

# Solar cookers

31-03-2014

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- Half the world's people must burn wood or dried dung to cook their food.
- Nearly 1.2 billion people, a fifth of the world's population, do not have access to clean drinking water.
- Over 1 million children die yearly because of unboiled drinking water.
- Wood cut for cooking purposes contributes to the 16 million hectares of forest destroyed annually.
- Half the world's population is exposed to indoor air pollution, mainly the result of burning solid fuels for cooking and heating.

# Type of solar cooker

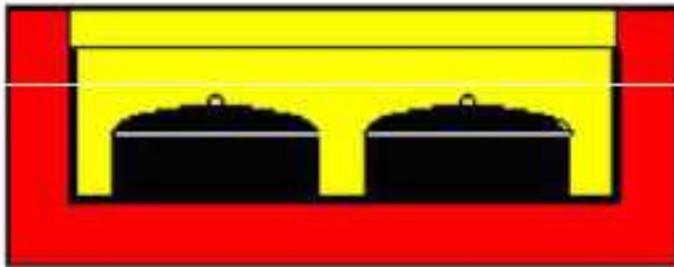
## Direct type

- Concentrating
  - Parabolic
  - Cylindrical
  - Fresnel
  - Spherical
- Non Concentrating (box type)
  - With reflector
  - *Without reflector*

