Solar Energy
Renewable Energy

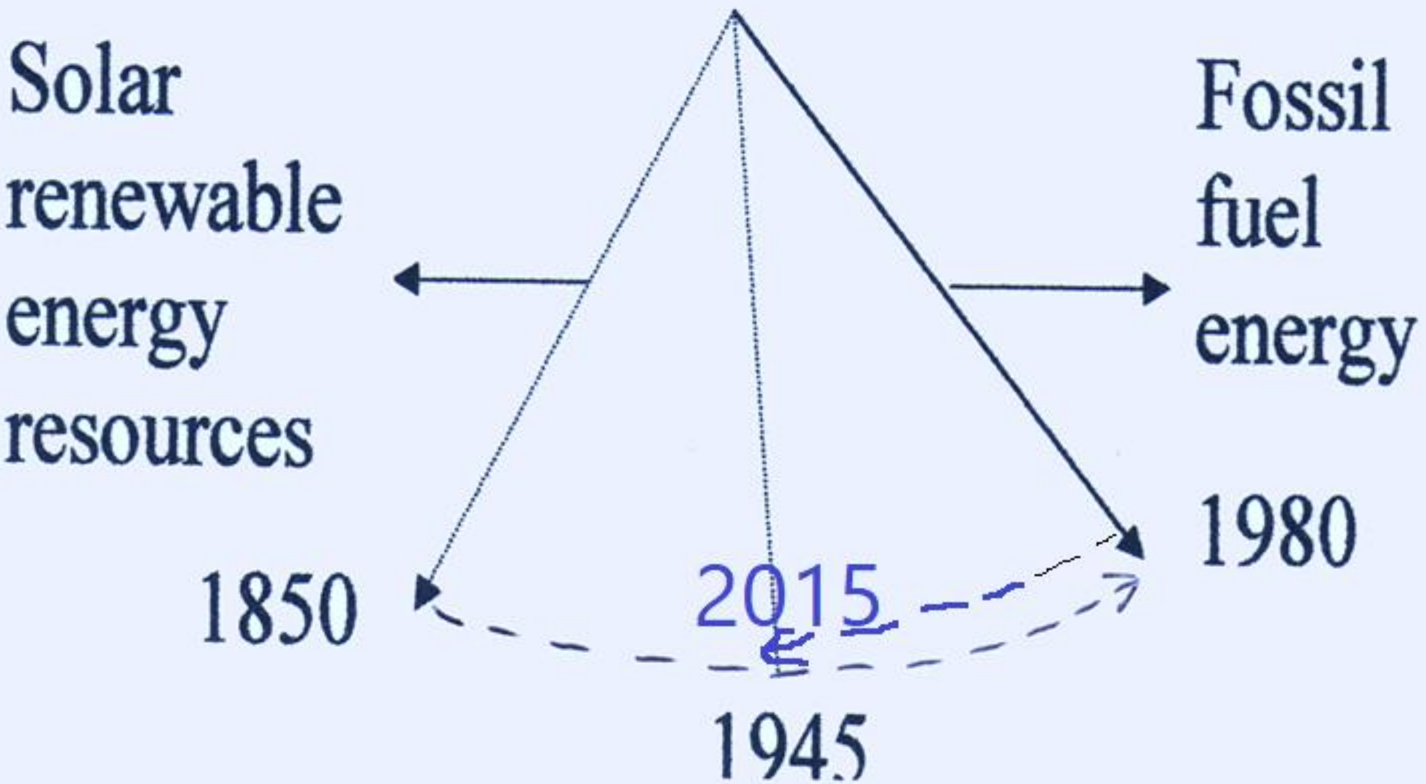
Science and Engineering

Common Notes

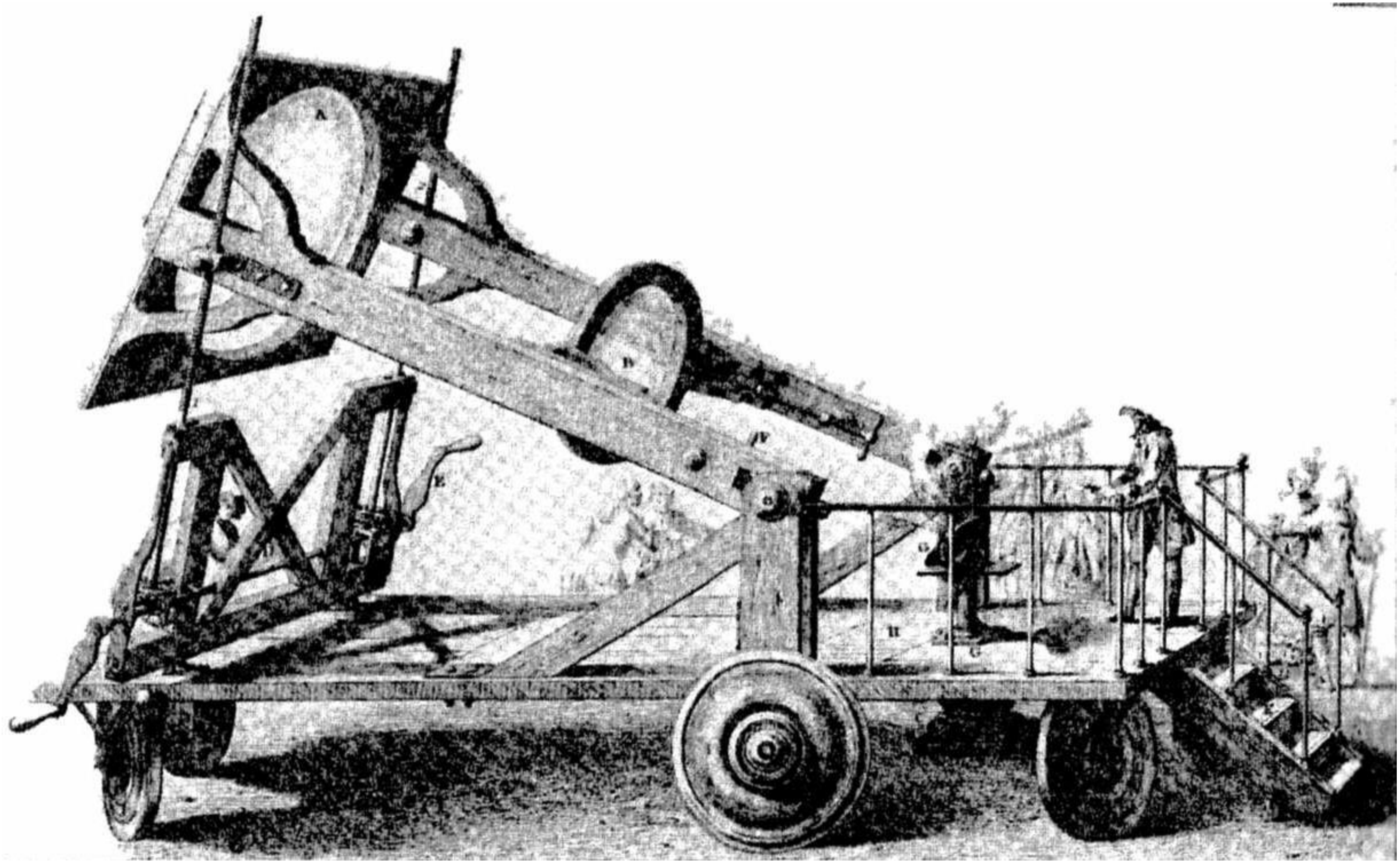
- Solar energy is not a new form of energy.
- Old nation used solar energy.
- Cheap form of energy.
- Available for any body or nation.
- No Pollution.
- Collection is expensive.
- Commercial scale production $\Rightarrow$Still under development.
- Example: power plant of 1000 MW requires a collecting area of a few miles.

See next slides

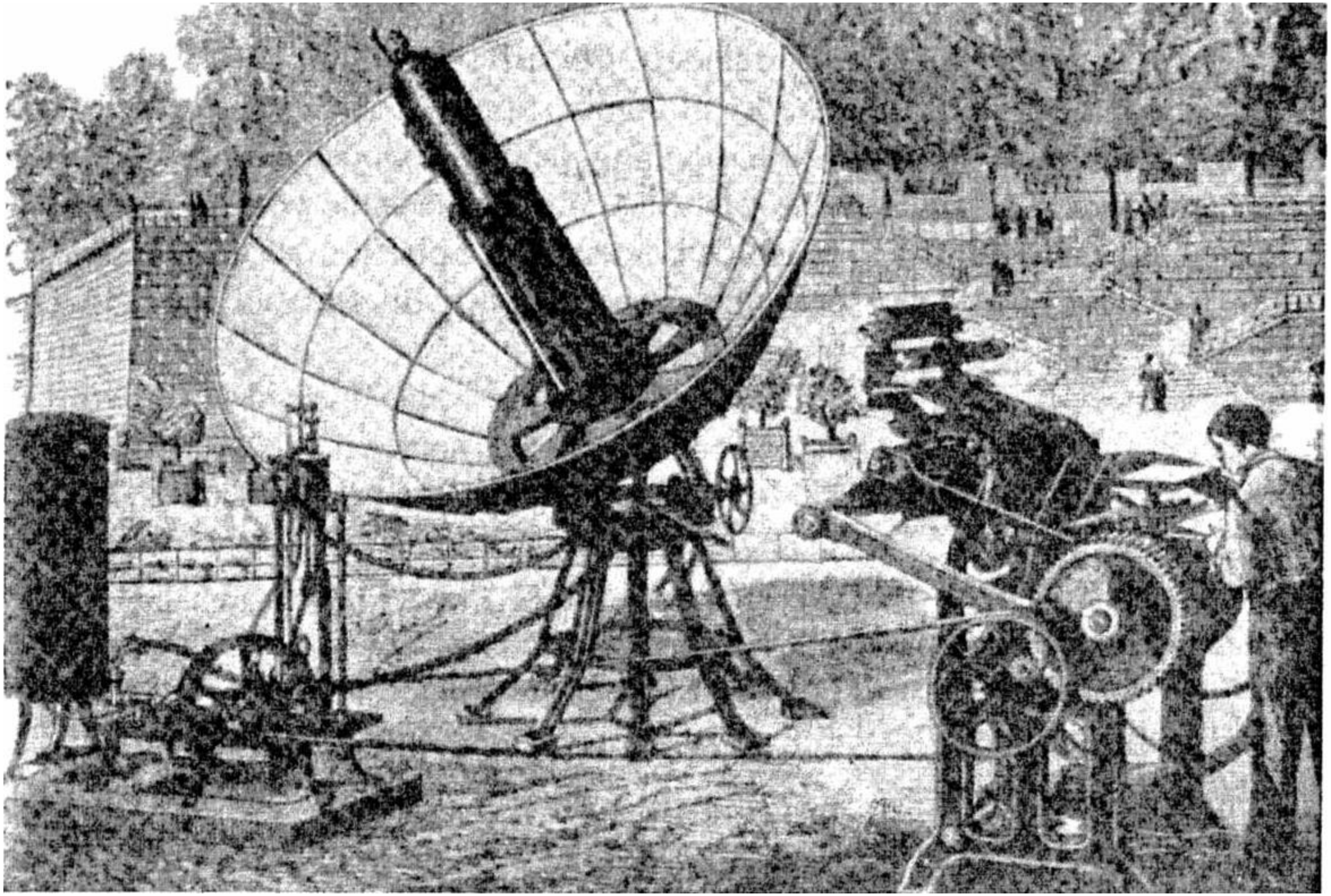
Pendulum Swinging from Renewable to Nonrenewable energy



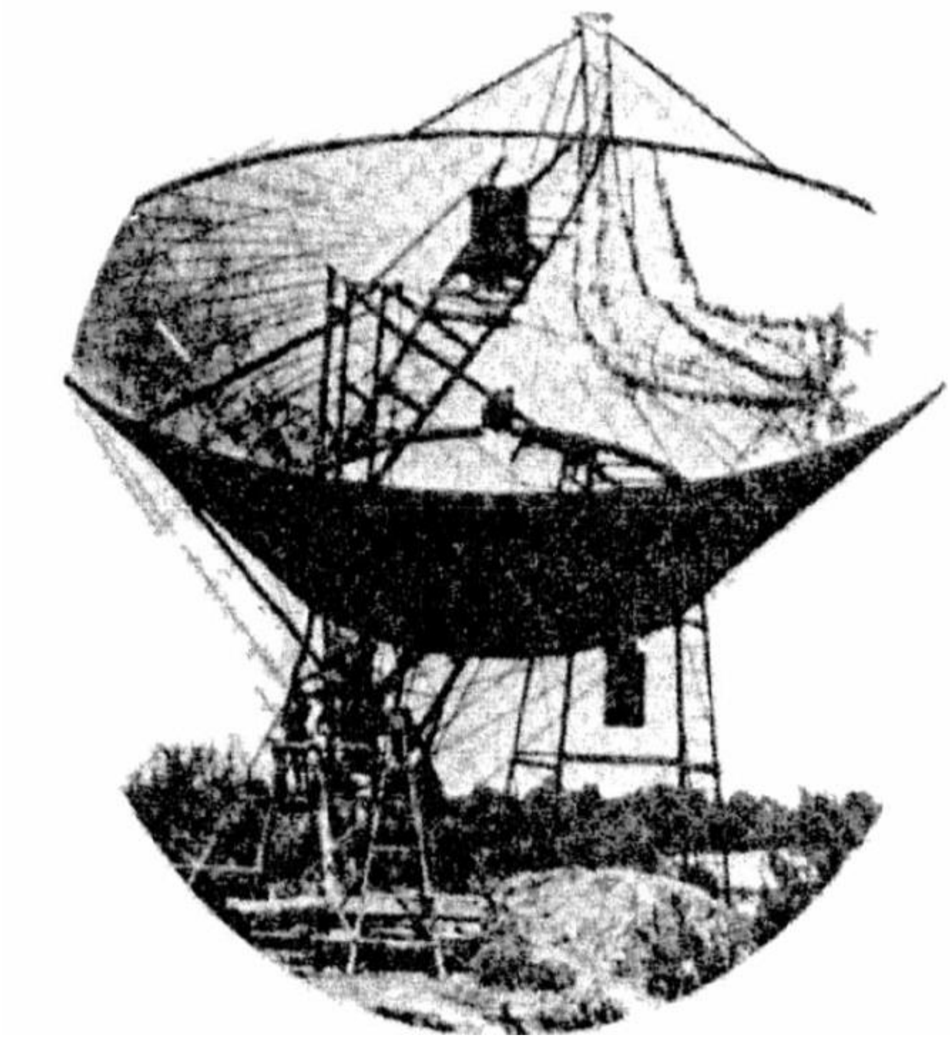
Solar furnace used by Lavoisier in 1774



Parabolic collector powered a printing press at the 1878 Paris Exposition

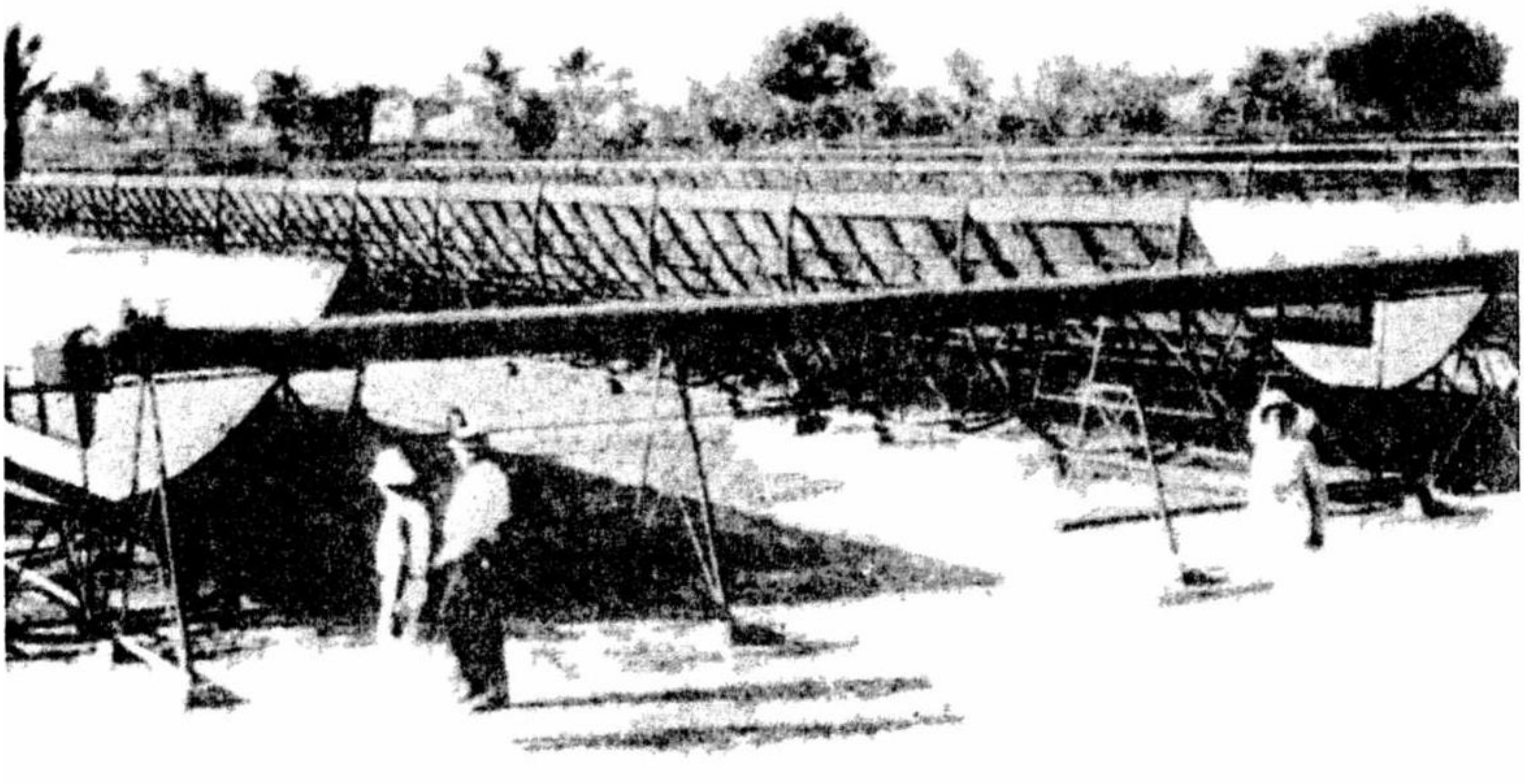


Irrigation pumps were run by a solar powered steam engine in Arizona in early 1900s.



