Energy Resources

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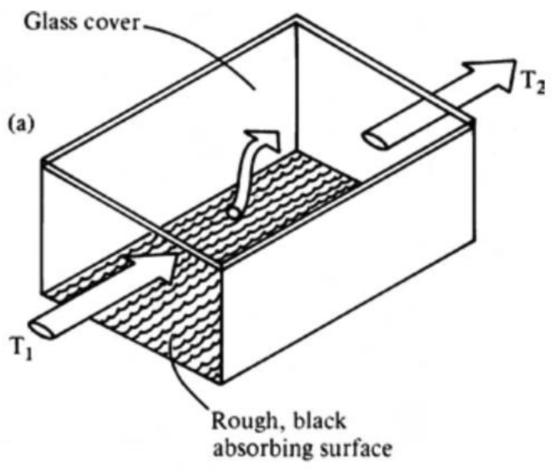
Lecture Contents

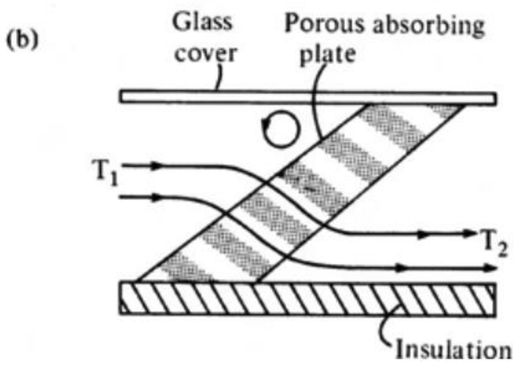
- Solar Air Heaters
- Energy Efficient Buildings
- Crop Driers
- Space Cooling
- Water Desalination

Solar Air Heaters

$$P_u = \rho c Q(T_2 - T_1)$$

For similar energy input which fluid (air or water) can have a higher volumetric flow rate?





Solar Air Heaters

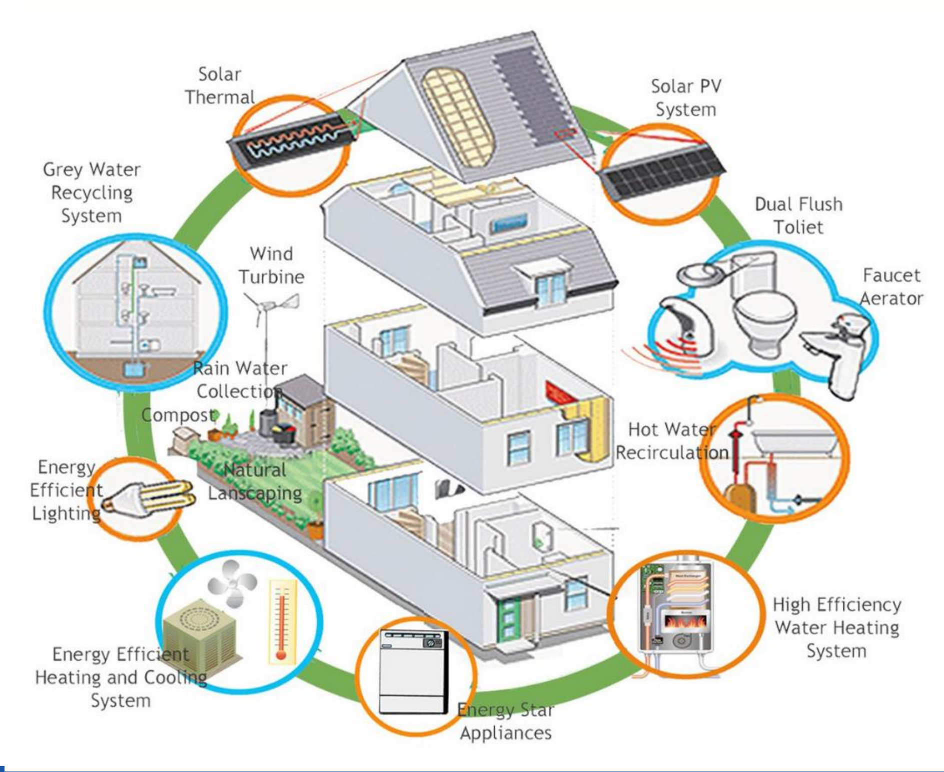
Thermal Conductivity of air is much less than water, therefore heat transfer from fluid to plate is low.

How can the heat transfer be improved?

$$\eta_c = \rho c Q \frac{(T_2 - T_1)}{G_c A}$$

$$P_u = f A G_c \tau_{cov} \alpha_p - U_c A (T_p - T_a)$$

Energy Efficient Buildings



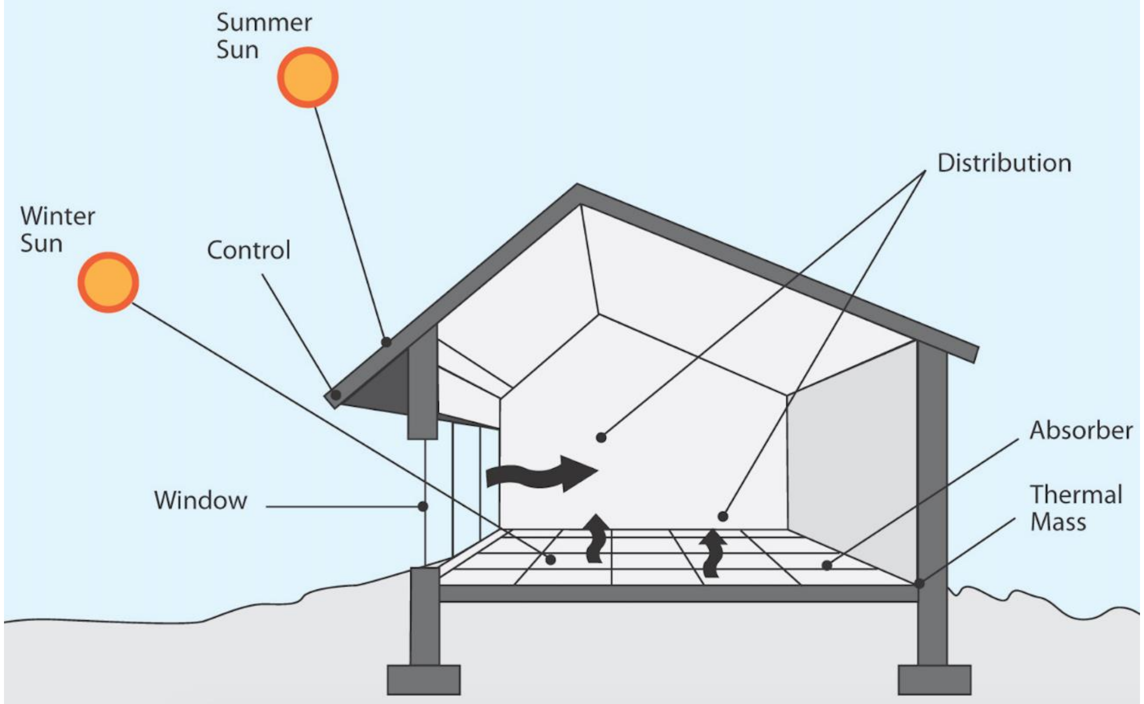
Energy Efficient Buildings

$$mc\frac{\mathrm{d}T_{\mathrm{r}}}{\mathrm{d}t} = \tau\alpha GA + P_{\mathrm{boost}} - \frac{(T_{\mathrm{r}} - T_{\mathrm{a}})}{R}$$

Two types of solar heating systems :

