exchangers.



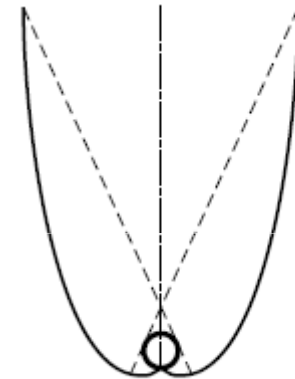
Flat absorber



Bifacial absorber

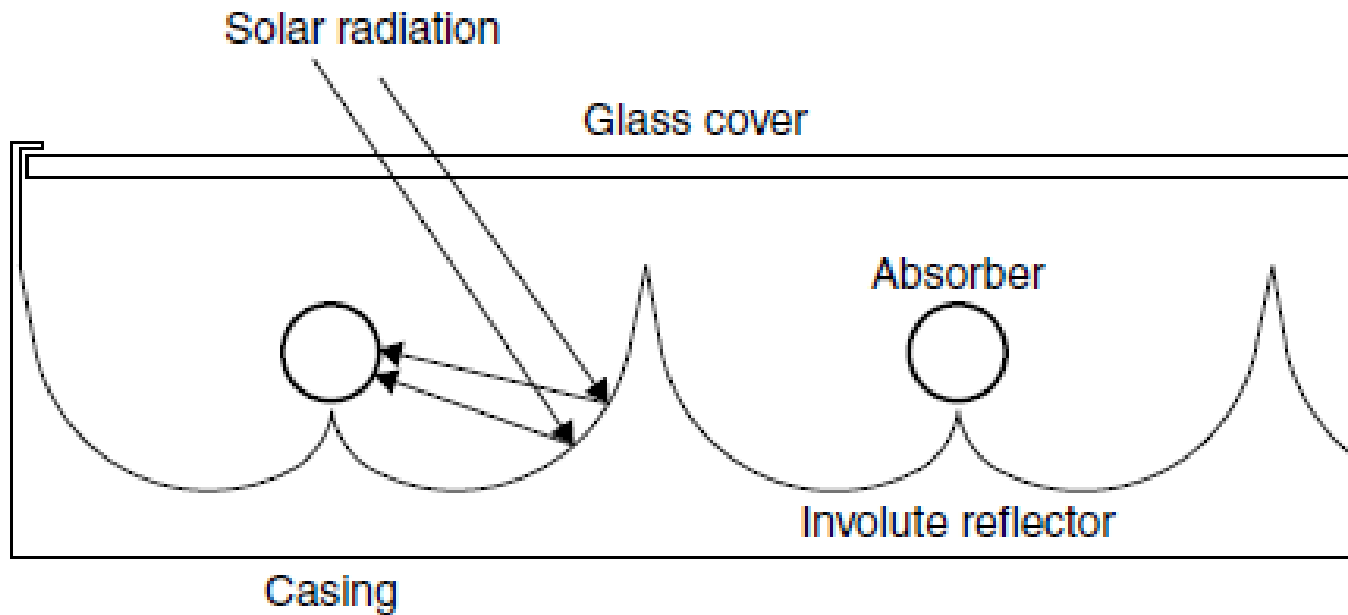


Wedge absorber



Tube absorber

Various absorber types of CPCs.



Compound parabolic collectors can be manufactured either as one unit with one opening and one receiver or panel