The system consisted of an inverted cone that focused rays of the sun on the boiler.

Solar irrigation pump (50 hp) operating in 1913 in Egypt



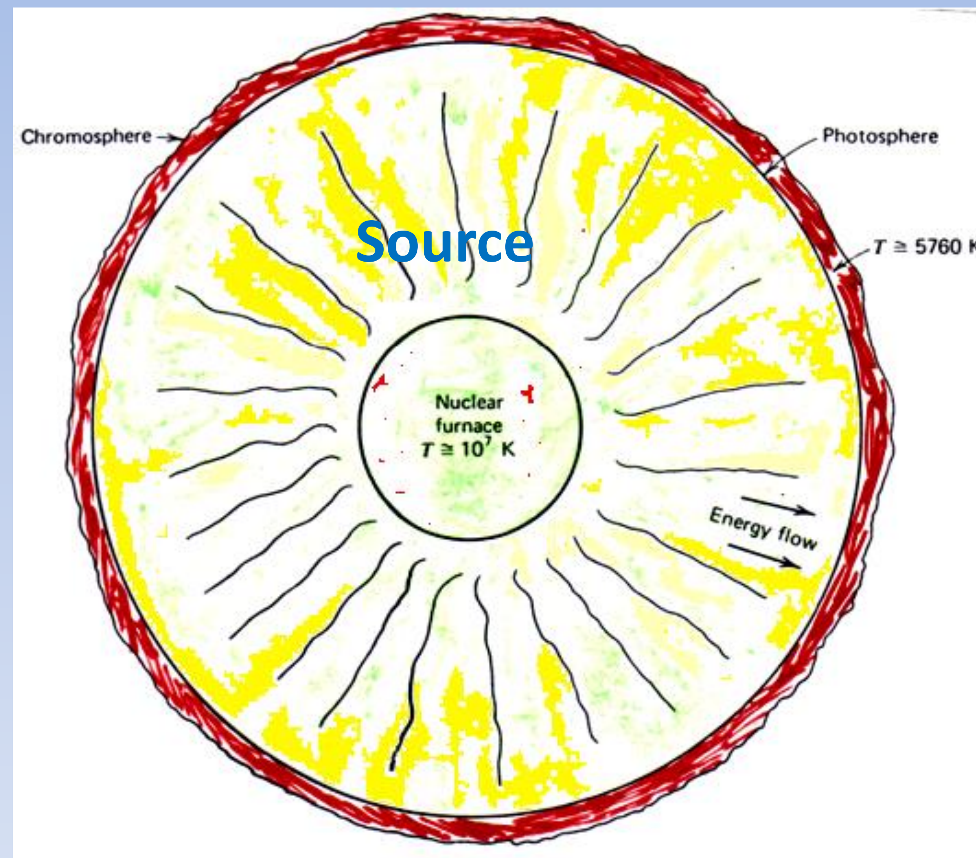
Solar Energy

- Source
- Facts
- Model

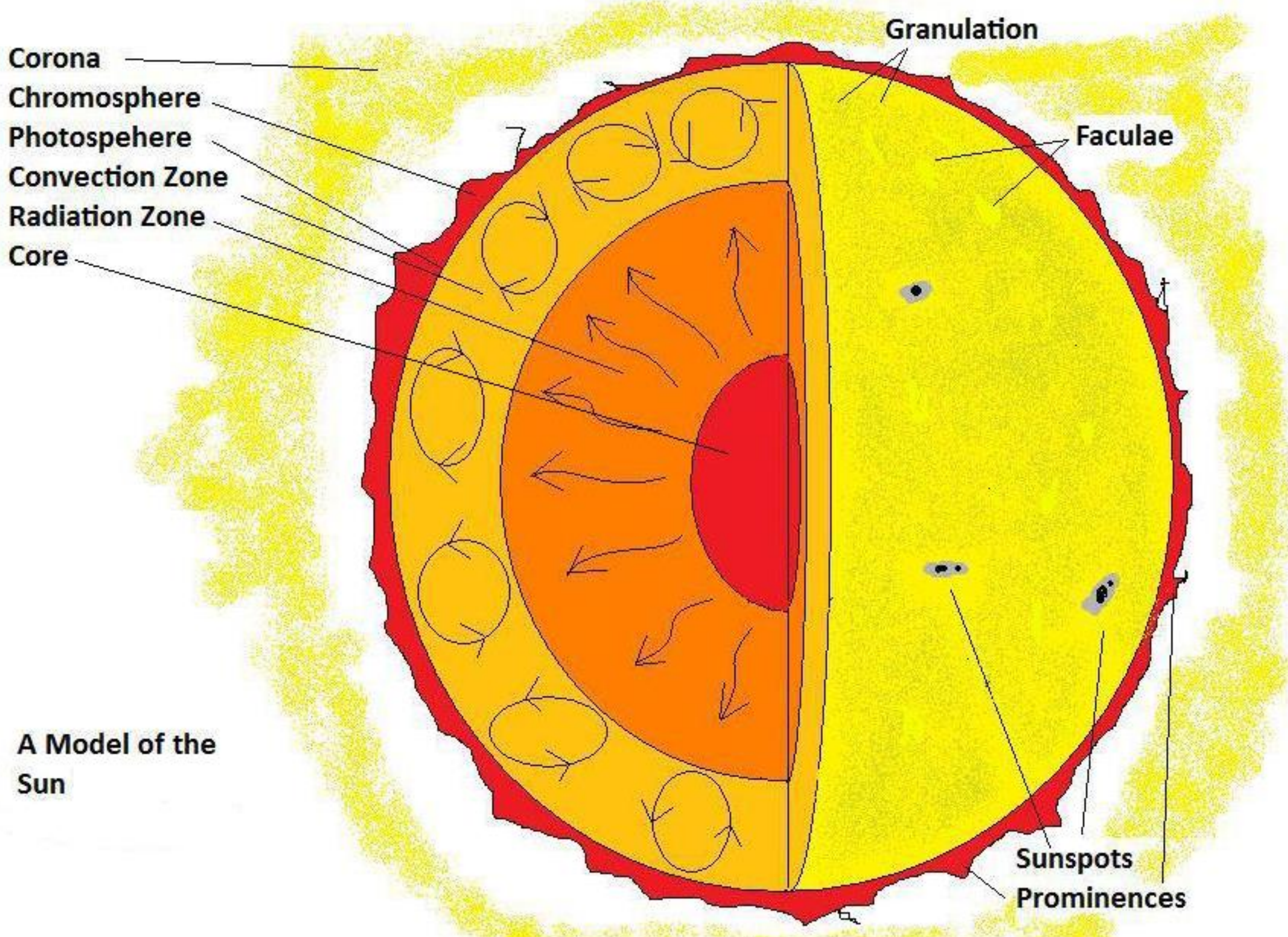
Simplified model of the sun

✓Chemical composition: H_2, He
✓$T_{interior}$: 15×10^6 K
✓Sun is the Origin of most energy available on earth.
✓Mass sun: 1.99×10^{30} kg ($\approx 3.3 \times 10^5$ earth mass)
✓Radius : 6.96×10^8 m ($\approx$109 earth radii)
✓It produces the necessary attraction to keep our planet in a nearly circular orbit.
✓Energy is generated as a result of nuclear fusion of H_2 into He. This energy diffuses to the surface then is emitted into space in the form of electromagnetic radiation.

Facts

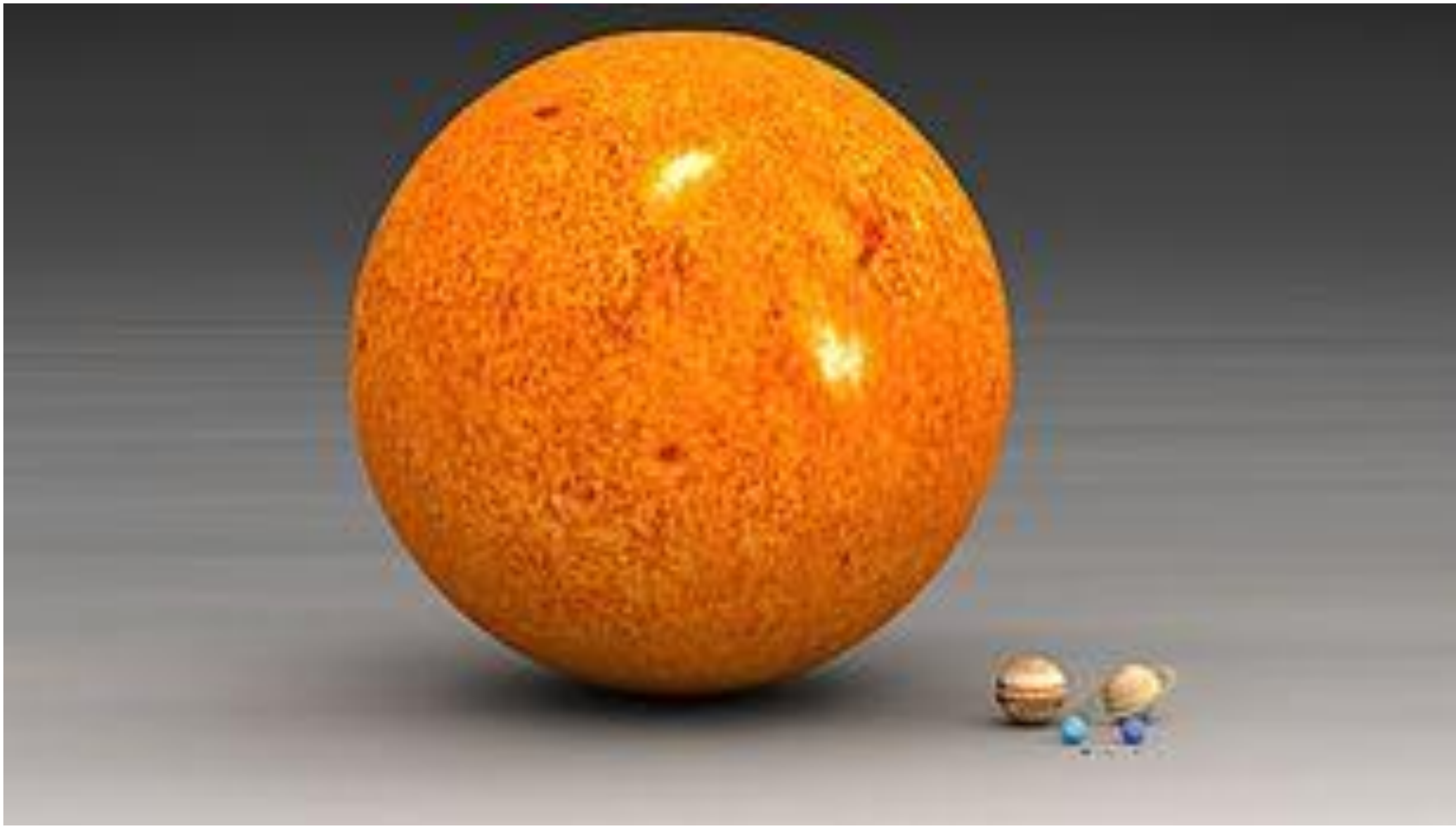


Nuclear Furnace



A Model of the Sun

The Sun compared to the planets

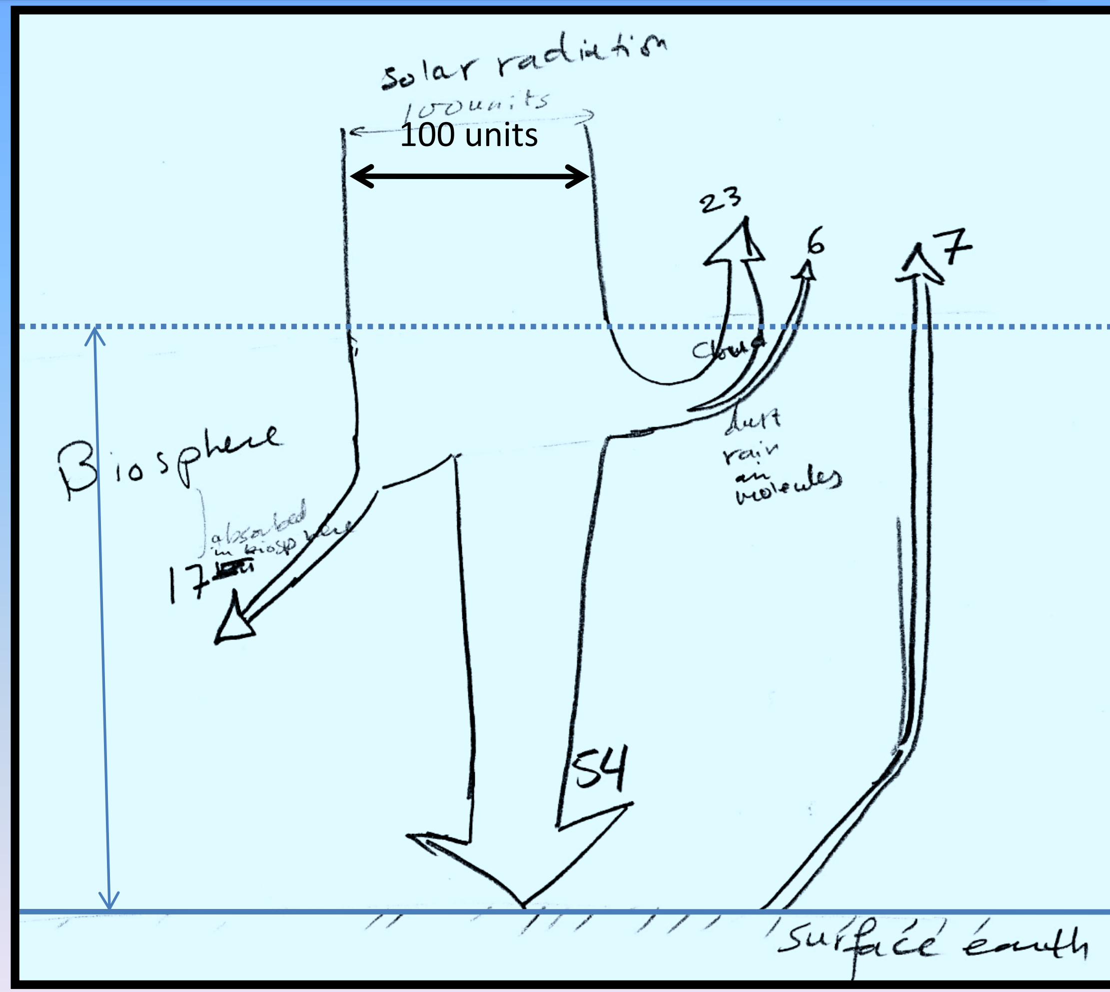


Definition _ Albedo ‘a’