1. *Passive Solar Systems*
2. *Active Solar Systems*

Elements of Passive Solar Design



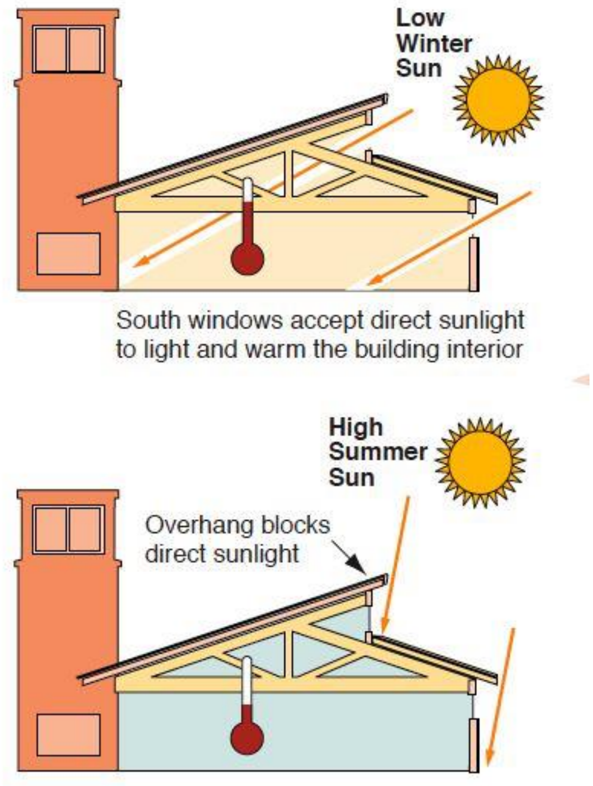
Passive Solar Systems

- Three major factors to consider are :
  - Mass *m*
  - Resistance *R*
  - Area of collector *A*
- Increase insulation to reduce *R*
- Orientation, size and position of windows
  - Sufficient GA in winters
  - Shading in summers
  - Multi surface construction of windows

Passive Solar Systems

- Main elements of a passive solar building:
  - Properly oriented windows
  - Thermal mass (concrete, brick, stone, and tile)
  - Distribution mechanisms (conduction, convection, radiation)
  - Control strategies (shades, sensor mechanism, low emissivity blinds)
  - Insulation and air sealing

Passive Solar Systems



Types of Passive Solar System

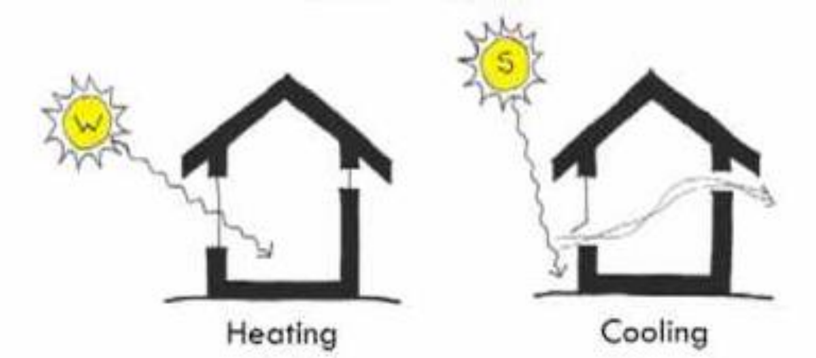
- ***Direct Gain***

A direct-gain passive system includes:

-south-facing windows (very often with movable insulation

-overhang shading,

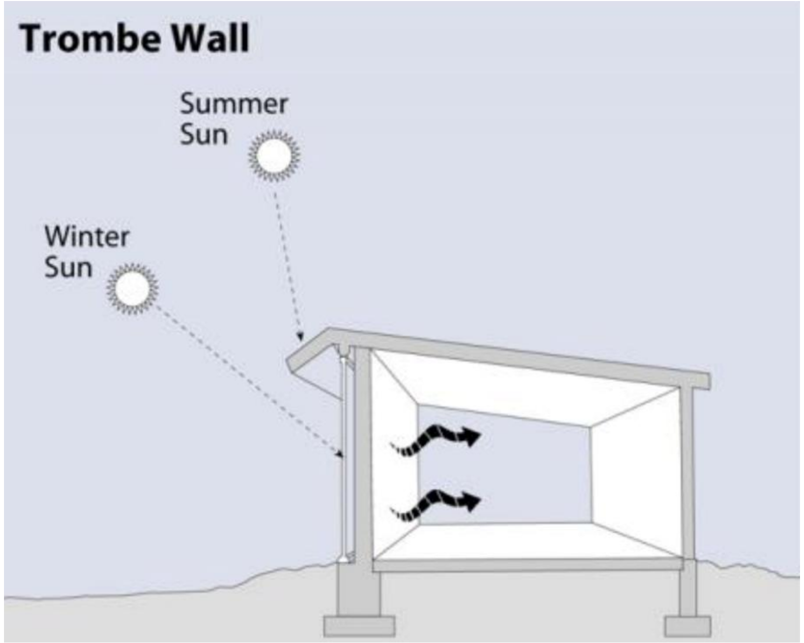
-rooms behind the windows serving as cavity absorbers & energy storage devices.



Types of Passive Solar System

Indirect Gain

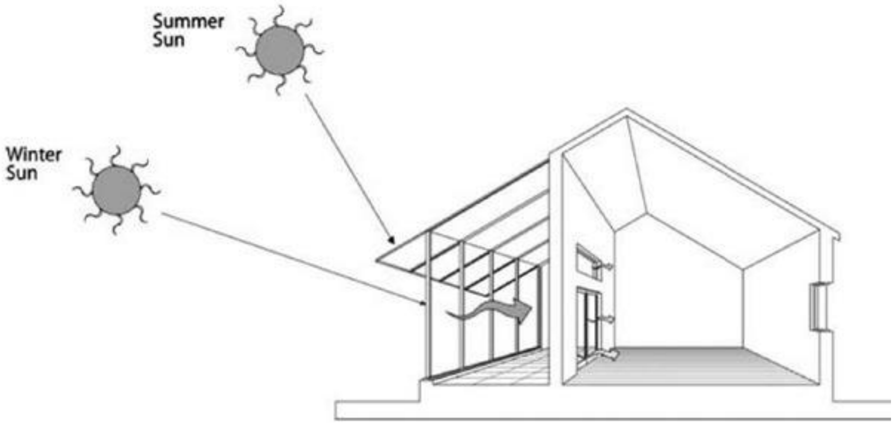
An indirect-gain passive solar home has its thermal storage between the south-facing windows and the living spaces. The most common indirect-gain approach is a Trombe wall (collector-storage) .



Types of Passive Solar System

Isolated Gain

- Sun space
- Main function is heat distribution
- Energy store is building itself
- Air is the heat transfer fluid



(c) Isolated solar gain (sunspace)