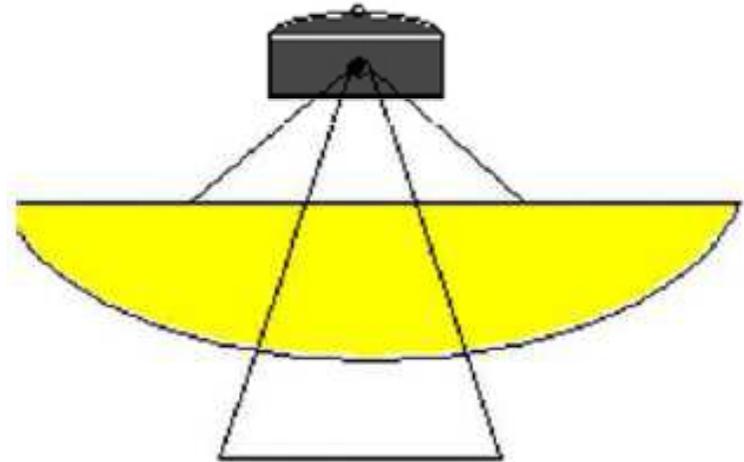
## *Indirect type*

- *Steam based*
- *Chemical or fluid based*

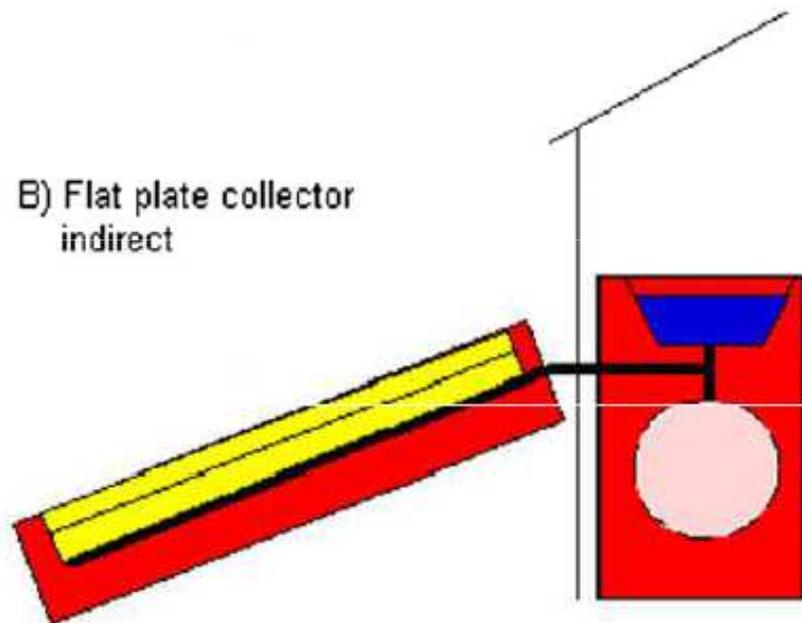
A) Box cooker



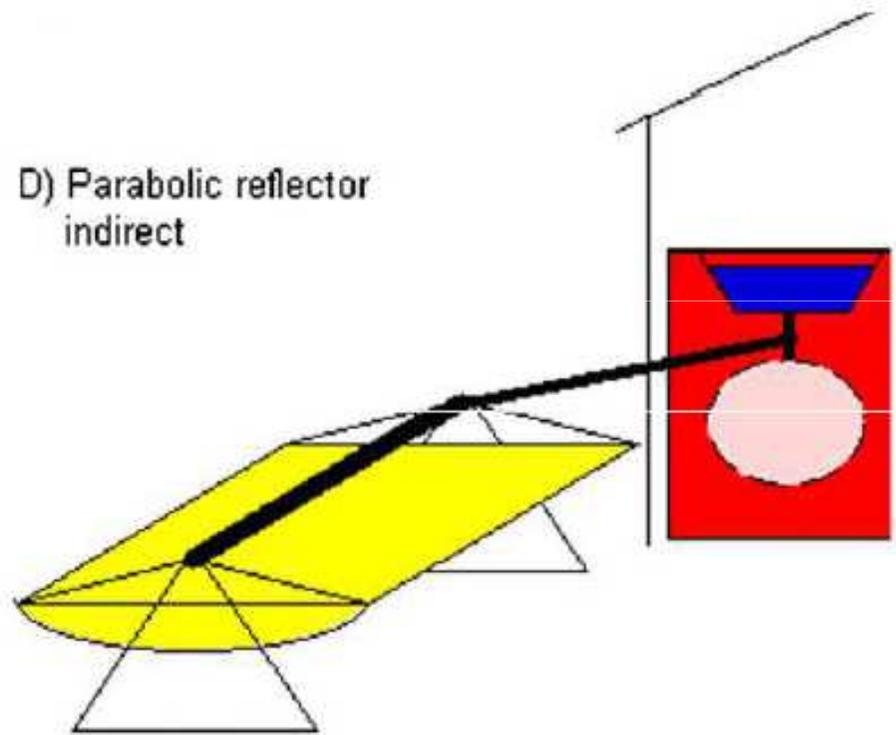
C) Parabolic reflector direct



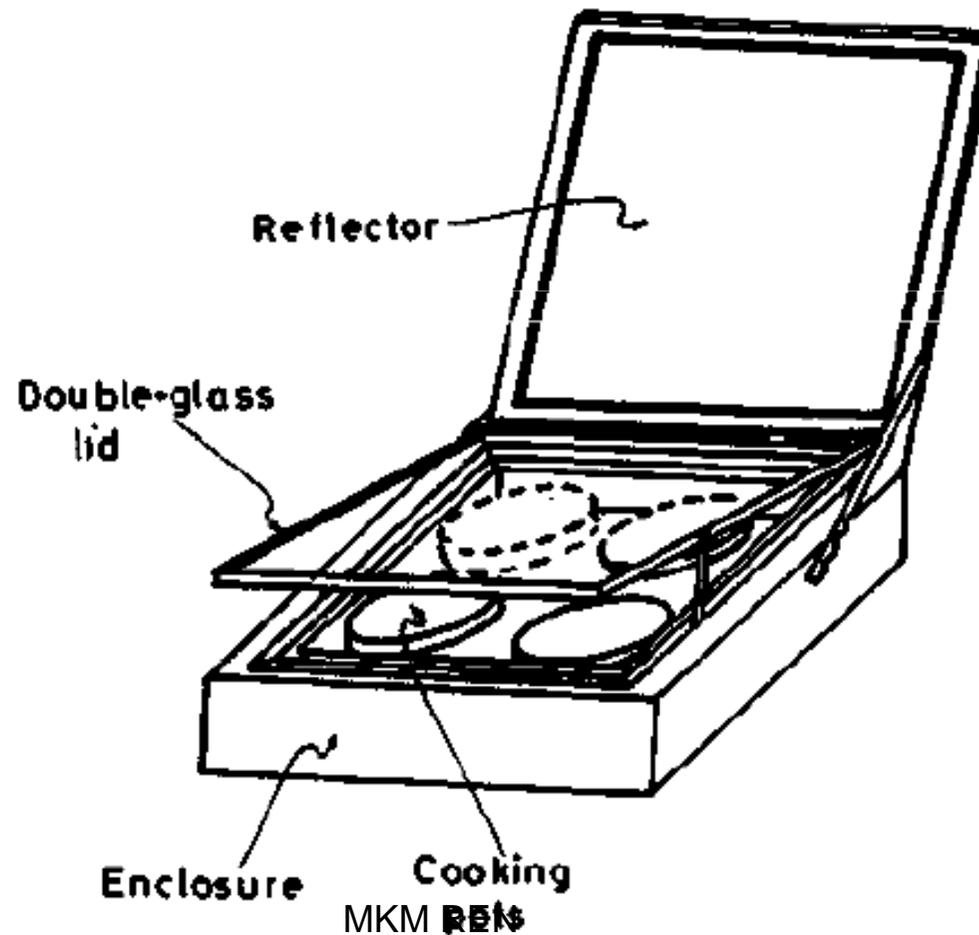
B) Flat plate collector indirect

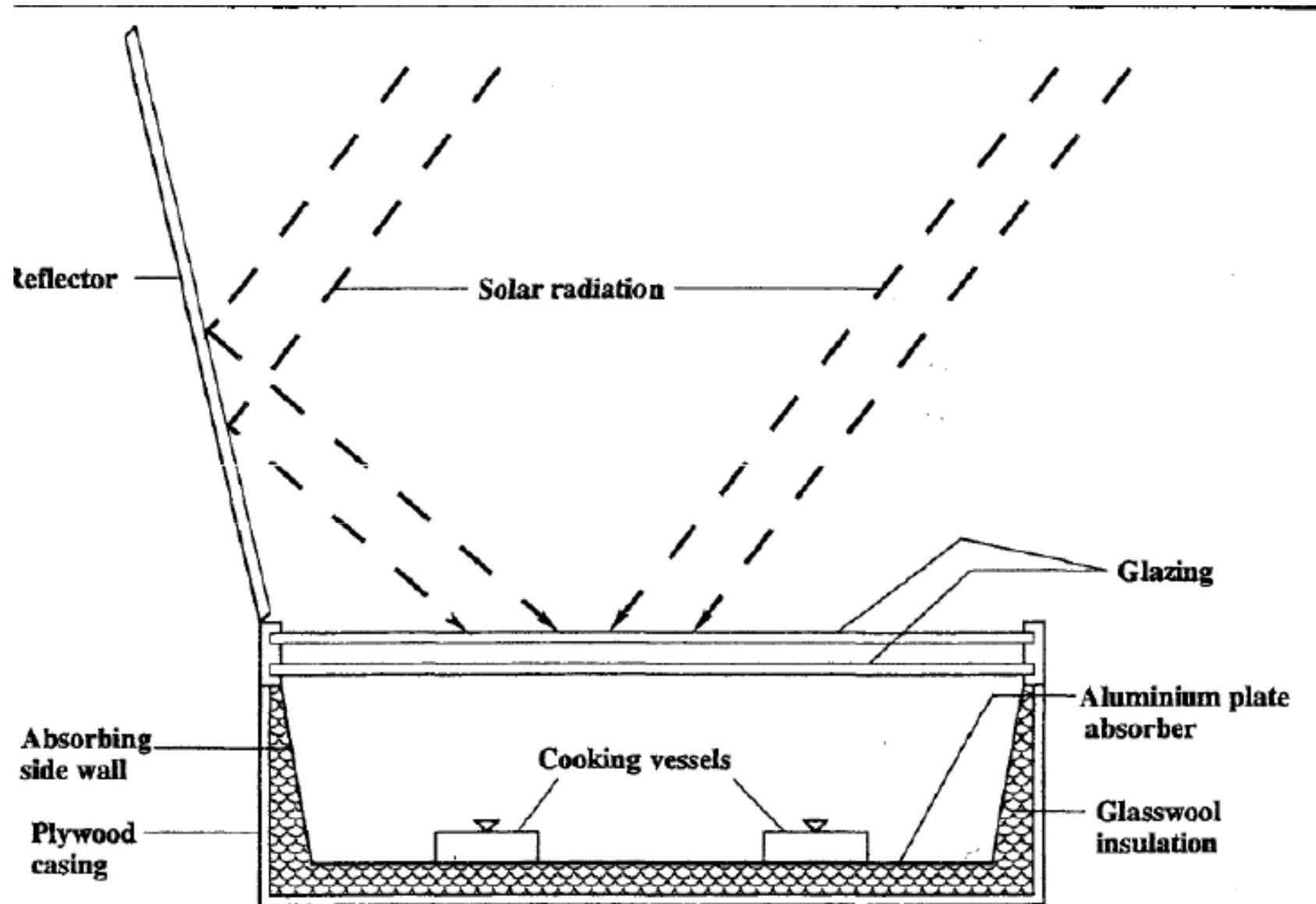


D) Parabolic reflector indirect



# Different parts of a Box type cooker





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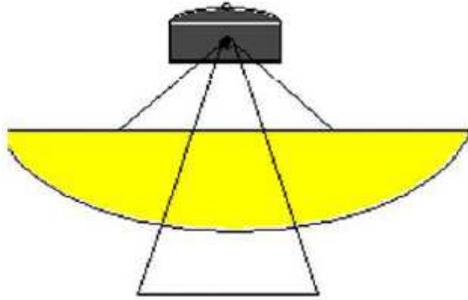
# **Important Parts of Box type Solar Cooker**

- **Outer box,**
- **inner cooking box or tray,**
- **the double glass lid,**
- **Thermal insulator,**
- **mirror**
- **cooking containers**