The total fraction reflected back is called ‘albedo’, a

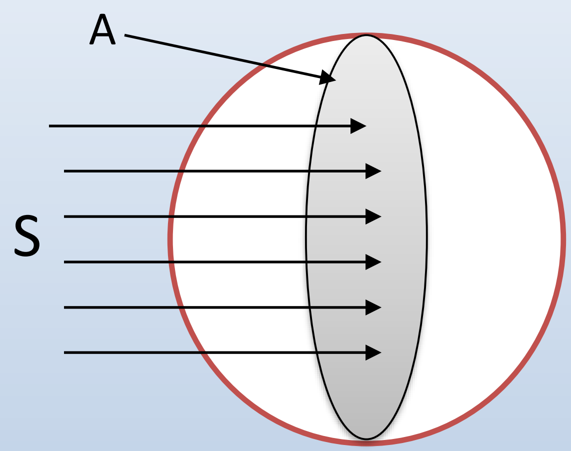
Total units retained = 17+54−7
= 64 units

$$a = \frac{7+6+23}{100} = 0.36$$



- ✓ **If S is the energy flux of the sun ≡ Solar constant = 0.136 W/cm^2**

- ✓ **A means the effective earth area of interception.**



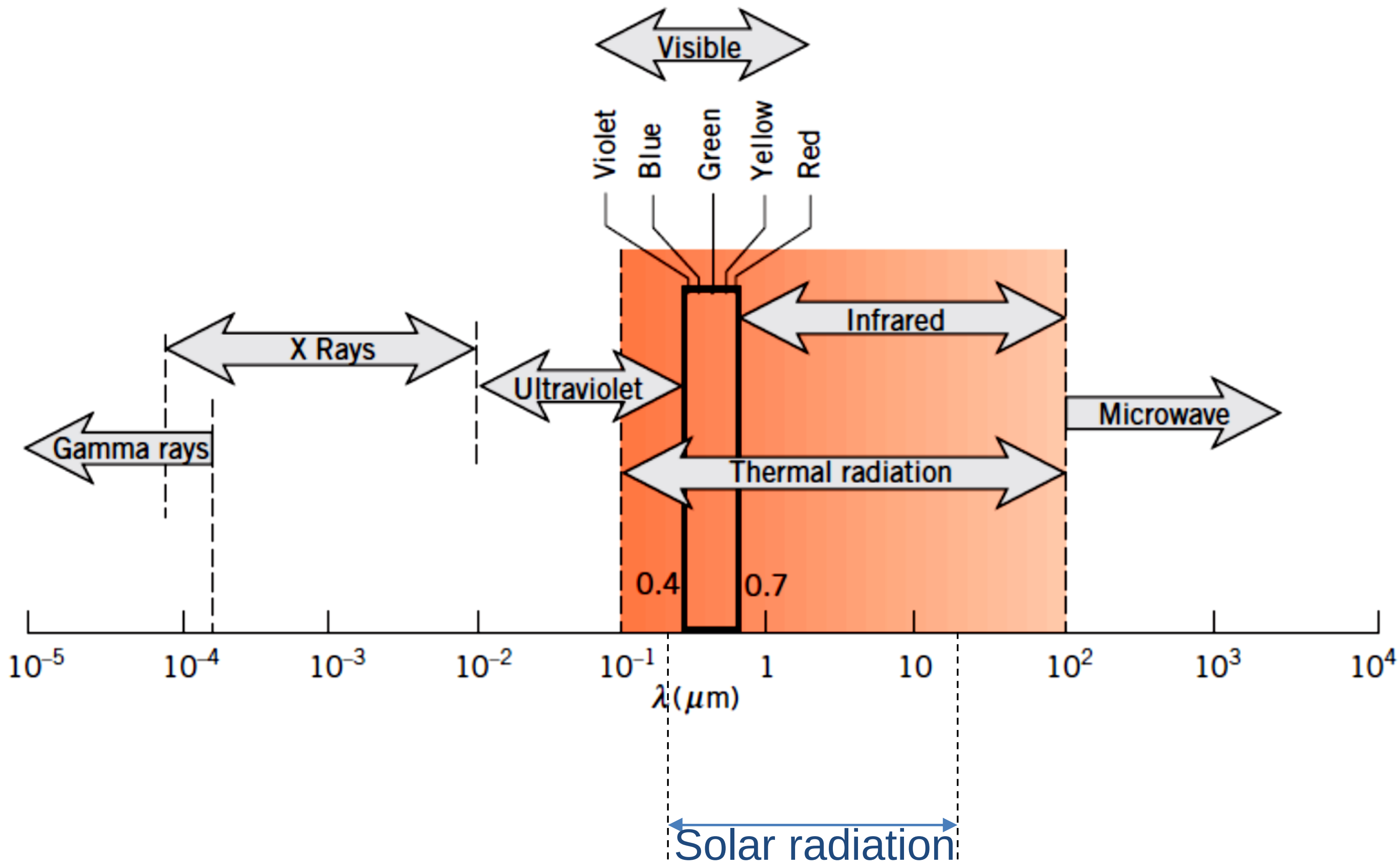
- ✓ **The fraction of radiation reaching the surface = S* A * (1-a)**
  = S* A * (1-0.36)

- ✓ **The fraction of radiation which reflected back, q_{albedo} = S* A * a**

In General

- ✓ Solar radiation reaches the Earth's surface at a maximum flux density of about 1.0 kW/m^{-2} in a wavelength band between 0.3 and 25μm.
- ✓ This is called short wave radiation and includes the visible spectrum.
- ✓ For inhabited areas, this flux varies from about 3 to 30MJm^{-2} day^{-1}, depending on place, time and weather.
- ✓ The flux can be used both thermally (e.g. for heat engines) or, more importantly, for photochemical and photophysical processes (e.g. photovoltaic power and photosynthesis).

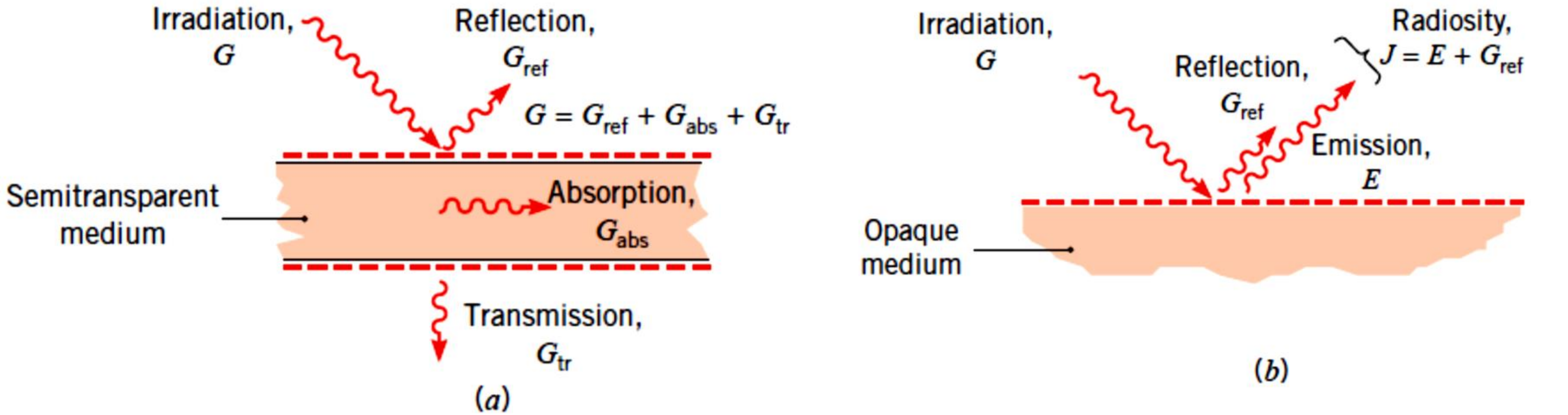
Spectrum of electromagnetic radiation



Note

The sun radiates in all regions of the spectrum, from radio waves to gamma rays. Our eyes are sensitive to less than one octave of this, from 0.4 to 0.75 μm, a region known as visible.

Radiation at a surface



(a) Reflection, absorption, and transmission of irradiation for a semitransparent medium.
(b) The radiosity for an opaque medium.

The solar spectrum can be divided into three main regions:

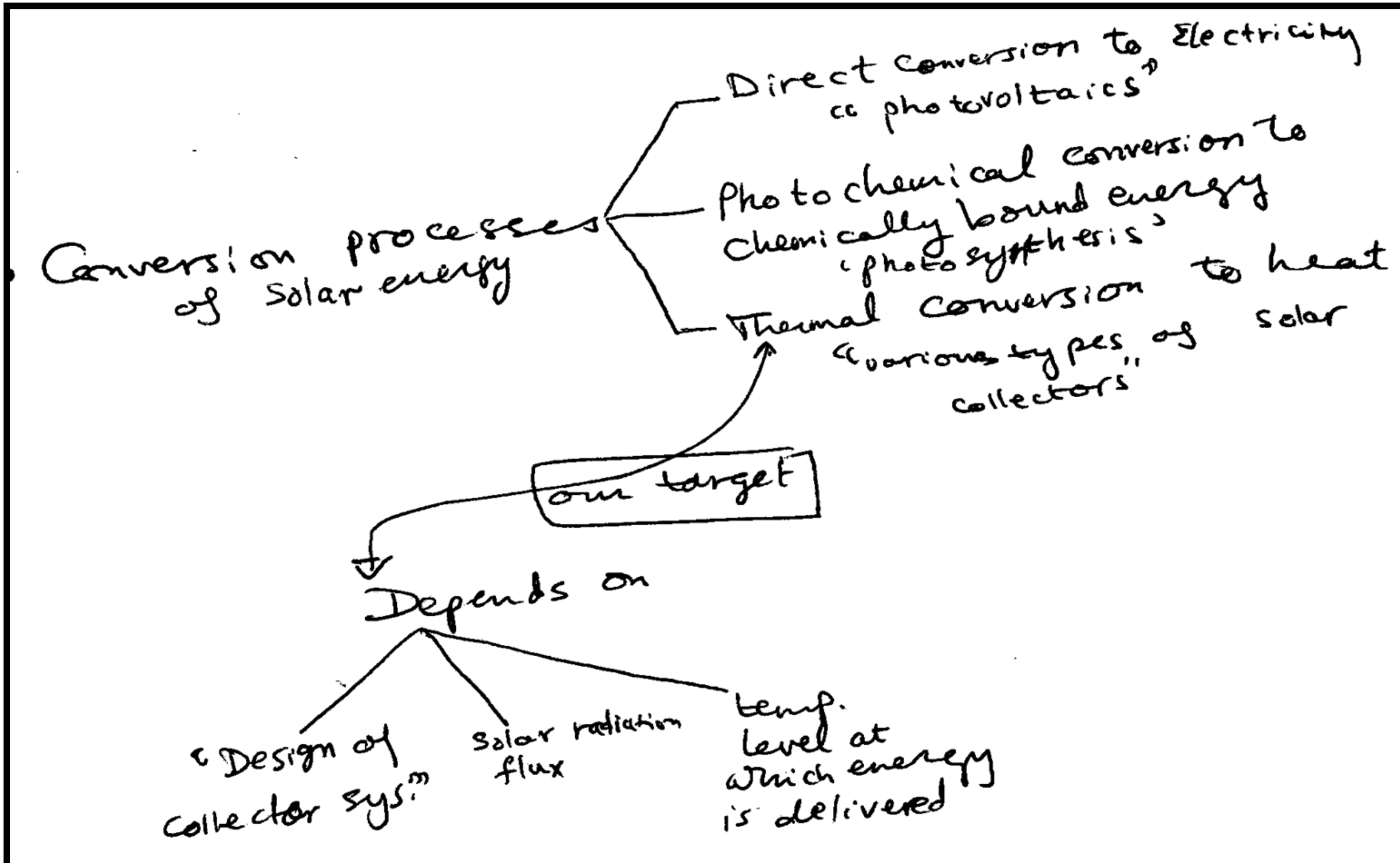
1	Ultraviolet region ($\lambda < 0.4\,\mu m$)	~5% of the irradiance
2	Visible region ($0.4\,\mu m < \lambda < 0.7\,\mu m$)	~43% of the irradiance
3	Infrared region ($\lambda > 0.7\,\mu m$)	~52% of the irradiance.

The proportions given above are as received at the Earth's surface with the Sun incident at about 45.

Radiative fluxes (over all wavelengths and in all directions)

Flux (W/m^2)	Description	Comment
Emissive power, E	Rate at which radiation is emitted from a surface per unit area	$E = \varepsilon\sigma T_s^4$
Irradiation, G	Rate at which radiation is incident upon a surface per unit area	Irradiation can be reflected, absorbed, or transmitted
Radiosity, J	Rate at which radiation leaves a surface per unit area	For an opaque surface $J = E + \rho G$
Net radiative flux, $q''_{\text{rad}} = J - G$	Net rate of radiation leaving a surface per unit area	For an opaque surface $q''_{\text{rad}} = \varepsilon\sigma T_s^4 - \alpha G$

Solar Energy



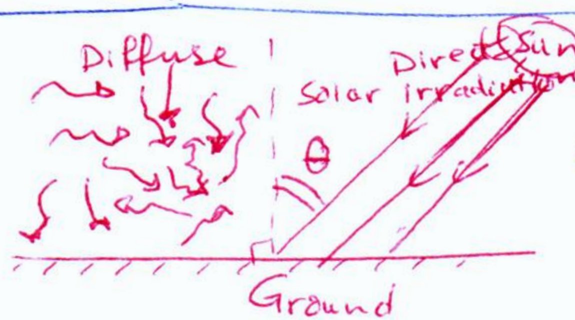
Components of Solar radiation

Beam or direct radiation

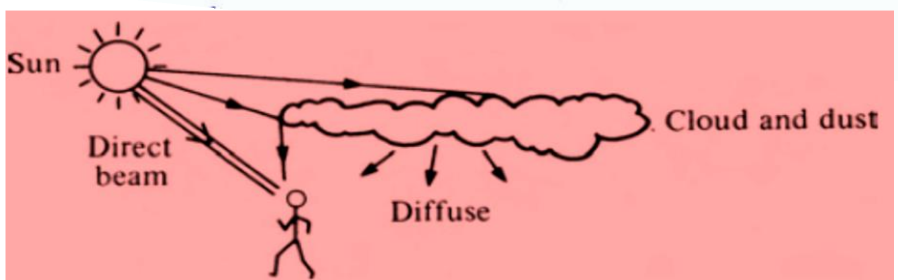
θ = angle of incidence

$\theta = 90^\circ$ zero direct rad.

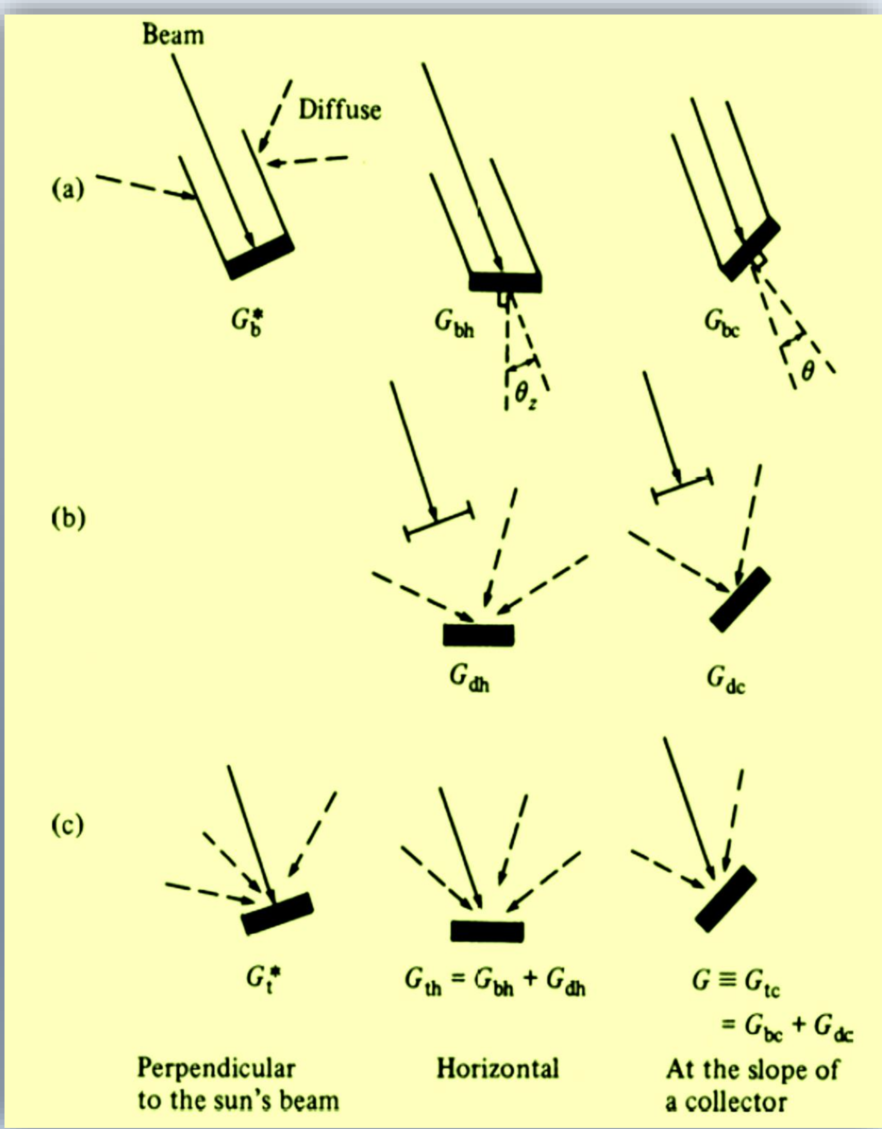
$\theta = 0^\circ$ max. " "