Active Solar Systems

Active solar systems use separate collector with air or water

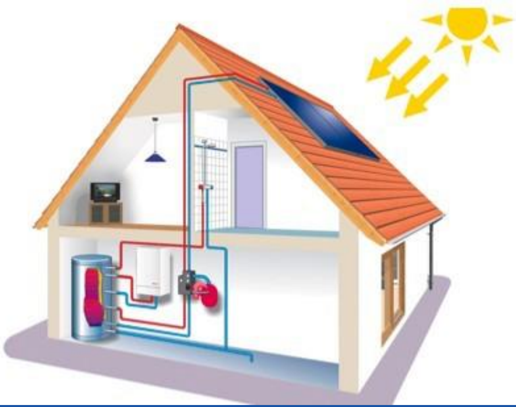
Easier to control

Can be retrofitted ~ though not very easy

Large storage systems

Heat Exchangers ~ water based systems

Ducting ~ air based systems

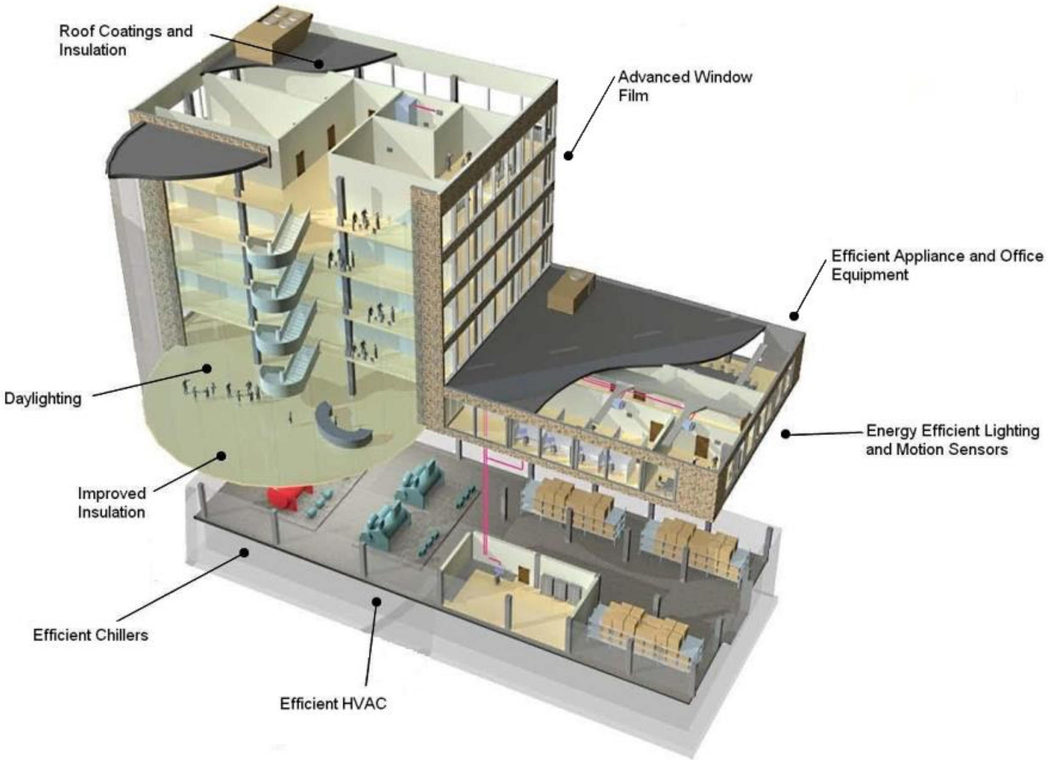


https://energy.gov/energysaver/active-solar-heating

Integrated energy-efficient buildings

Integrated energy systems in the building envelope or structure that utilizes the available on-site energy resources in a way that minimizes the need for purchased energy and maintains a satisfactory indoor environment.

Integrated energy-efficient buildings



Crop Driers

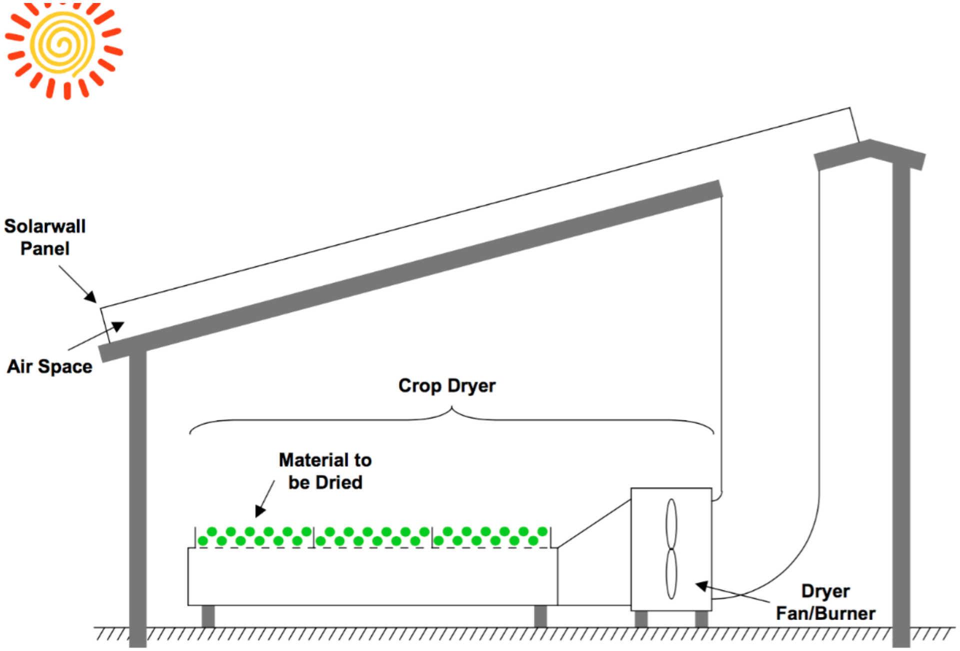
Wheat, rice coffee, copra (coconut flesh), certain fruits, and timber

Need drying before storage

Important factors for crop drying:

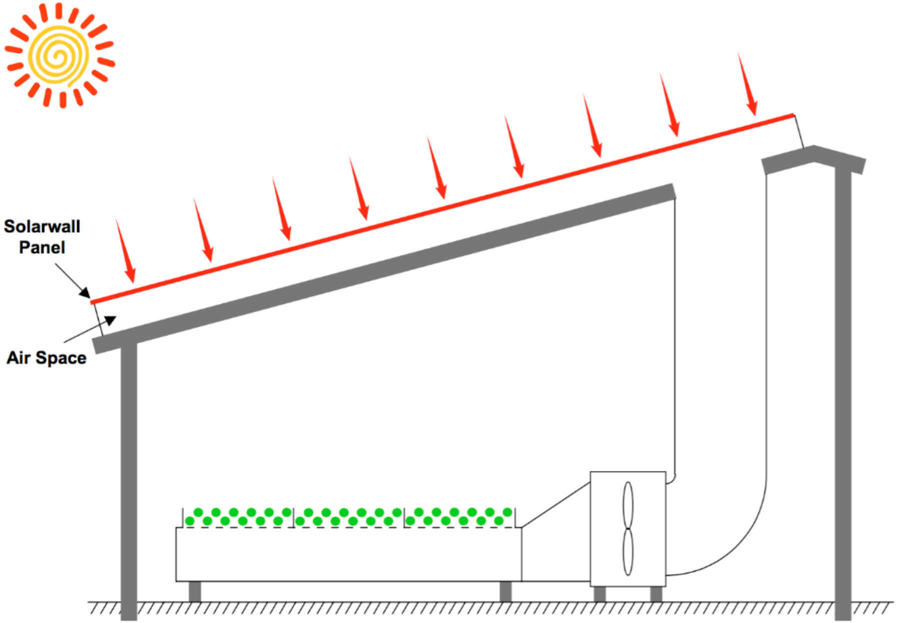
- Water vapour and air
- Water content of crop
- Energy balance and temperature for drying

Crop Driers



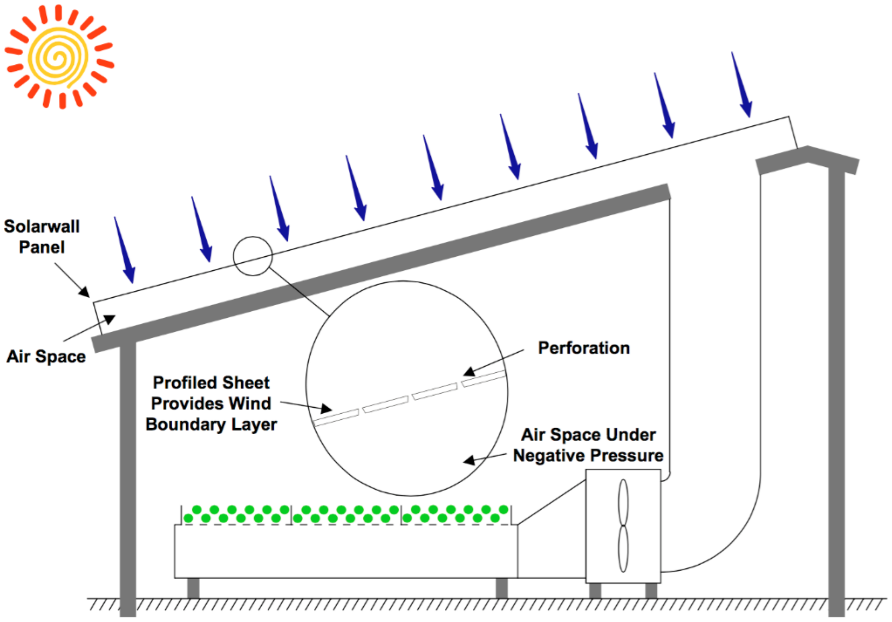
Main components of a solar crop drying system