# Sun-tracking concentrating collectors

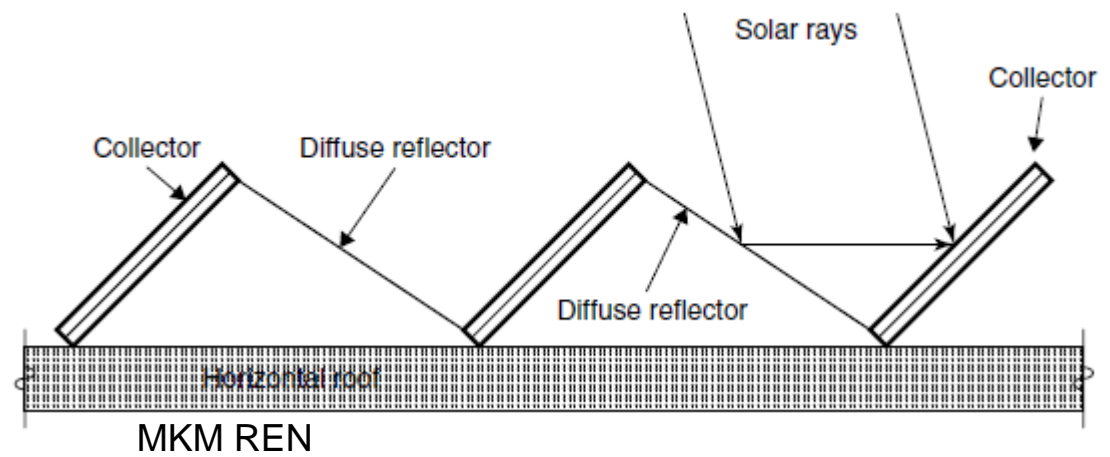
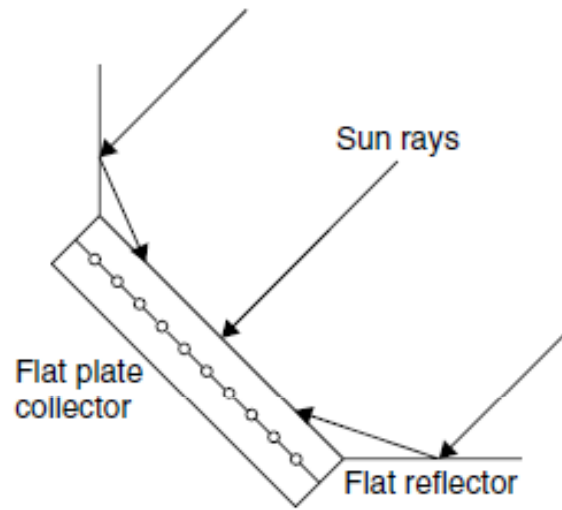
- Energy delivery temperatures can be increased by decreasing the area from which the heat losses occur. Temperatures far above those attainable by flatplate collectors can be reached if a large amount of solar radiation is concentrated on a relatively small collection area. This is done by interposing an optical device between the source of radiation and the energy-absorbing surface.