Diffuse radiation



Techniques to measure various components of solar radiation



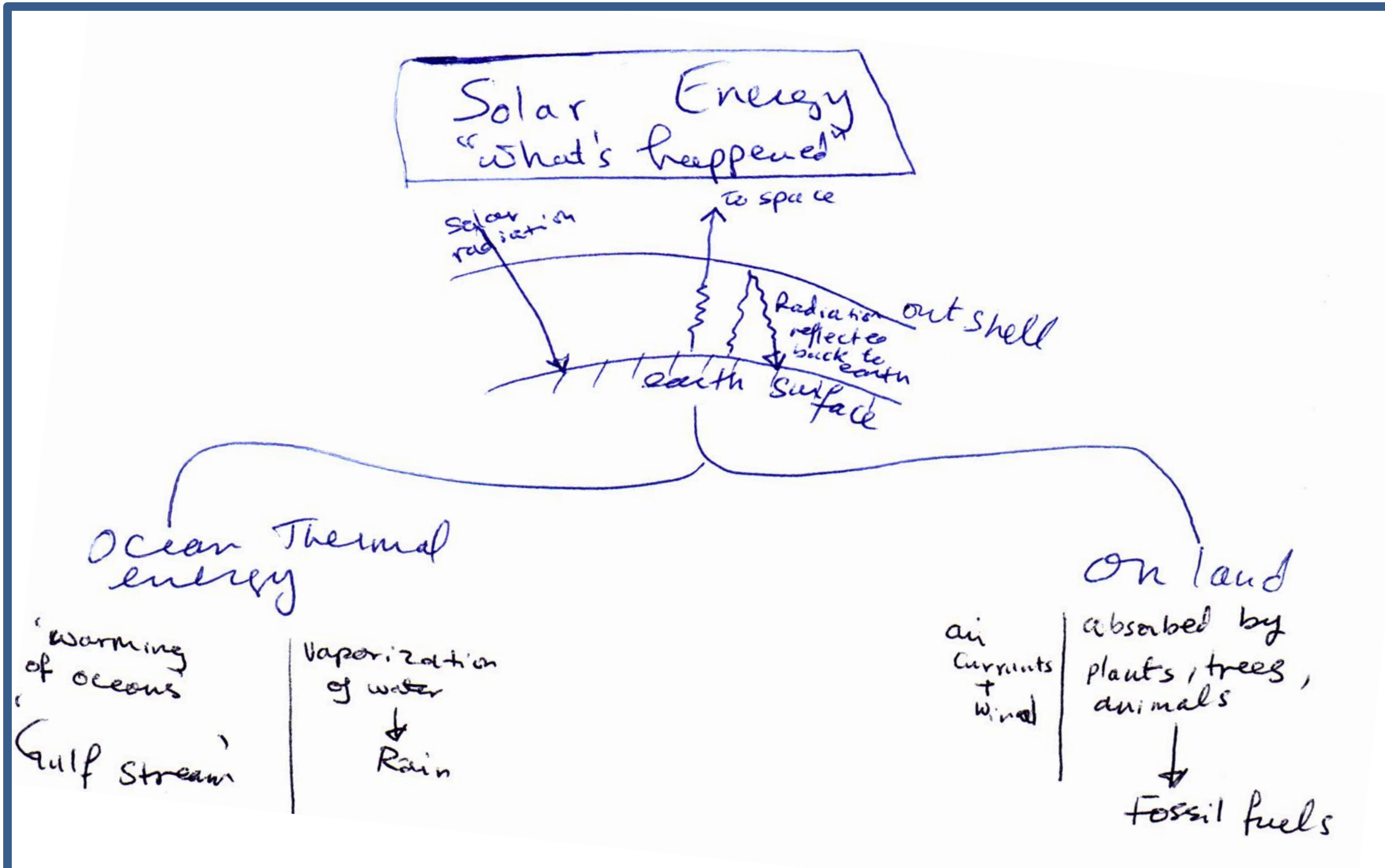
The detector is assumed to be a black surface of unit area with a filter to exclude long wave radiation. (a) Diffuse blocked. (b) Beam blocked. (c) Total

From the figure we can write the following equations:

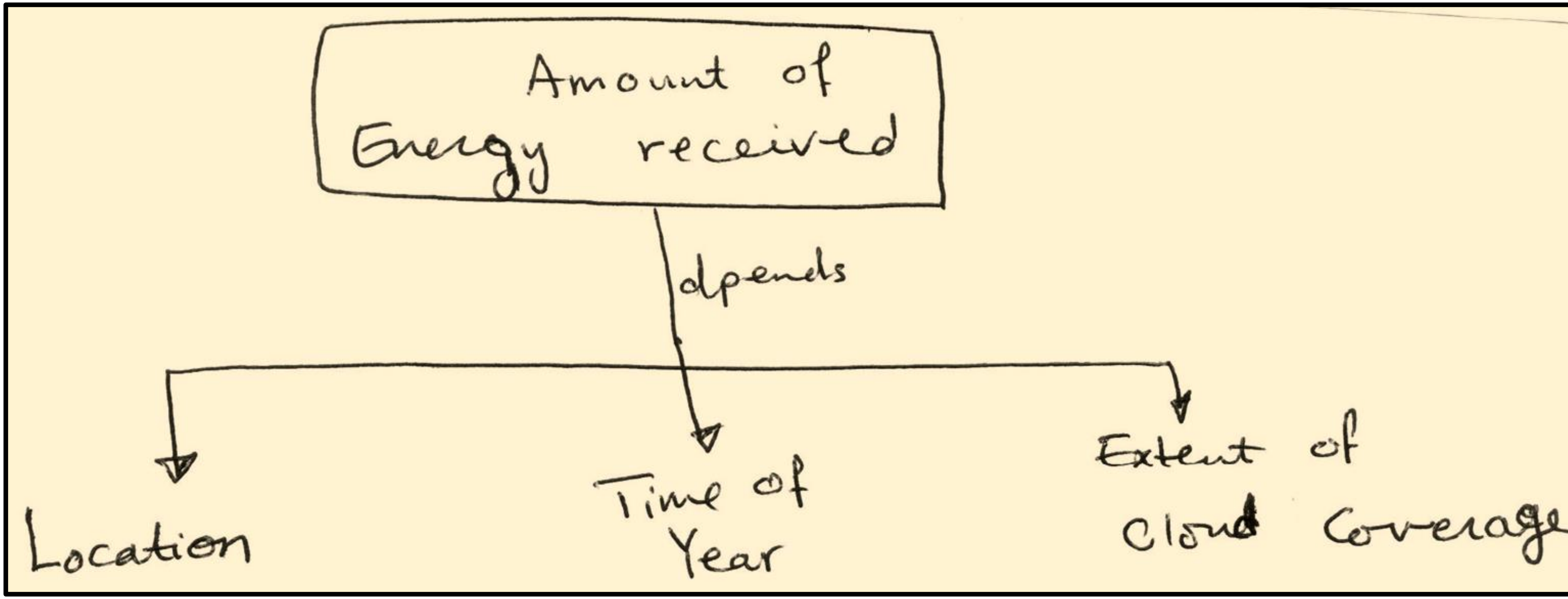
$$G_{bc} = G_b^* \cos\theta$$

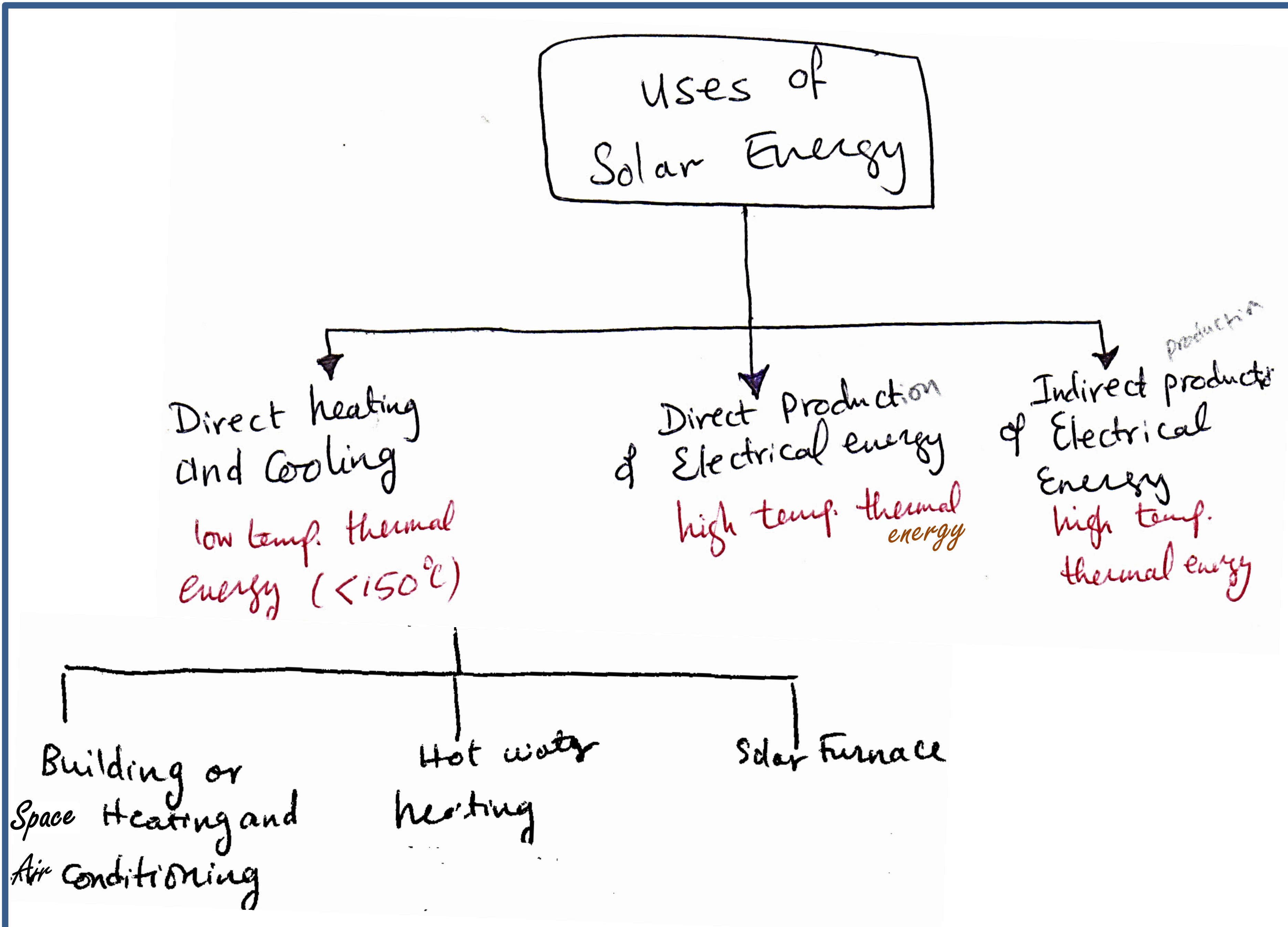
$$G_{bh} = G_b^* \cos\theta_z$$

$$G_t = G_b + G_d$$

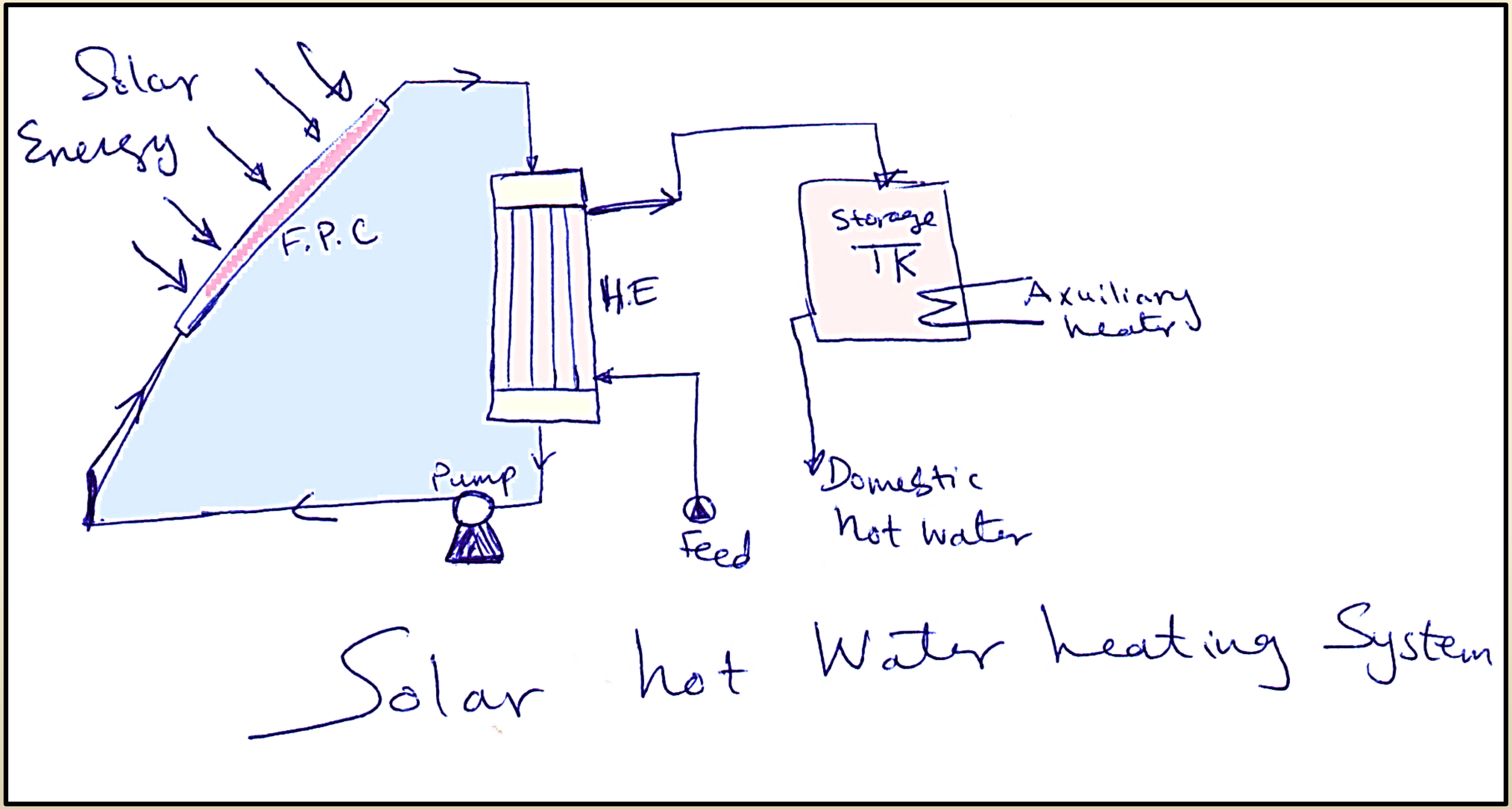


Solar Energy
"What's happened"
to space
Solar radiation
Radiation reflected back to earth
out shell
earth surface
Ocean Thermal energy
warming of oceans
Gulf stream
Vaporization of water
Rain
On land
air currents + wind
absorbed by plants, trees, animals
Fossil fuels

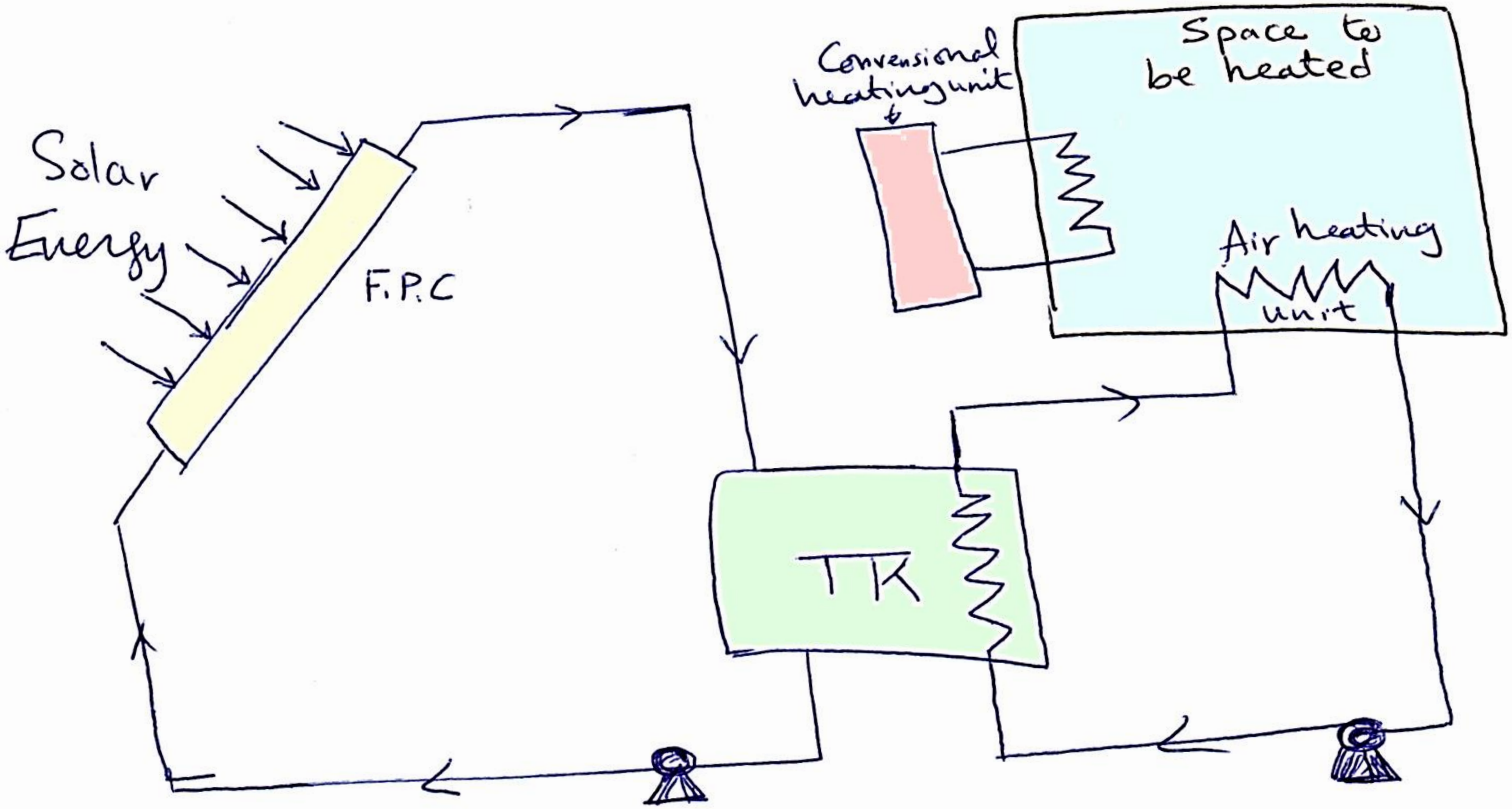

Amount of Energy received
dpends
Location
Time of Year
Extent of Cloud Coverage


Uses of Solar Energy
Direct heating and Cooling
low temp. thermal energy (<150°C)
Direct Production of Electrical energy
high temp. thermal energy
Indirect production of Electrical Energy
high temp. thermal energy
Building or Space Heating and Air Conditioning
Hot water heating
Solar Furnace