- **Outer Box:** The outer box of a solar cooker is generally made of G.I. or aluminum sheet or fibre reinforced plastic.
- **Inner Cooking Box (Tray) :** This is made from aluminum sheet. The inner cooking box is slightly smaller than the outer box. It is coated with black paint so as to easily absorb solar radiation and transfer the heat to the cooking pots.
- **Double Glass Lid:** A double glass lid covers the inner box or tray. This cover is slightly larger than the inner box. The two glass sheets are fixed in an aluminum frame with a spacing of 2 centimeters between the two glasses. This space contains air which insulates and prevents heat escaping from inside. A rubber strip is affixed on the edges of the frame to prevent any heat leakage.
- **Thermal Insulator:** The space between the outer box and inner tray including bottom of the tray is packed with insulating material such as glass wool pads to reduce heat losses from the cooker. This insulating material should be free from volatile materials.

- **Mirror:** Mirror is used in a solar cooker to increase the radiation input on the absorbing space and is fixed on the inner side of the main cover of the box. Sunlight falling on the mirror gets reflected from it and enters into the tray through the double glass lid. This radiation is in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the inside temperature of the cooker.
- **Containers:** The cooking containers (with cover) are generally made of aluminum or stainless steel. These pots are also painted black on the outer surface so that they also absorb solar radiation directly