Crop Driers



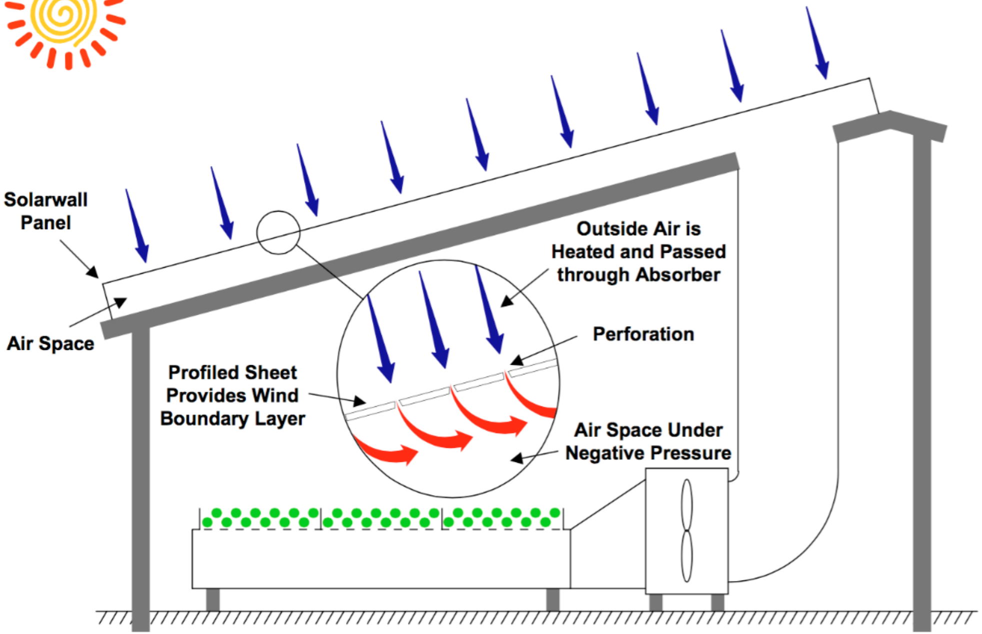
The Solarwall panel absorbs the sun's energy

Crop Driers



The boundary layer air is heated and drawn through tiny perforations into the air space

Crop Driers



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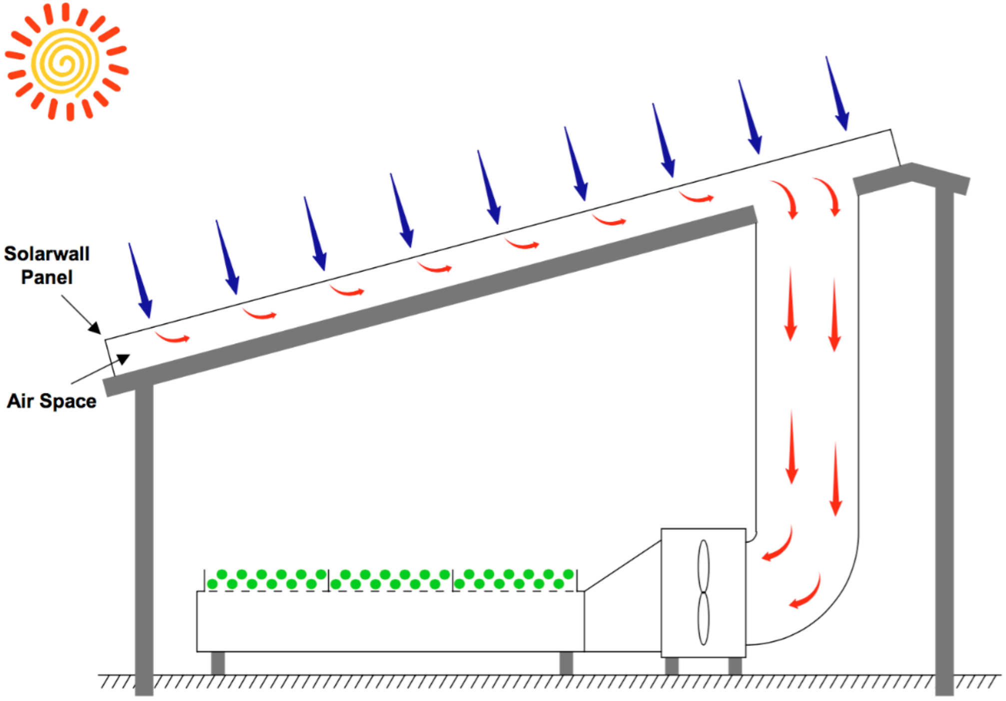
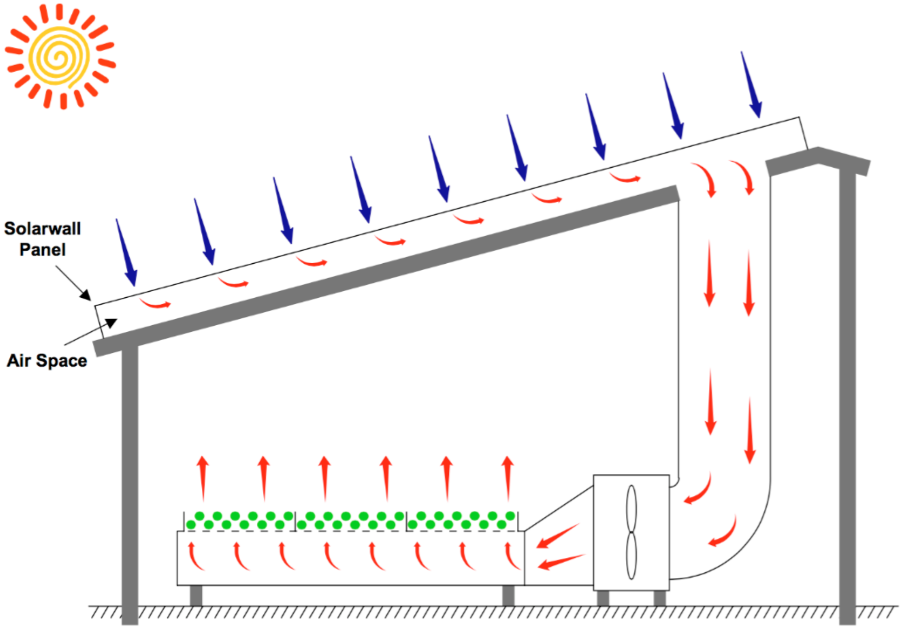
Crop Driers



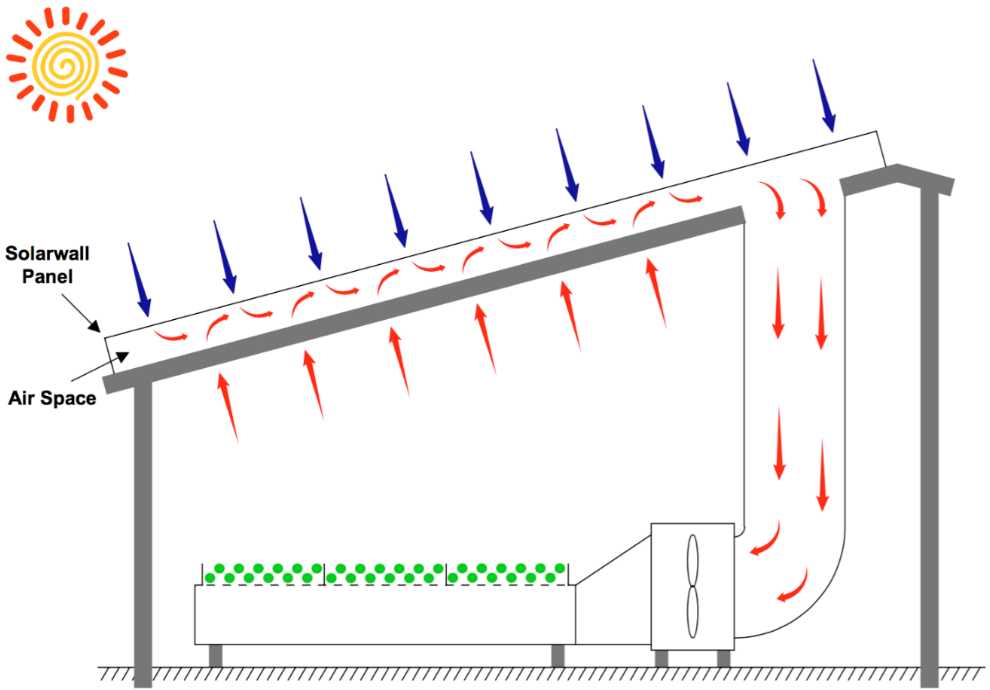
The heated air travels up to the air intake and is drawn into the dryer