Solar hot water heating system

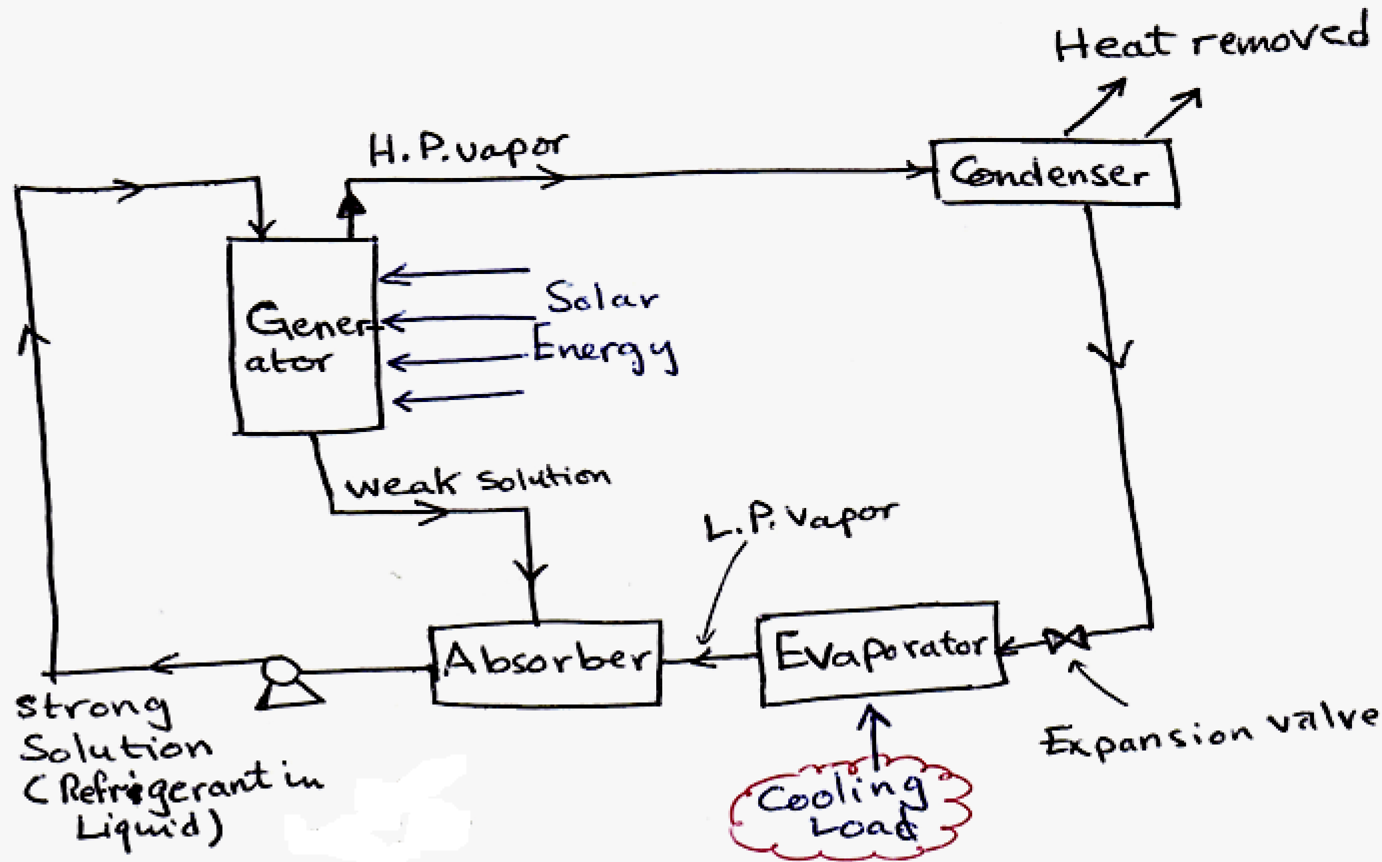


Solar space heating unit



Solar Space heating Unit

Solar air conditioning

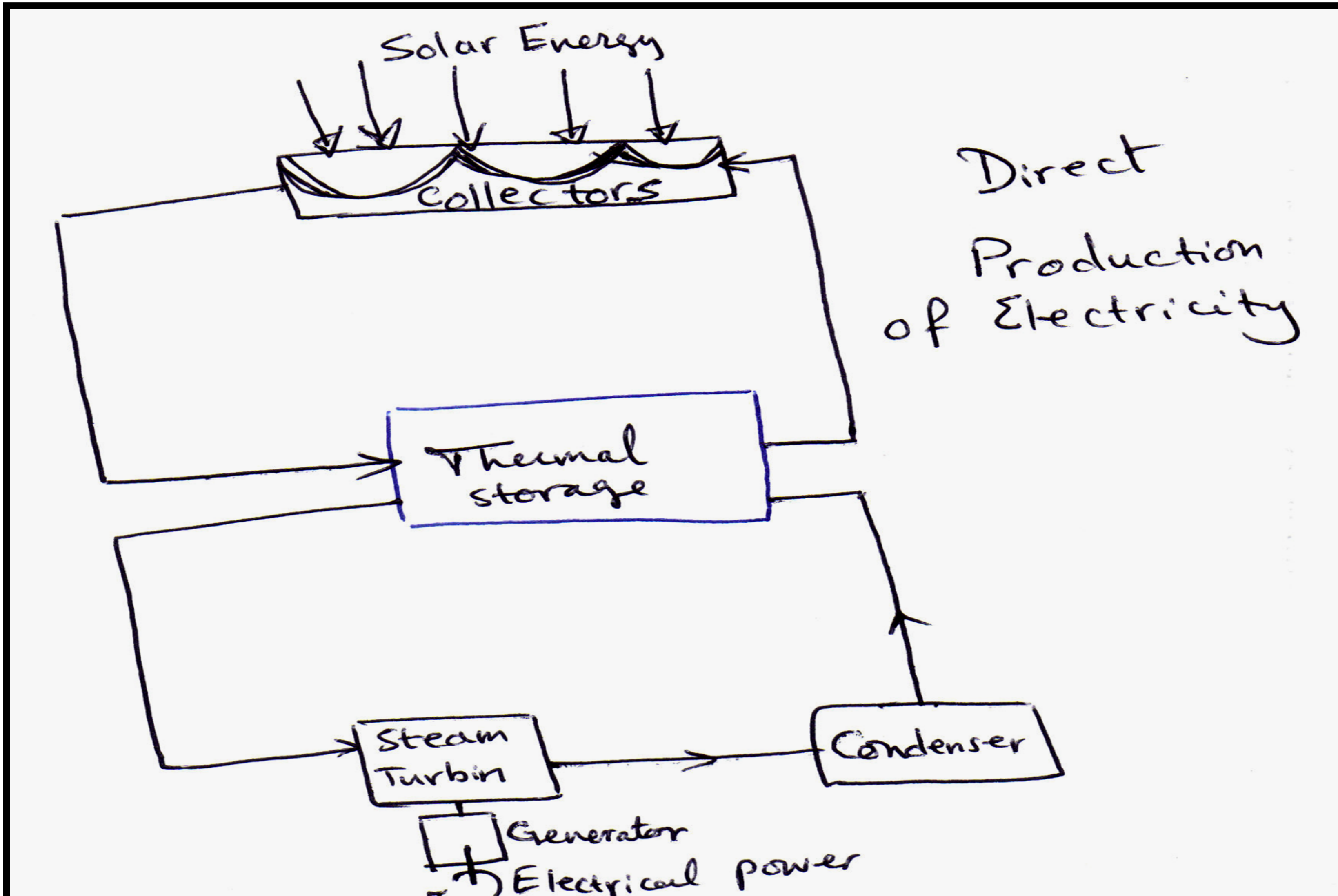


Elements of absorption system for Solar air conditioning.

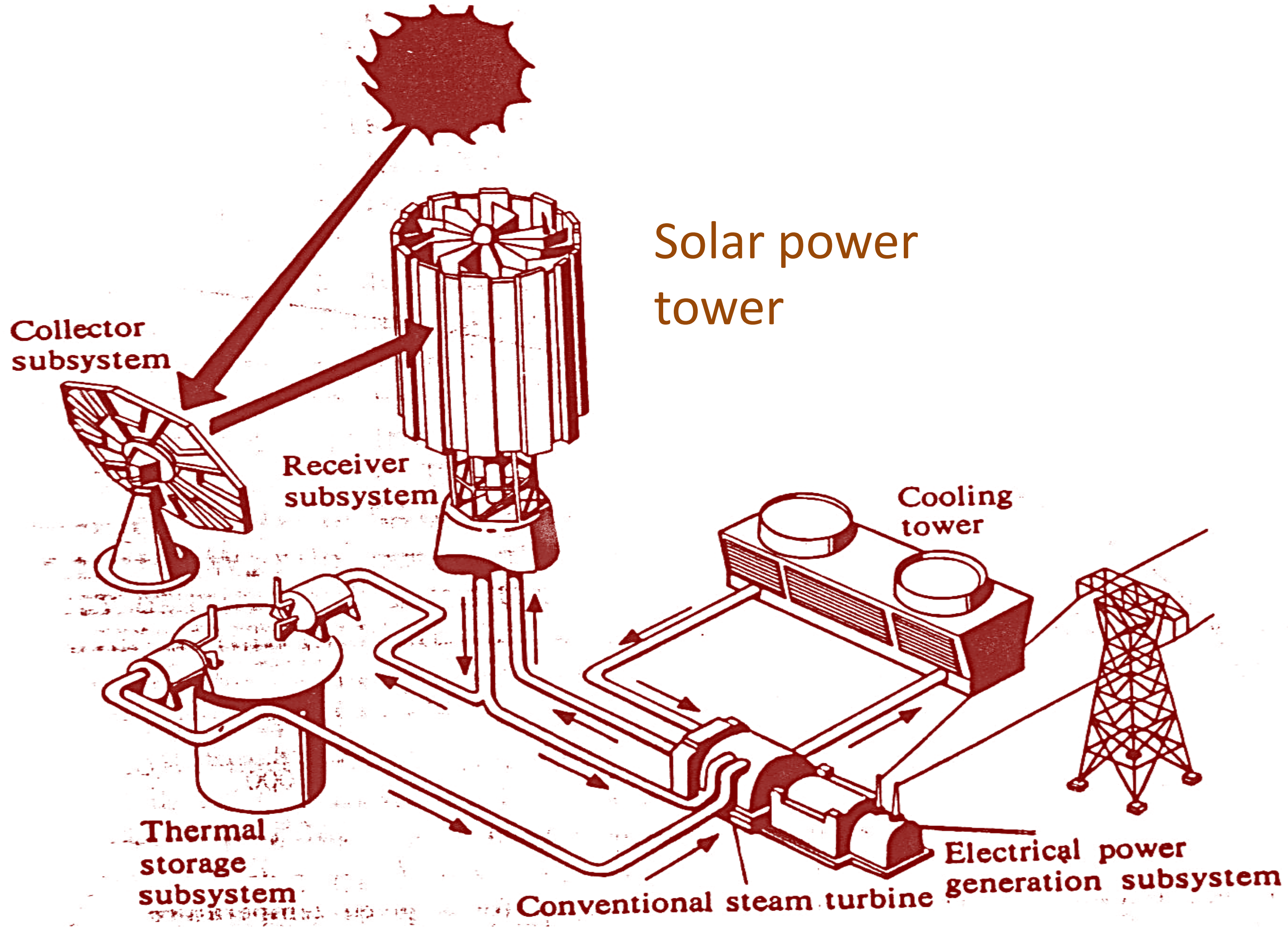
H.P : High Pressure

L.P. : Low Pressure

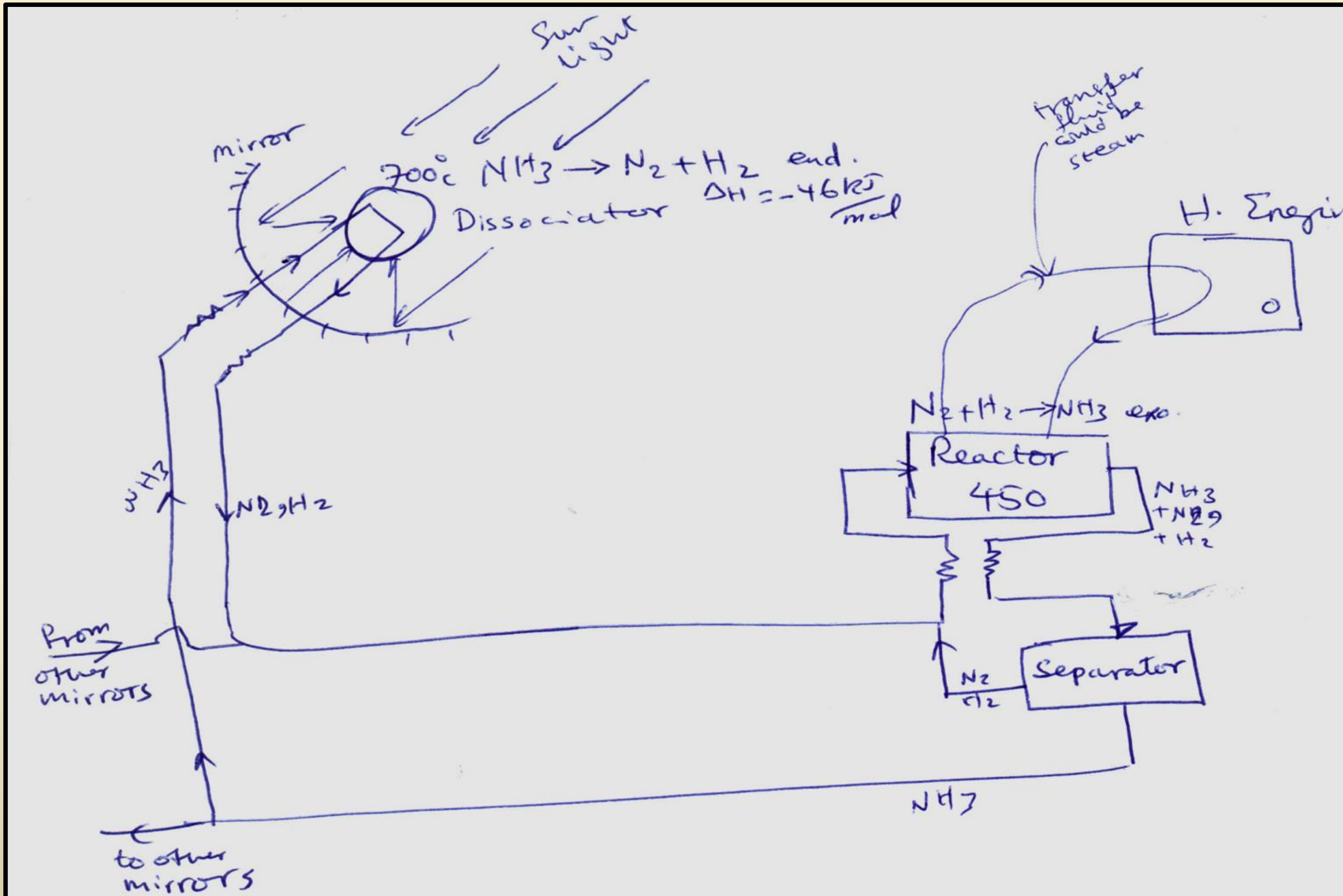
Direct production of electricity



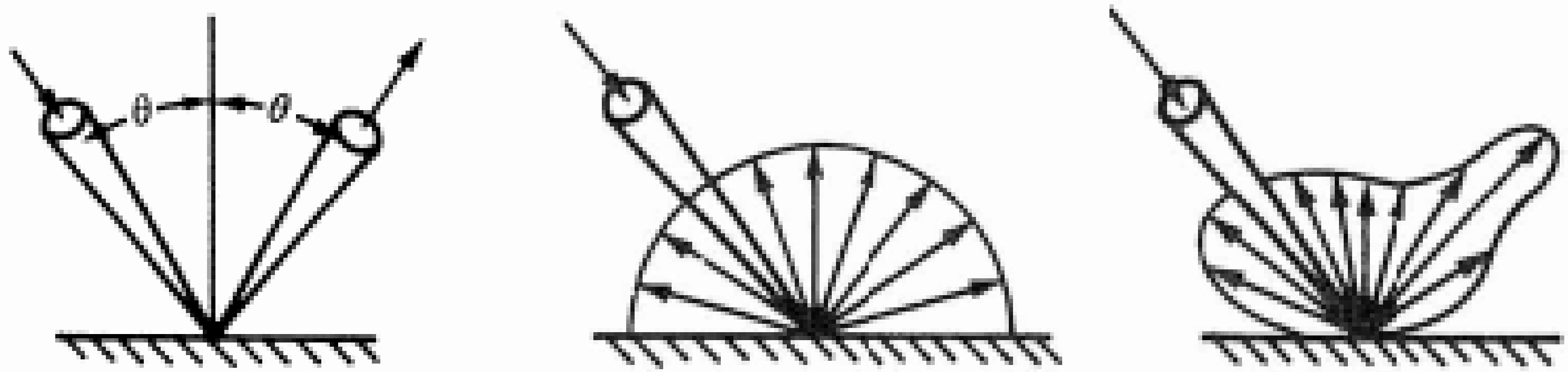
Electric generation system_ basic units



Dissociation and synthesis of ammonia as a storage medium for solar energy. (Indirect method)