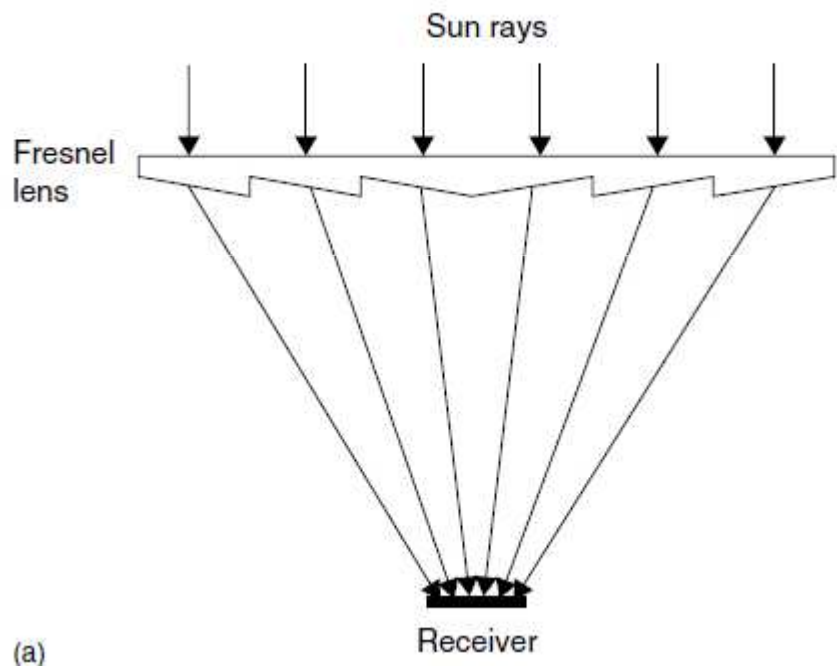
# advantages

1. The working fluid can achieve higher temperatures in a concentrator system than a flat-plate system of the same solar energy-collecting surface. This means that a higher thermodynamic efficiency can be achieved.
2. It is possible with a concentrator system to achieve a thermodynamic match between temperature level and task. The task may be to operate thermionic, thermodynamic, or other higher-temperature devices.
3. The thermal efficiency is greater because of the small heat loss area relative to the receiver area.
4. Reflecting surfaces require less material and are structurally simpler than flat-plate collectors. For a concentrating collector, the cost per unit area of the solar-collecting surface is therefore less than that of a flatplate collector.
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.

# Disadvantages

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.





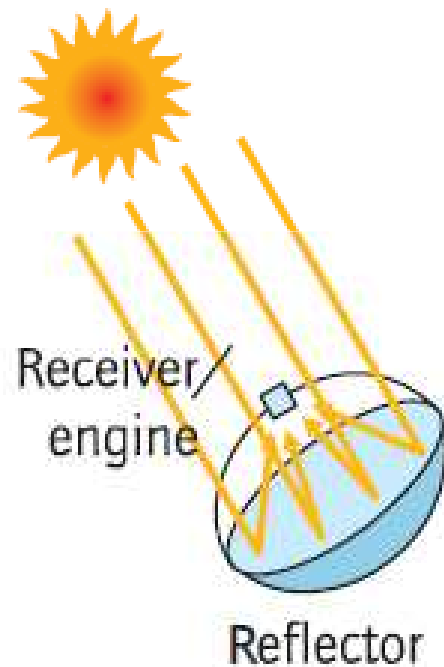
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# Parabolic dish reflector

Solar Thermal Energy

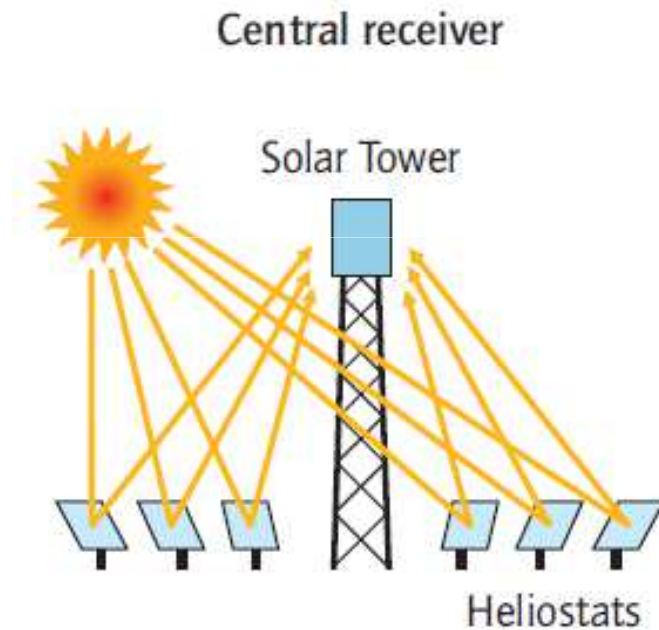
Parabolic dish



- Concentrate the sun's rays at a focal point propped above the centre of the dish. The entire apparatus tracks the sun, with the dish and receiver moving in tandem.
- Most dishes have an independent engine/generator (such as a Stirling machine or a micro-turbine) at the focal point.