Crop Driers



Additional heat is provided by the burner (if required) and the air passes through the material being dried

Crop Driers

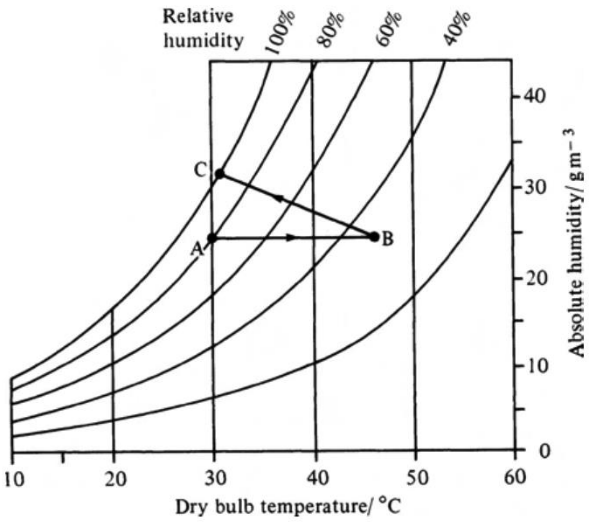


Heat loss through the roof is recovered when the fan is running

Crop Driers

Water Vapour and Air

- *absolute humidity* ☐ ✗ (or 'vapour concentration') ☐ is the mass of water vapour present in 1☐m^3 of the air at specified temperature and pressure. It is maximum at saturation.
- saturation humidity ✗ ☐s depends strongly on temperature
- ✗ ☐/ ✗ ☐s is called the relative humidity (0 -100%) (dry –saturated)



Crop Driers

Water Content of Crop

moisture content of a sample of grain (dry weight basis)

$$w = (m - m_0)/m_0$$

moisture content of a sample of grain (wet weight basis)

$$w' = (m - m_0)/m$$
$$= w/(w+1)$$

Crop Driers

Energy balance and temperature for drying

If a volume V of air is cooled from T_1 to T_2 in the process of evaporating a mass m_w of water, then

$$m_w \Lambda = \rho c (T_1 - T_2)$$

T_1 and V are critical parameters

High temperatures and high humidity are not desirable

Space Cooling

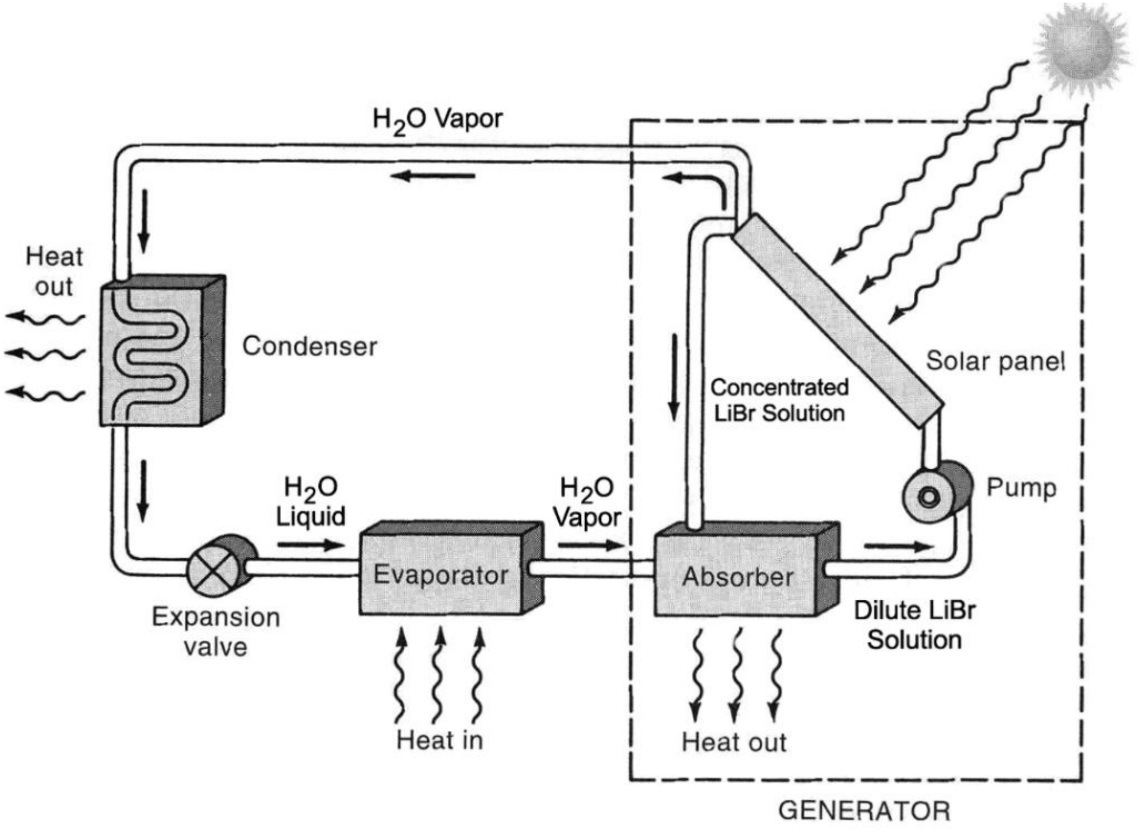
- Absorption refrigerator allows to use solar heat for cooling purpose

- Required pressure is achieved by difference in vapour pressure of the refrigerant
- water as refrigerant and lithium bromide as absorbent

$$\eta = \frac{\text{heat removed from cool space}}{\text{heat applied to generator}}$$

- Limited efficiency of commercial systems due to mechanical complexity & poor coefficient of performance ~0.7
- Variety of solar cycle refrigerators are available
- Passive solar systems are better at cooling spaces

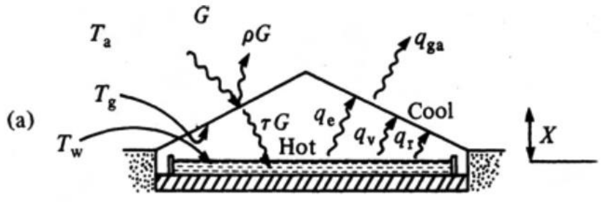
Space Cooling



Water Desalination

Basin solar still

- internally blackened basin
- shallow depth of water
- transparent vapour tight cover
- cover is sloped towards the collection channel



Water Desalination

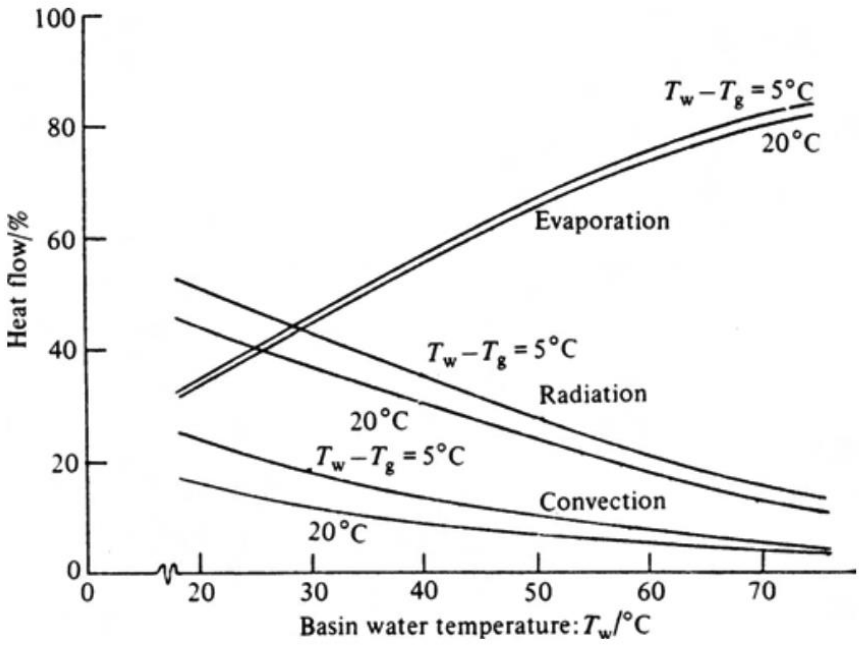
Basin solar still

- solar radiation warms the water, which then evaporates
- water vapour diffuses and moves convectively upwards and condenses on the cooler cover.
- condensed drops of water slide down the cover into the catchment trough.