Types of Reflection



Ideal specular reflection (a)

Ideal diffuse reflection (b)

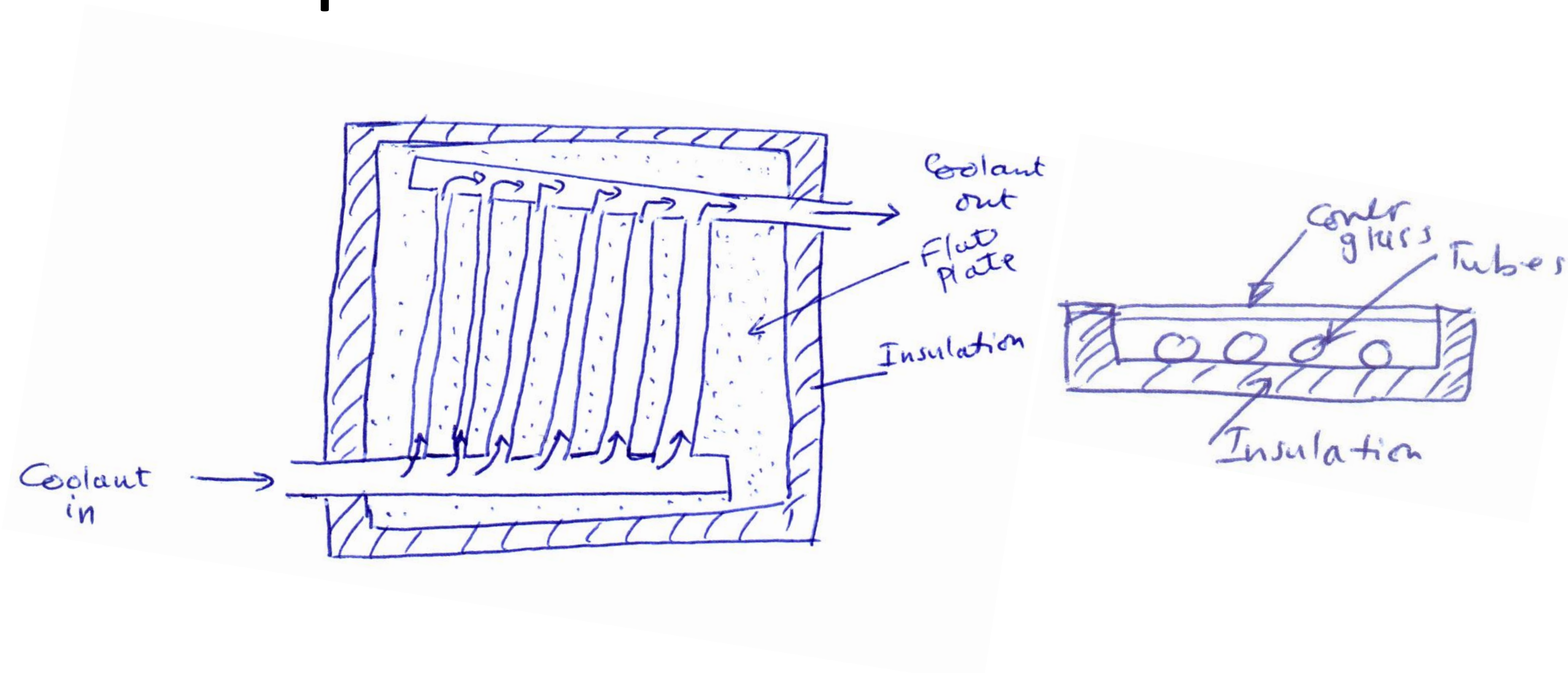
Reflection from real surface (c)

Types of Collectors

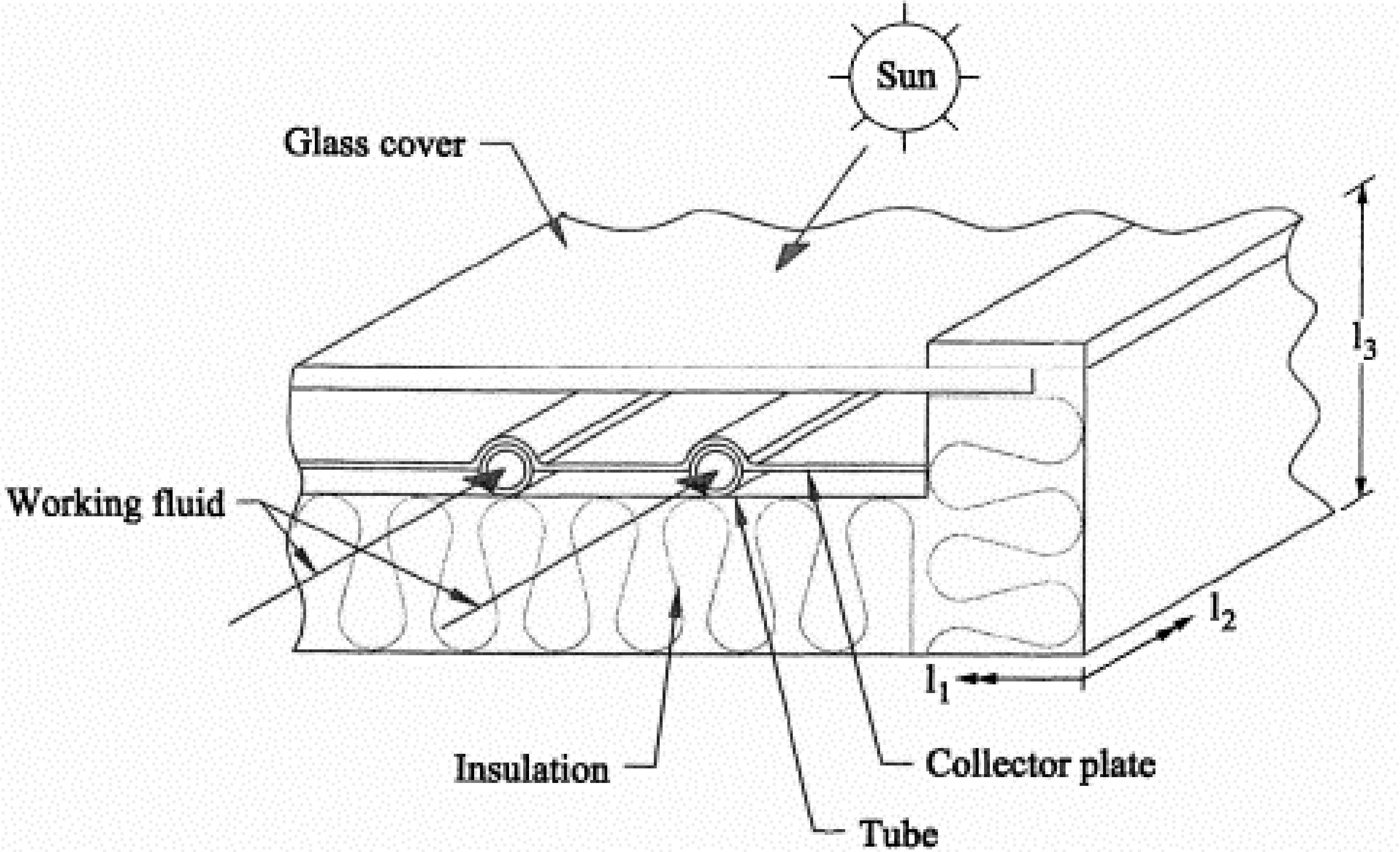
- None concentrating stationary
- Slightly concentrating with or without periodic adjustment
- Concentrating tracking collectors