# Heliostat field collector

Solar Thermal Energy



- A heliostat is a device that includes a plane mirror which turns so as to keep reflecting sunlight toward a predetermined target.
- Heliostat field use hundreds or thousands of small reflectors to concentrate the sun's rays on a central receiver placed atop a fixed tower.

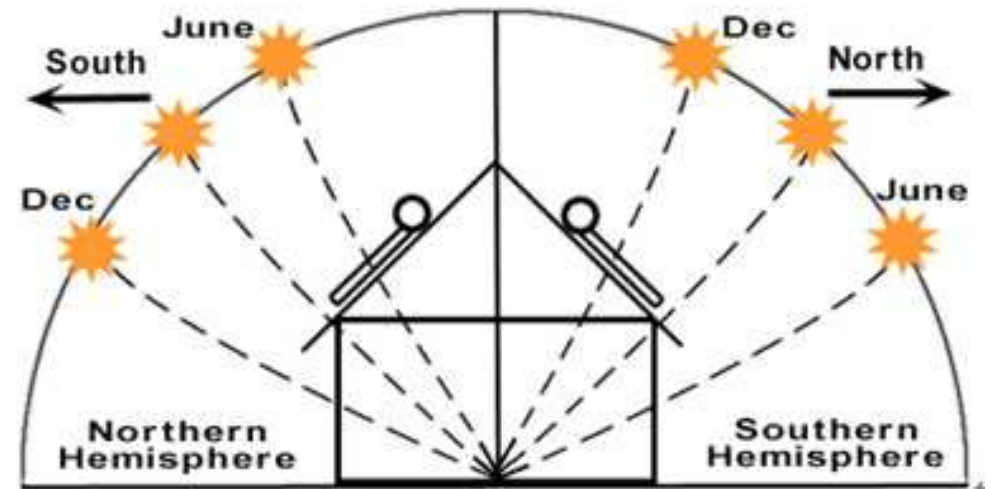
<b>Type of Collector</b>	<b>Conversion Factor</b>	<b>Thermal Loss Factor in W/m<sup>2</sup> °C</b>	<b>Temperature Range in °C</b>
Absorber (uncovered)	0,82 to 0,97	10 to 30	up to 40
Flat-plate collector	0,66 to 0,83	2,9 to 5,3	20 to 80
Evacuated-plate collector	0,81 to 0,83	2,6 to 4,3	20 to 120
Evacuated-tube collector	0,62 to 0,84	0,7 to 2,0	50 to 120
Reservoir collector	about 0,55	about 2,4	20 to 70
Air collector	0,75 to 0,90	8 to 30	20 to 50
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# Orientation of collector

- Installation direction
  - The collectors should be oriented directly toward the equator
    - For northern hemisphere → **Facing south**
    - For southern hemisphere → **Facing north**

- Installation tilt angle

- The angle of the collector is roughly equal to the **local latitude**



- The optimum tilt angle of the collector is equal to the latitude of the location, with angle variations of  $10^\circ$  to  $15^\circ$  more or less, depending on the application
- If the application is solar cooling, then the optimum angle is latitude  $-10^\circ$  so that the sun will be perpendicular to the collector during summertime, when the energy will be mostly required.
- If the application is space heating, then the optimal angle is latitude  $+10^\circ$ ;
- whereas for annual hot water production, it is latitude  $+5^\circ$ , to have relatively better performance during wintertime, when hot water is mostly required.

# Solar Water Heater

- Market potential of industrial process heating

Industrial sector	Process	Temperature level [°C]
Food and beverages	drying	30 - 90
	washing	40 - 80
	pasteurising	80 - 110
	boiling	95 - 105
	sterilising	140 - 150
	heat treatment	40 - 60
Textile industry	washing	40 - 80
	bleaching	60 - 100
	dyeing	100 - 160
Chemical industry	boiling	95 - 105
	distilling	110 - 300
	various chemical processes	120 - 180
All sectors	pre-heating of boiler feed water	30 - 100
	heating of production halls	30 - 80