Water Desalination

- Fraction of heat going to evaporation is independent of $(T_W - T_G)$

- It is strongly dependent on T_w
- Max. production is only 50% of the ideal theoretical still

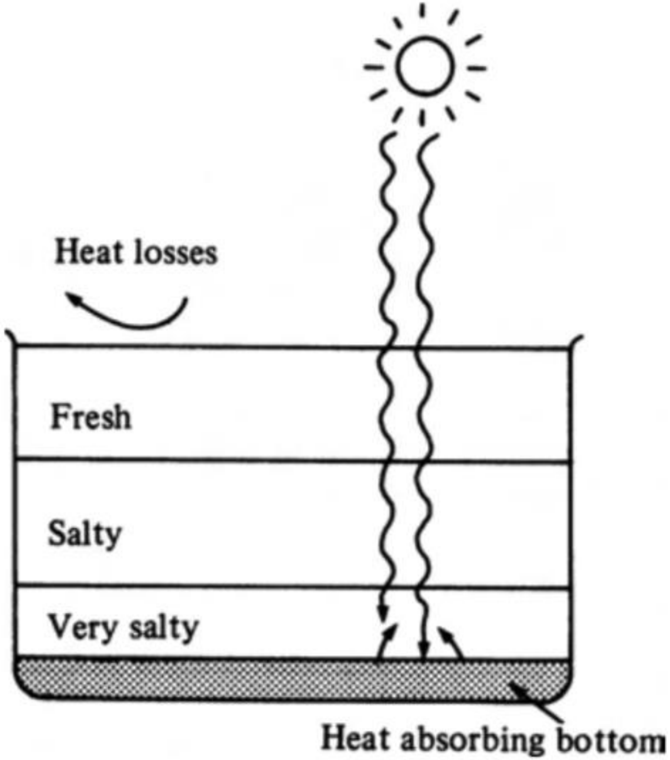


Water Desalination

Multiple effect still

- Heat given off by condensation is used to heat second mass of saline water
- Heat given off by condensation of second mass is used to heat third mass of saline water
- Limited practical performance due to imperfect heat transfer and complexity
- Other options ~ water storage for rainfall, reverse osmosis using PV

Solar Pond



Solar Concentrators

Collectors are oriented to track the sun so that the beam radiation will be directed onto the absorbing surface

Collector: Receiver and the concentrator

Receiver: Radiation is absorbed and converted to some other energy form (e.g. heat).

Concentrator: Collector that directs radiation onto the receiver. The aperture of the concentrator is the opening through which the solar radiation enters the concentrator

Solar Concentrators

Concentration Ratio

The concentration ratio X for a solar concentrator is defined as the ratio of the area of aperture to the area of the receiver.

$$X = A_a / A_r$$

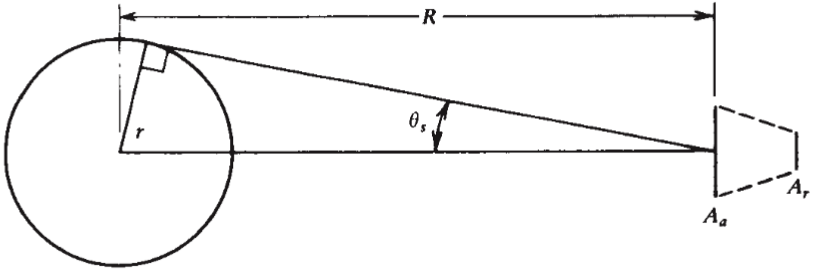
where,

A_a projected area of the concentrator facing the beam

A_r area of the receiver

Solar Concentrators

Concentration Ratio



$$\left(\frac{A_a}{A_r}\right)_{\text{circular,max}} = \frac{R^2}{r^2} = \frac{1}{\sin^2 \theta_s}$$

$$\left(\frac{A_a}{A_r}\right)_{\text{linear,max}} = \frac{1}{\sin\ \theta_s}$$

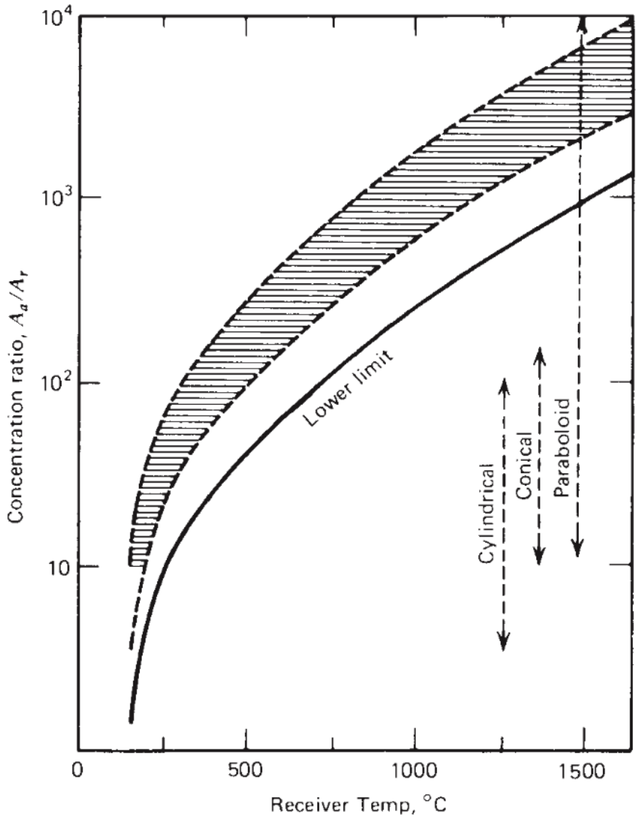
Max concentrator ratio in this case is 45000

Max concentrator ratio in this case is 212

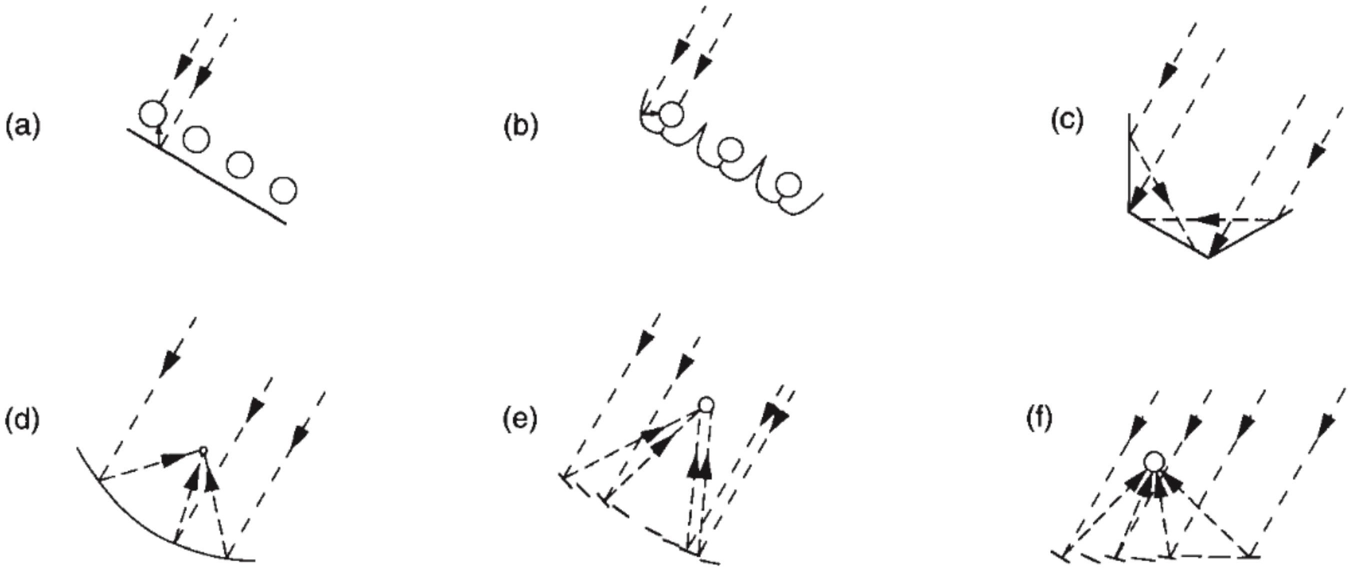
Solar Concentrators

Concentration Ratio

- The “lower limit” curve represents concentration ratios at which the thermal losses will equal the absorbed energy
- shaded range corresponds to collection efficiencies of 40 to 60%