None concentrating stationary

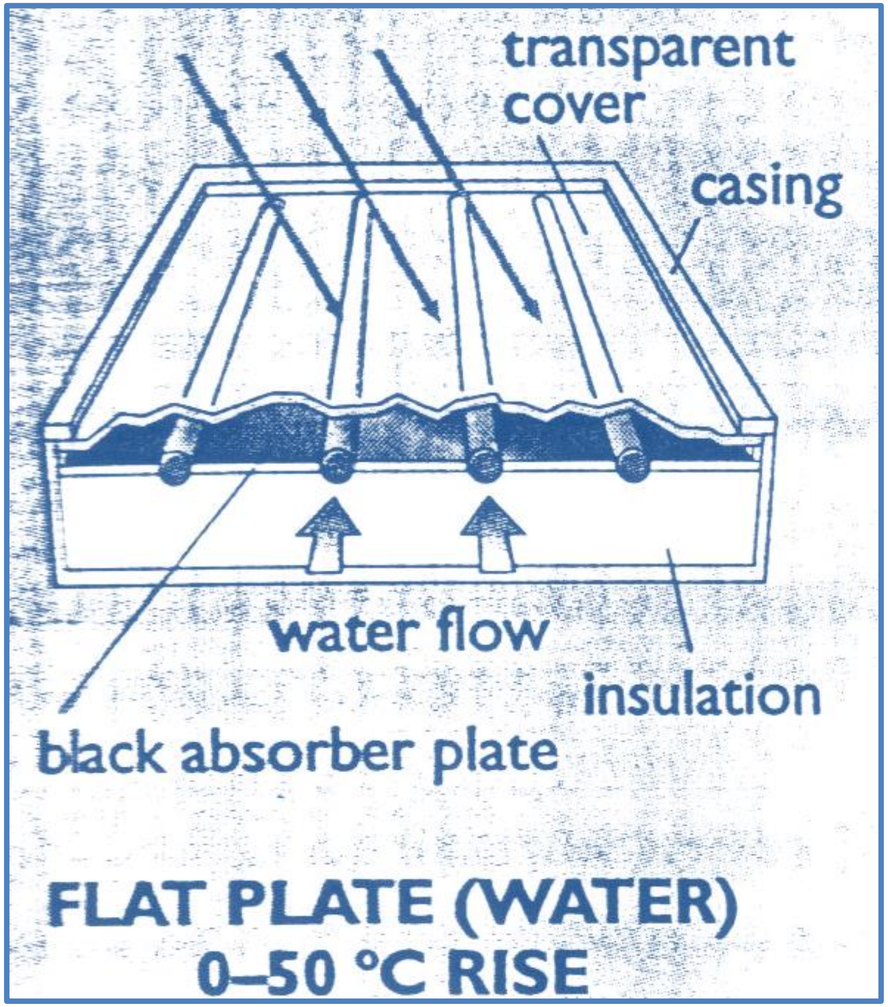
- Flat-plate collectors

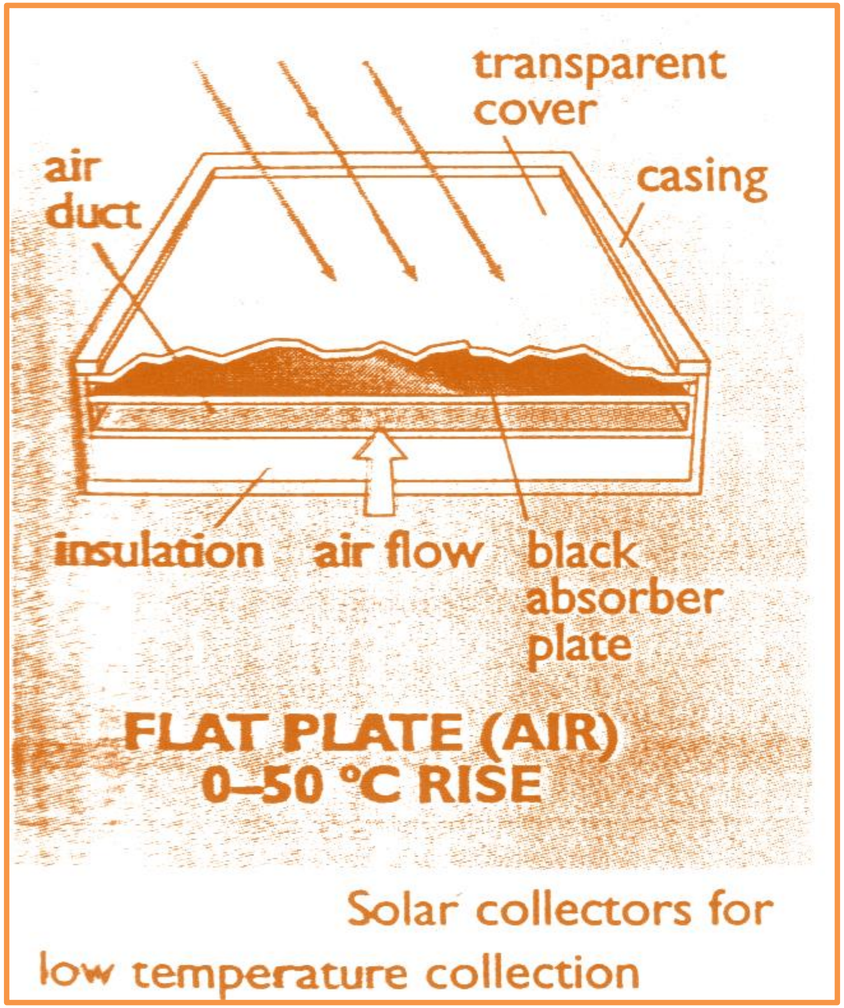


Schematic diagram of solar collector Main components

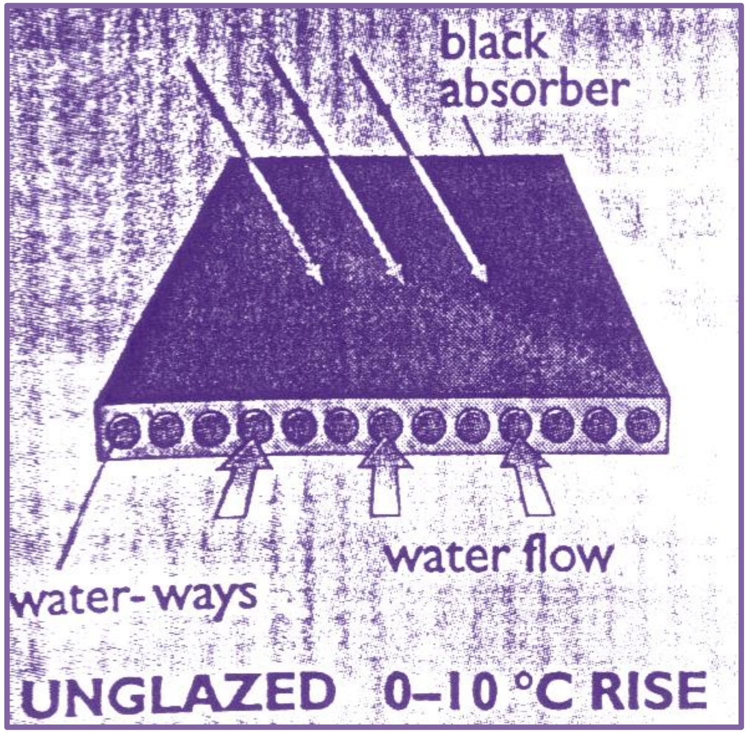


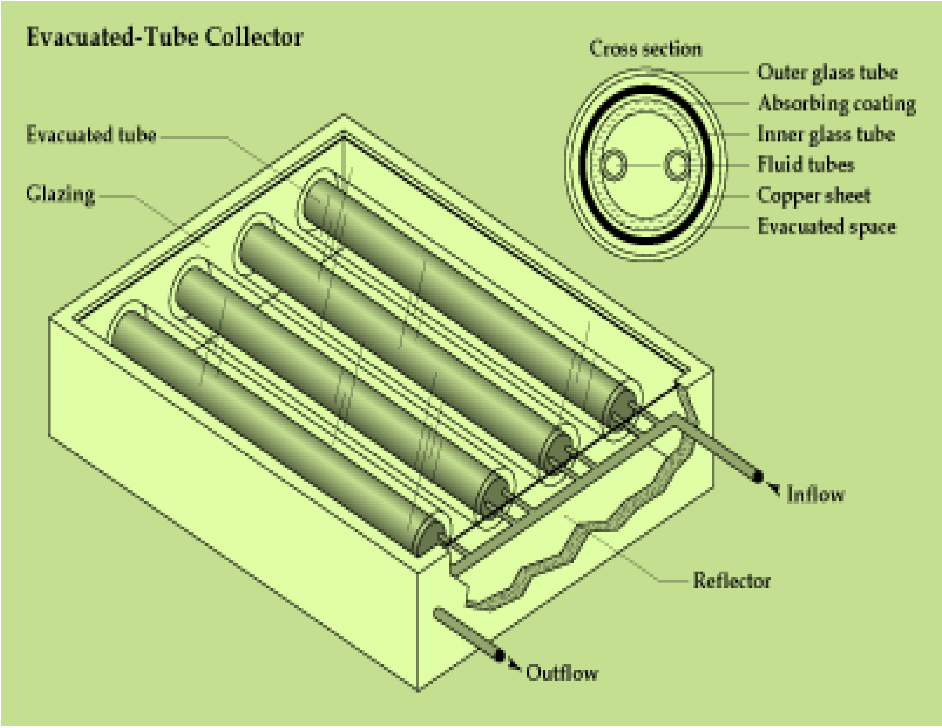
Flat plate collectors _ main components



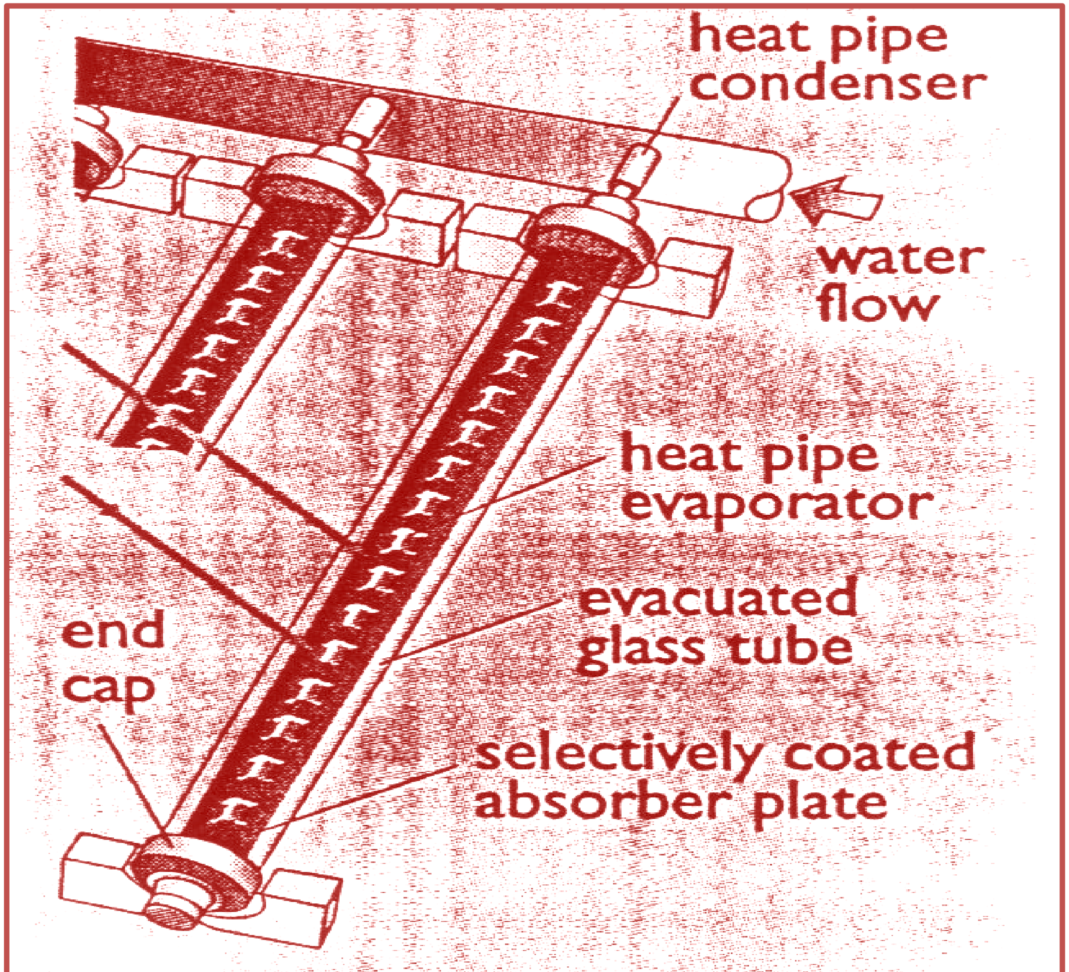


Flat plate collectors

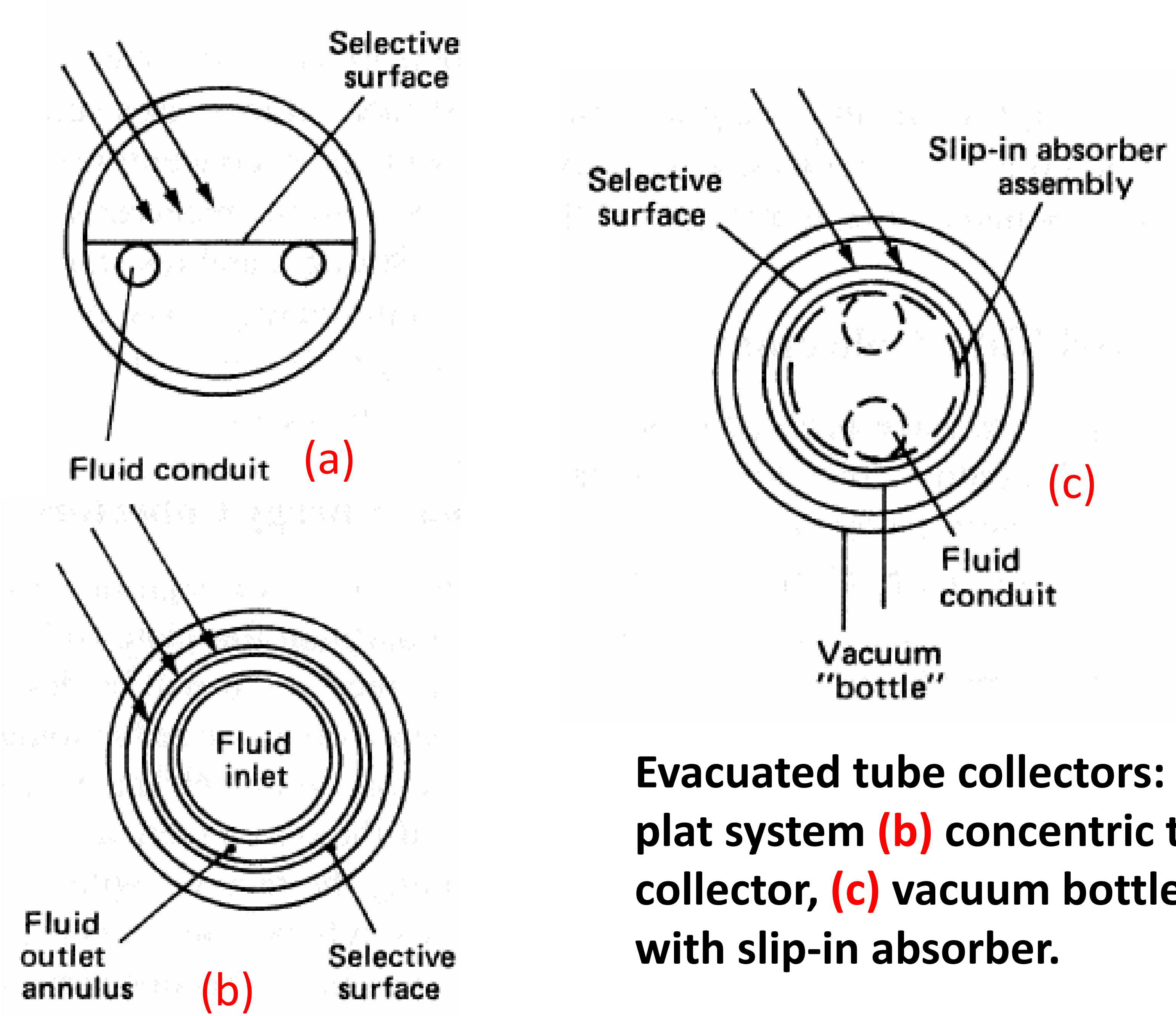




Evacuated tube

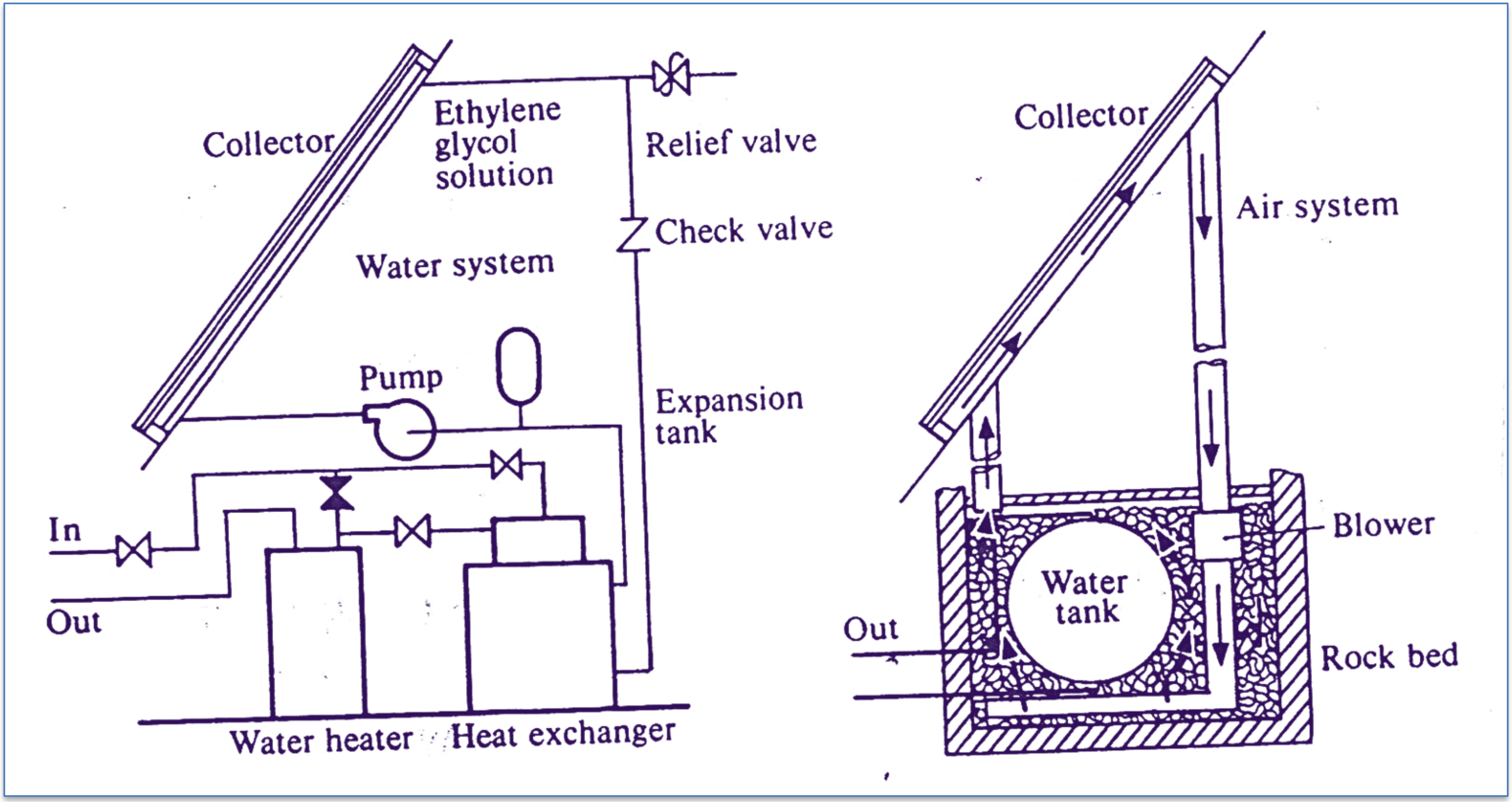


EVACUATED TUBE
10–150 °C RISE

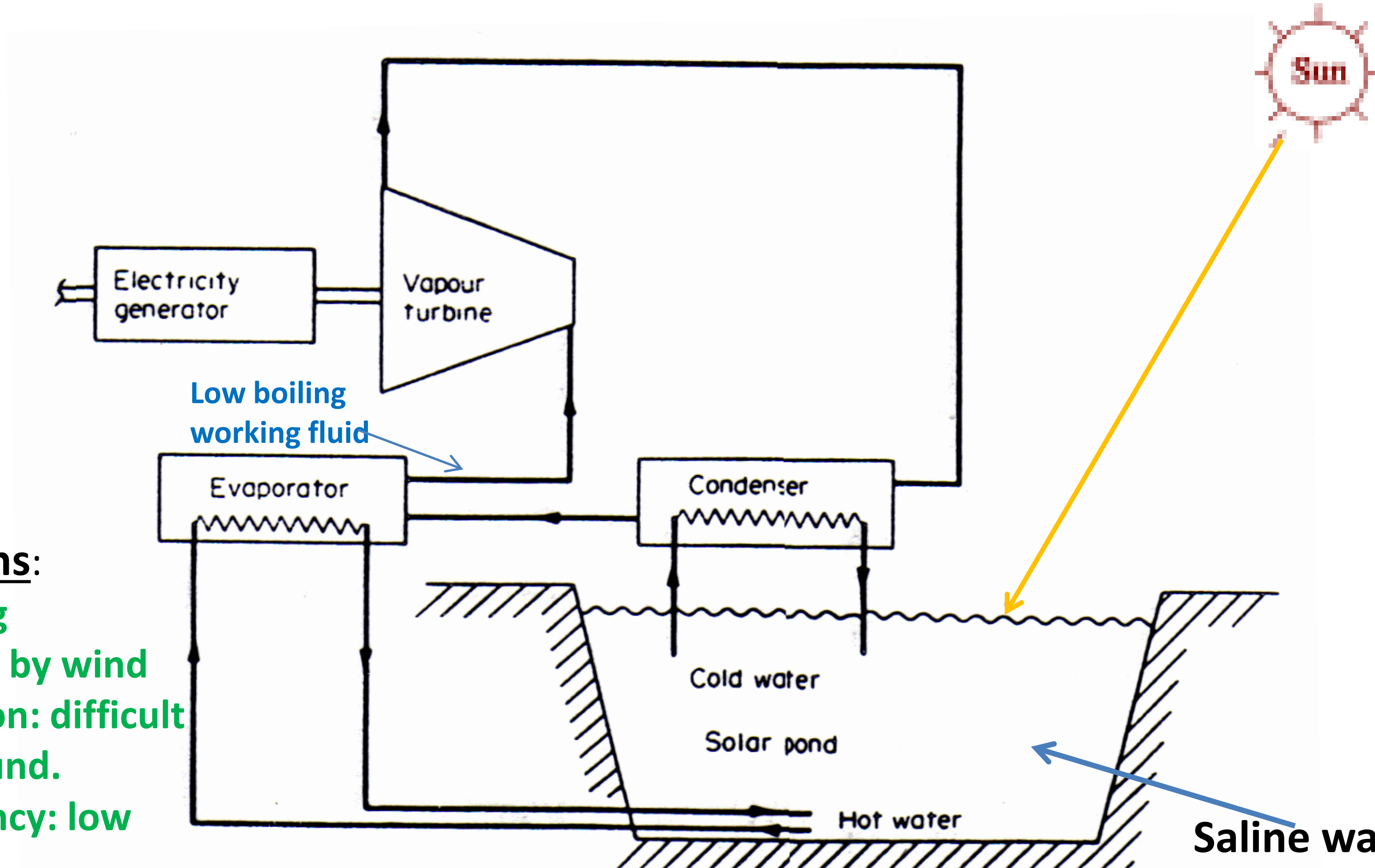


Evacuated tube collectors: (a) flat plat system (b) concentric tubular collector, (c) vacuum bottle collector with slip-in absorber.

Typical flat plate collector_ different heat storage _ different working fluids



Solar salt pond



Saline water 'saturated with salt'

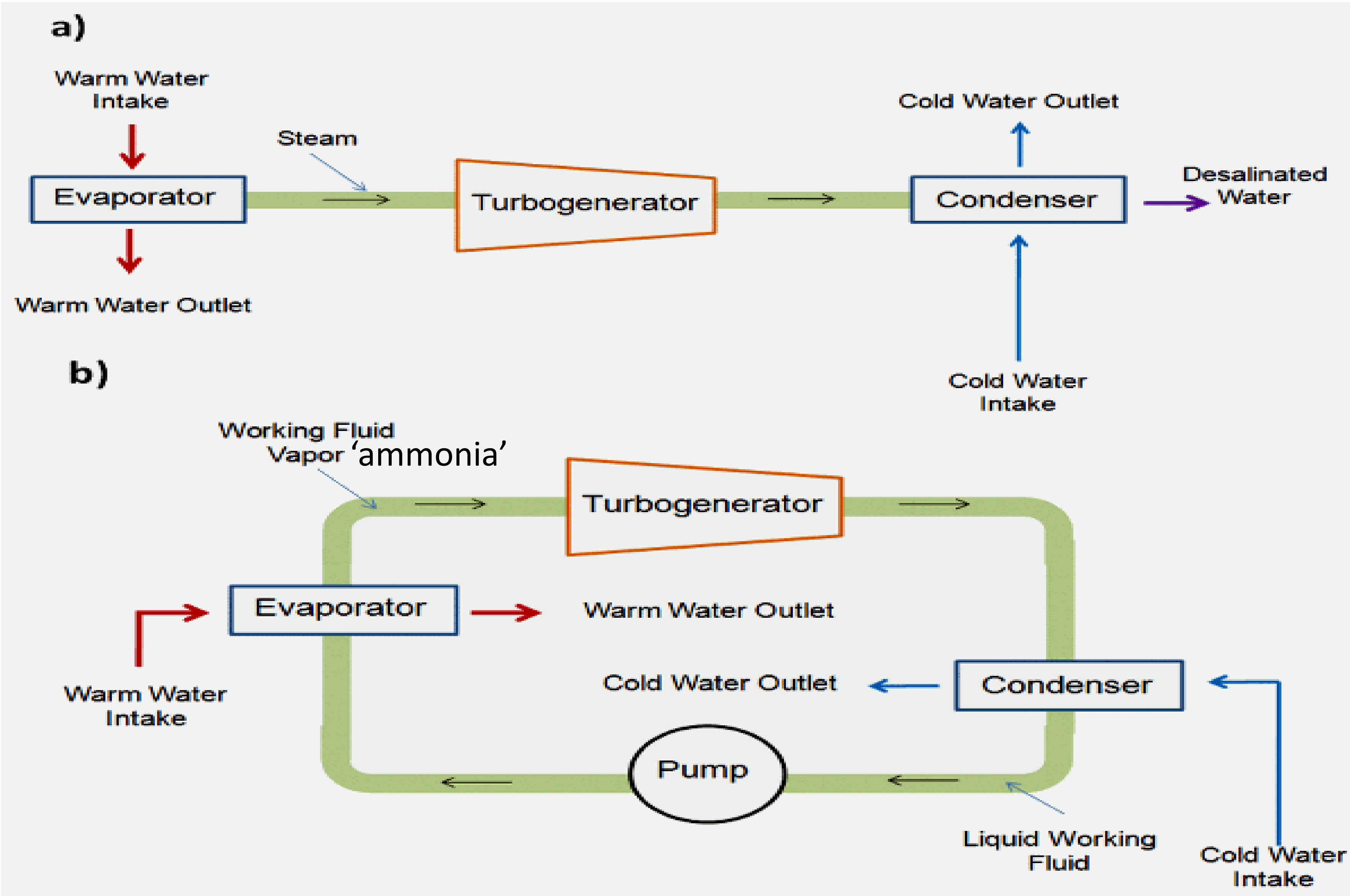
Problems:
- ✓Fouling
- ✓Mixing by wind
- ✓Location: difficult to be found.
- ✓Efficiency: low

The bottom water layer is more hotter than the surface water. Give the reason.