Solar Concentrators



Solar Concentrators

Planar and non-concentrating type which provides concentration ratios of up to four and are of the flat plate type.

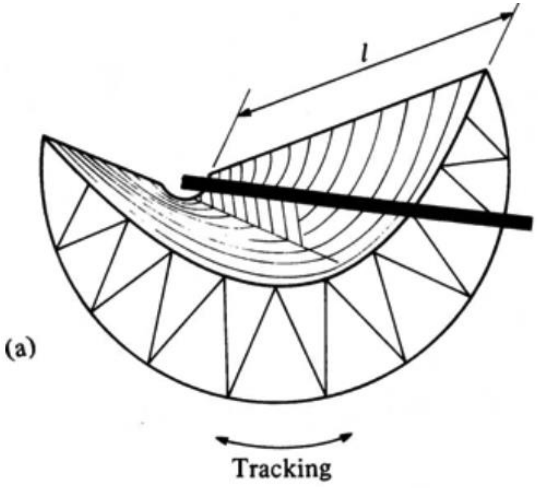
Line focusing type produces a high density of radiation on a line at the focus. Cylindrical parabolic concentrators are of this type and they could produce concentration ratios of up to ten.

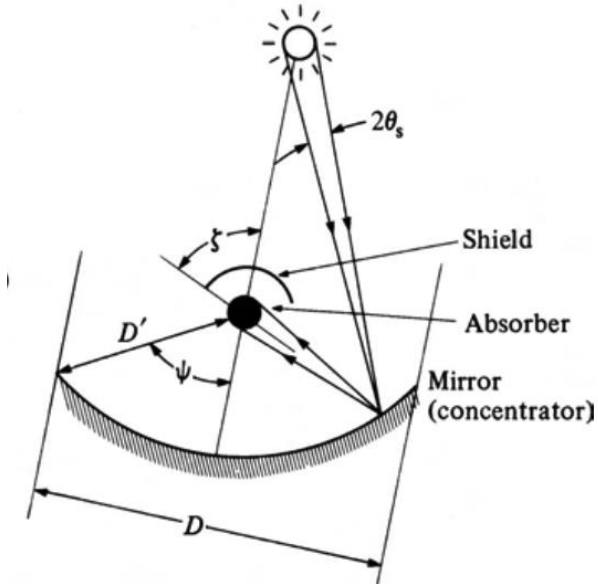
Point focusing type generally produce much higher density of radiation in the vicinity of a point. Paraboloids are examples of point focus concentrators.

Solar Concentrators

Trough Collector

- Concentration in only 1 D
- Mechanically Simple





$$P_{abs} = \rho_c \alpha l D G_b$$

Solar Concentrators

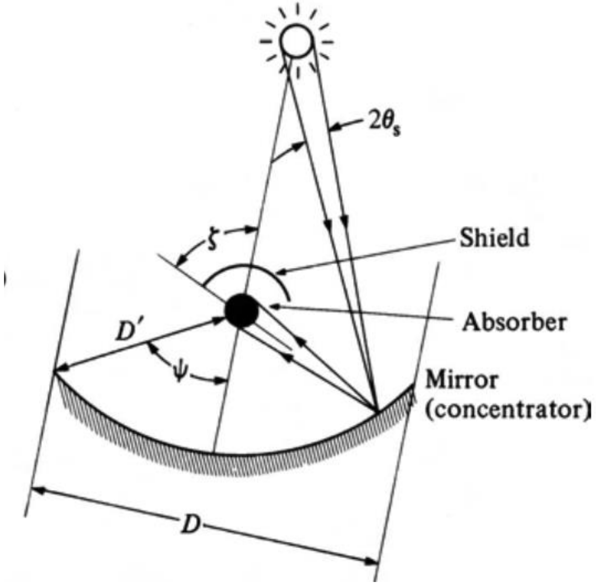
$$P_{abs} = \rho_c \alpha l D G_b$$

$$P_{rad} = \varepsilon\left(\sigma T_r^4\right)(2\pi r l)(1 - \zeta/\pi)$$

$$r = D'\theta_s$$

$$T_r = \left[\frac{\alpha\rho_c\tau_a G_0 \cos\omega}{\varepsilon\sigma}\right]^{\frac{1}{4}} \left[\frac{D}{2\pi r(1-\zeta/\pi)}\right]^{\frac{1}{4}}$$

$$T_r^{(max)} = \left[\frac{\alpha\rho_c\tau_a G_0 \cos\omega}{\varepsilon\sigma\theta_s}\right]^{\frac{1}{4}} = 1160\,\mathrm{K}$$



Solar Concentrators

Theoretical $T_r = 1160K$

Practical temperatures are less than T_r for two main reasons:

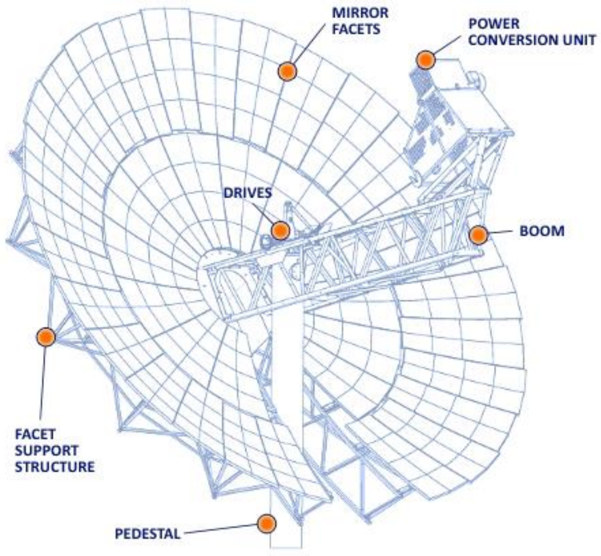
- Practical troughs are not perfectly parabolic, so that the solar image subtends angle θ□s′ > θ□s = R_s/L.
- Useful heat P_u is removed by passing a fluid through the absorber, so

$$T_r^4 \propto P_{rad} = \square P_{abs} - P_u \square < P_{abs}$$

Solar Concentrators

Parabolic Bowl Concentrator

- Concentration in 2 D
- Complicated tracking arrangement
- The absorbed heat drives a Stirling motor, which converts the heat into motive energy and drives a generator to produce electricity.