Solar salt pond vis OTEC system

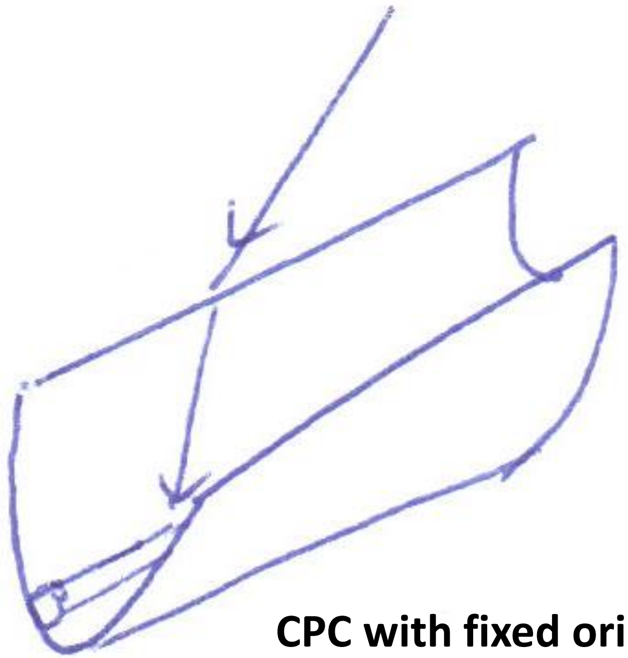
- Solar salt pond is of a small scale, inverse OTEC system.
- Ocean thermal energy conversion (OTEC) uses the temperature difference between cooler deep and warmer surface ocean waters to run a heat engine and produce useful work (electricity).
- In case of solar pond, as the surface water becomes warmer , the solubility of this warm water increases and the solution becomes heavier as it dissolves more salts. This condition causes the hot water to sink to the bottom of the pond.

Schematics of (a) open cycle and (b) closed cycle OTEC systems



Slightly concentrating with or without periodic adjustment

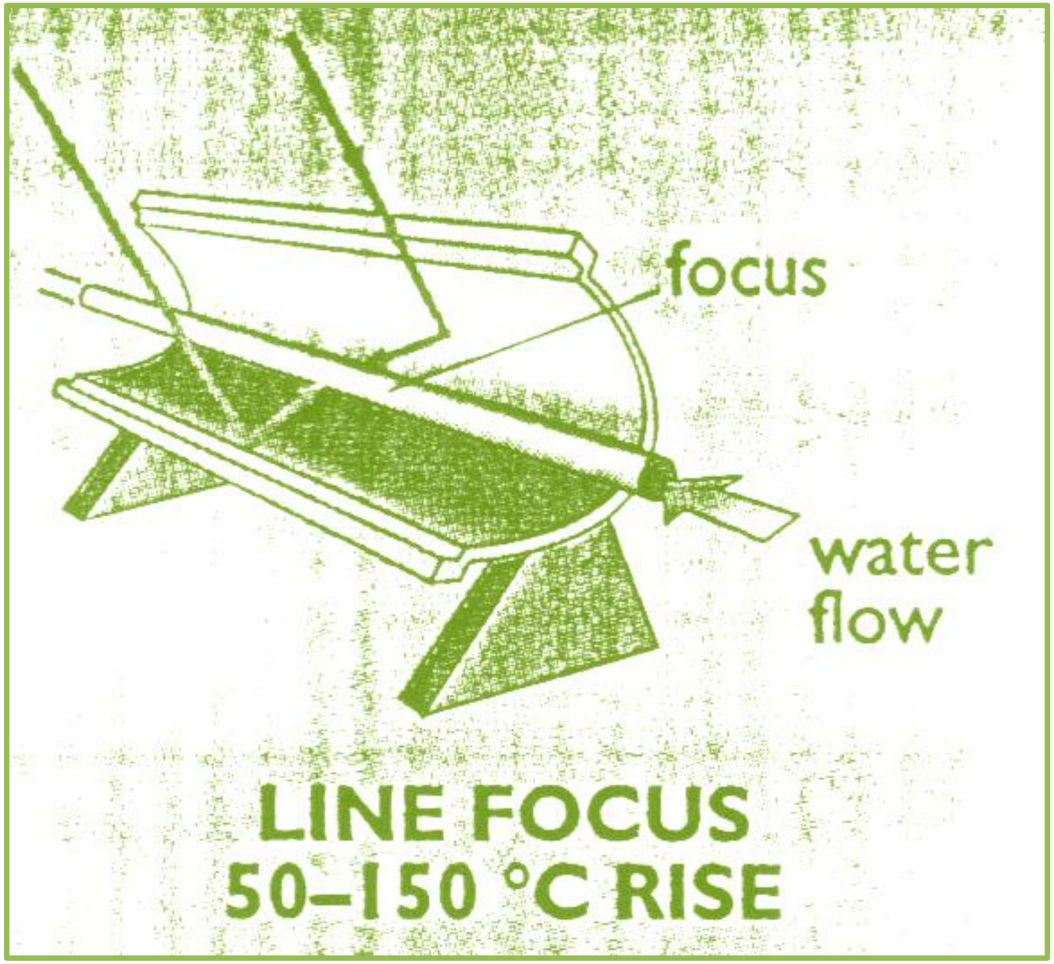
- Compound parabolic concentrator (CPC) and v trough



Temp range:
367- 533 K

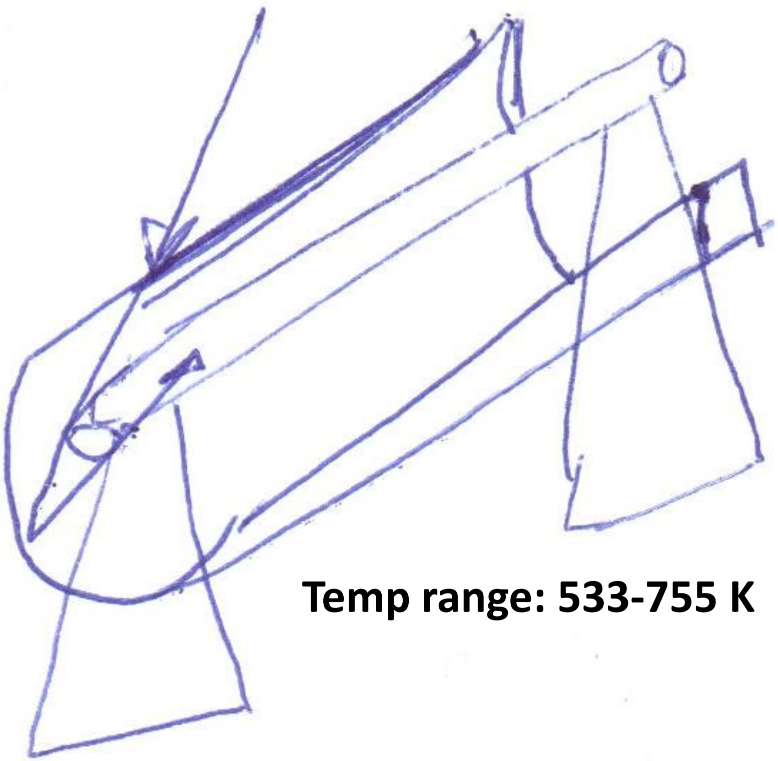
CPC with fixed orientation or periodic adjustment

parabolic concentrator



Concentrating tracking collectors

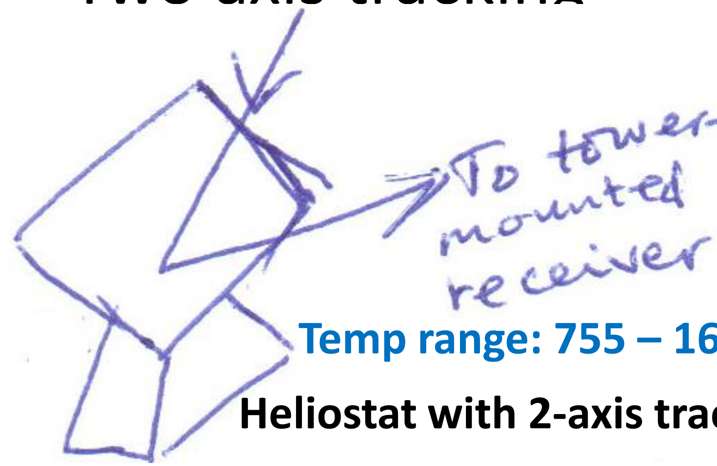
- One axis tracking



Temp range: 533-755 K

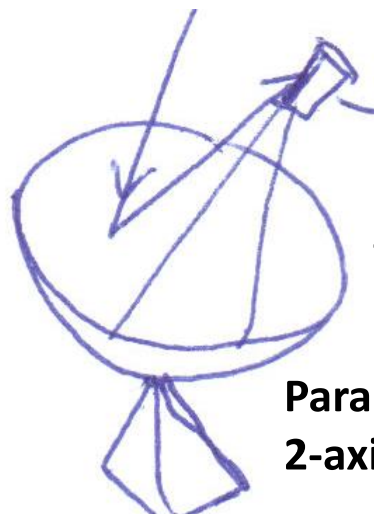
Parabolic trough with one axis tracking

- Two axis tracking



Temp range: 755 – 1645 K

Heliostat with 2-axis tracking

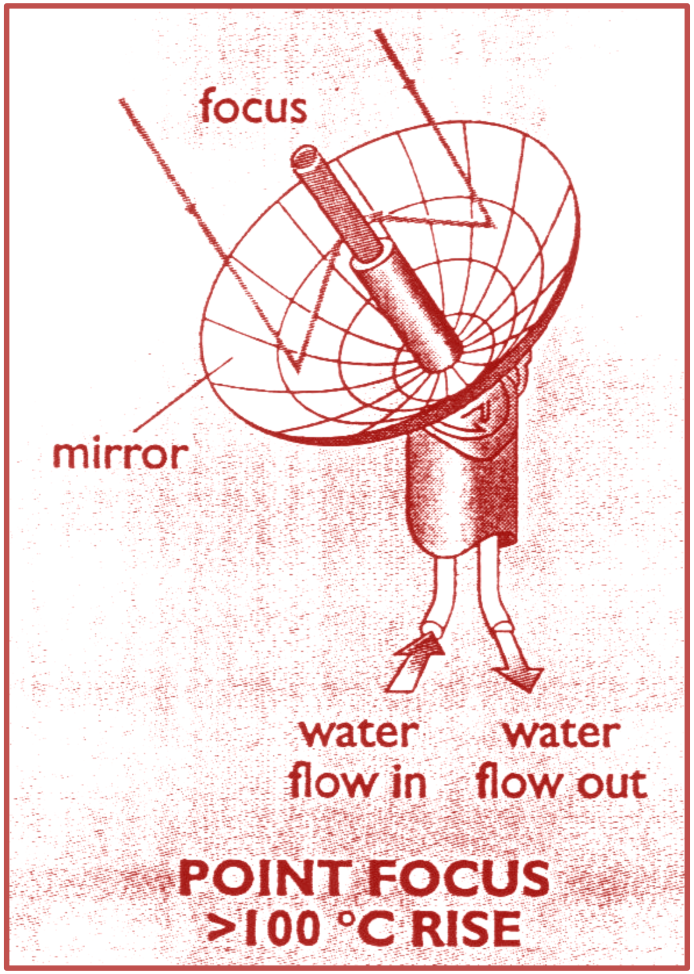


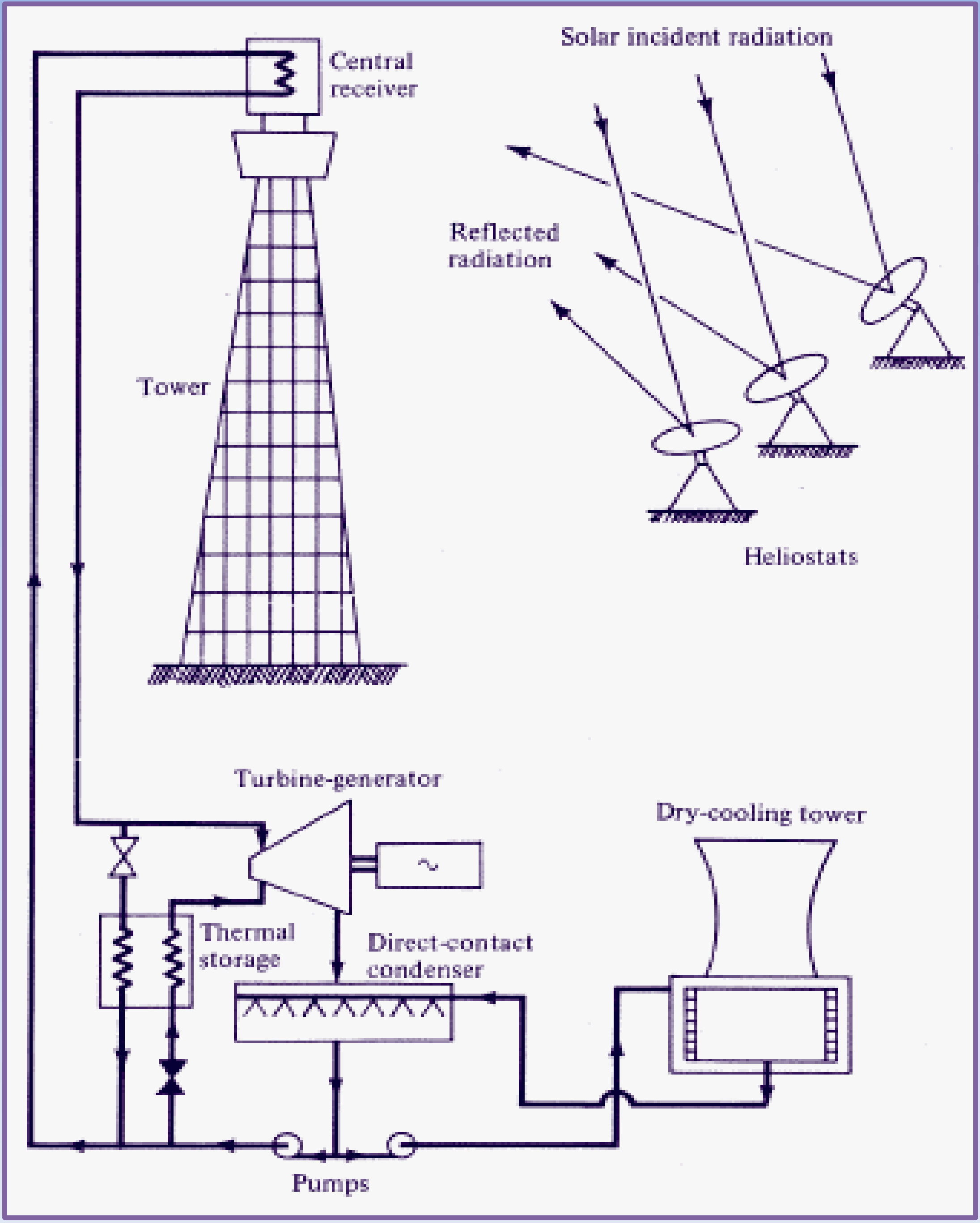
Cavity receiver

Temp range: 755 – 1645 K

Paraboloidal dish with 2-axis tracking

Focusing collector





Schematic of a Solar-thermal central-receiver system power plant.

Summary

Types of collector systems

- Photosynthetic collectors
- Flat plate collectors
- Focusing collectors
- Satellite collectors (large array of solar cells ⇒ convert electromagnetic energy of the sun into electricity ⇒ this energy is converted back into microwaves ⇒ this microwaves beam to an earth receiving system ⇒ finally this energy is converted back into electricity).
  This system can work continuously {no interruption}
  ~ See next slide

Put in orbit 35, 890 km around the earth

Space-based **solar** power 'Satellite collectors'