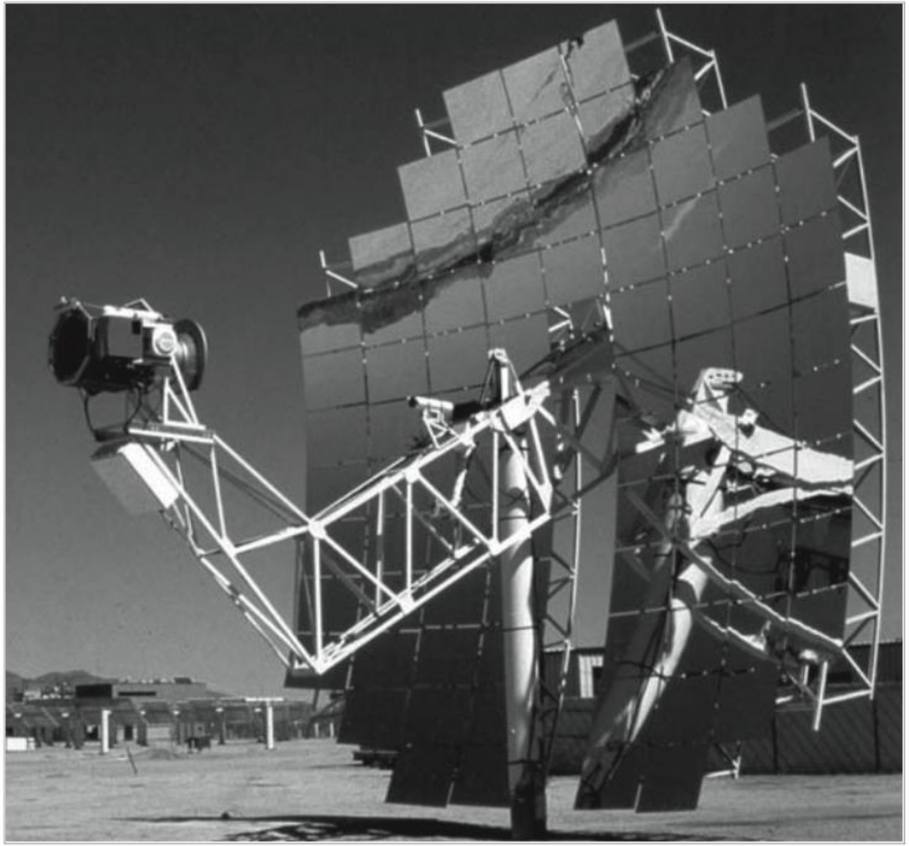


Solar Concentrators

Parabolic Bowl Concentrator

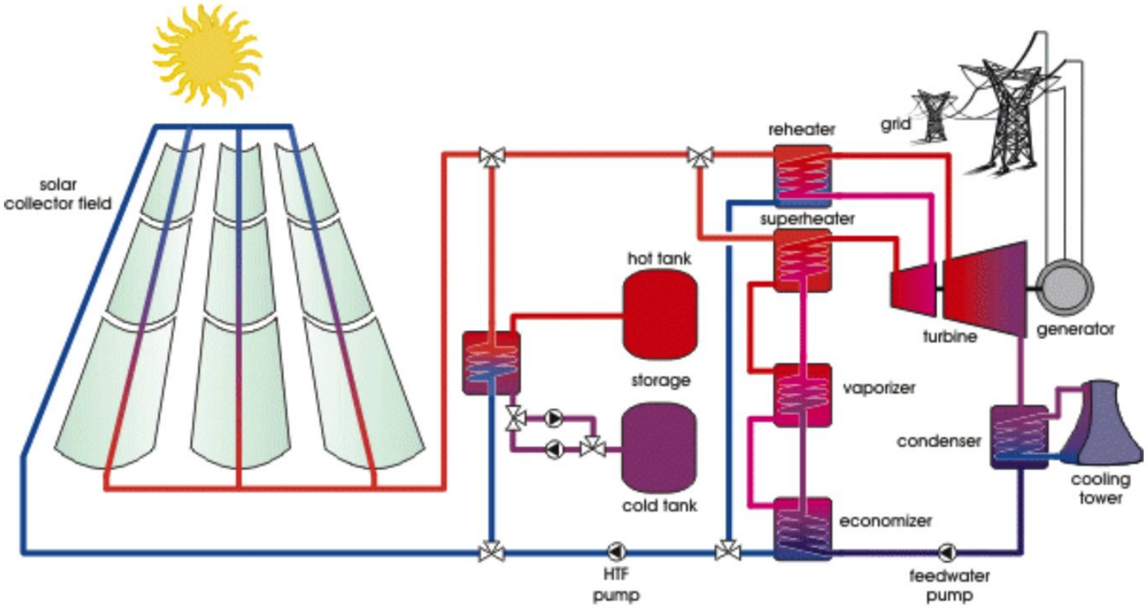
Solar Concentrators

Parabolic Bowl Concentrator



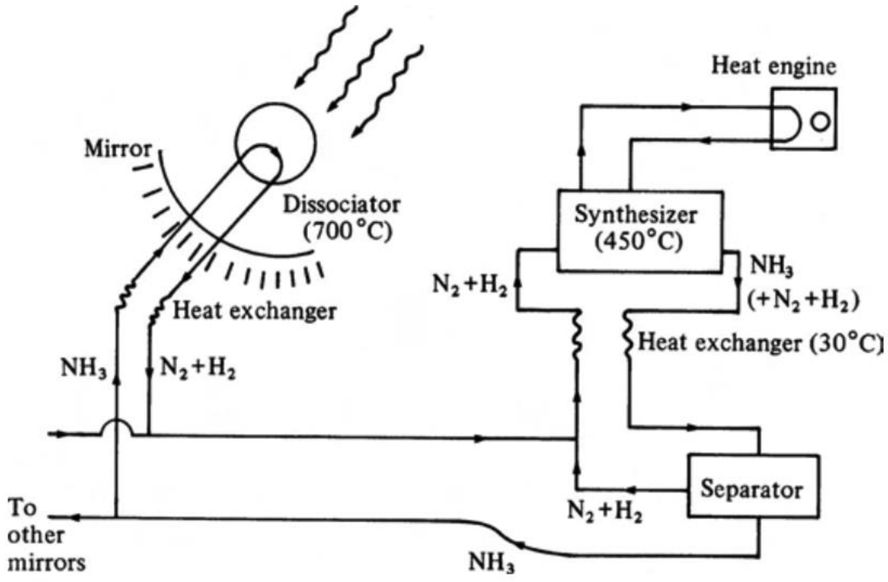
Solar Concentrators

Distributed Concentrator



Solar Concentrators

Distributed Concentrator



Solar Concentrators

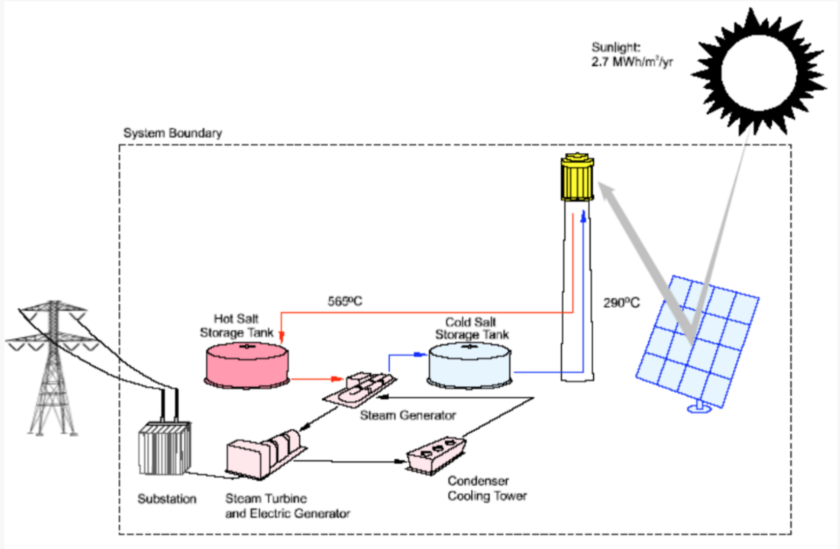
Power Tower

Solar Concentrators

Solar Power Tower

Electric power from sunlight by focusing concentrated solar radiation on a tower-mounted heat exchanger. Best suited for large scale

applications: 30-400 MW



Solar Concentrators

Solar Power Tower

Receiver: Smaller and simpler receivers are needed to improve efficiency and reduce maintenance.

Molten salt: Molten nitrate salt, though an excellent thermal storage medium, it is not an ideal material due to its relatively high freezing point of 220° C.

Home Work

Chapter 06: Renewable-Energy-Resources-By-John-Twidell-Tony-Weir
Examples: 6.1, 6.2, 6.3

Questions?

Thank You