C) Parabolic reflector  
direct



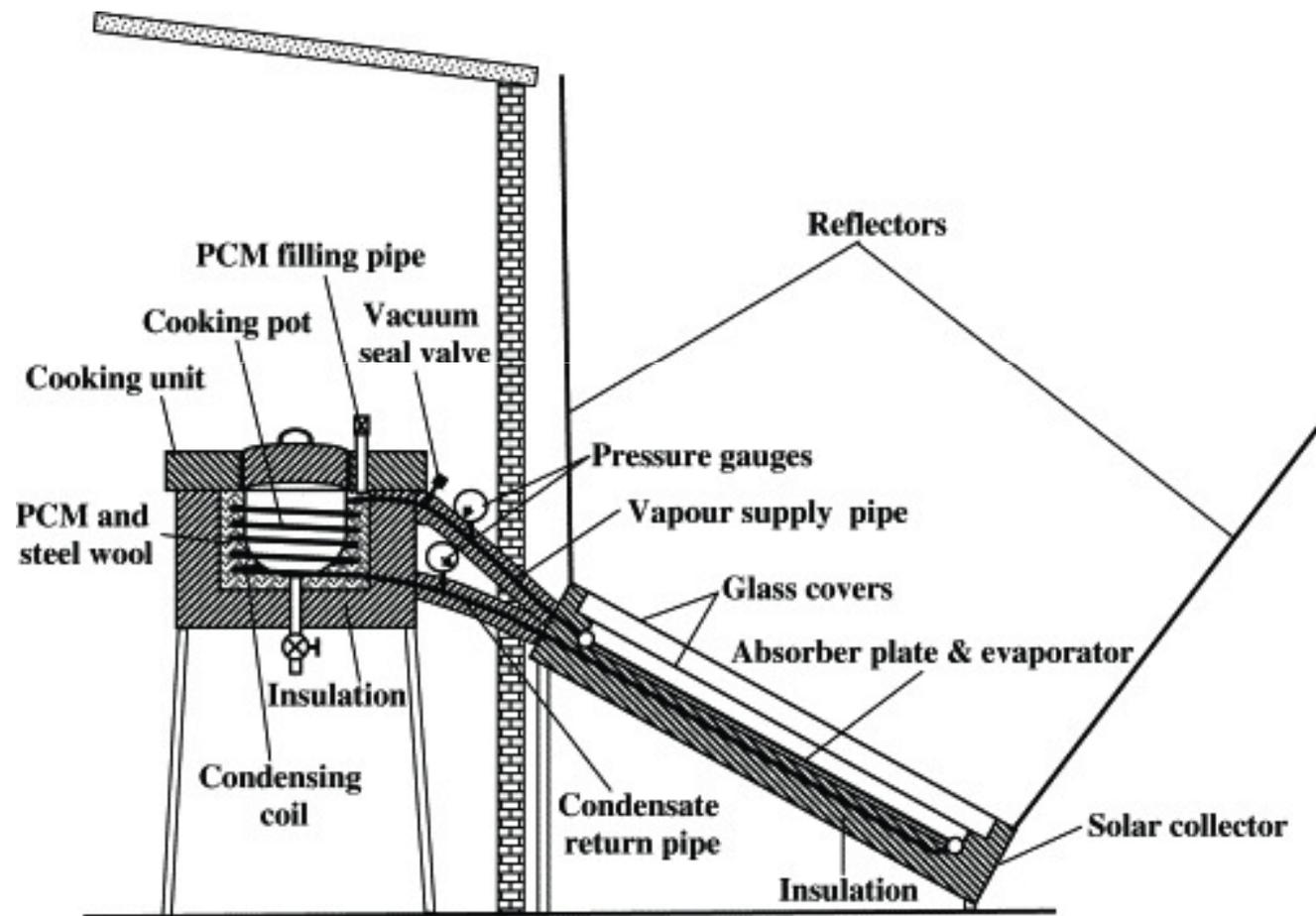
# Dish Solar Cooker

- **Paraboloid dish, made of single reflector, or by joining smaller pieces of reflector, fixed firmly to a rigid frame. Size and shape of the dish shall be such that when exposed to sun in the normal direction, a point focus would be formed.**
- **Dish diameter: 1.4 m, minimum**
- **Reflector material: Bright anodized aluminum sheets of thickness 0.4 mm, or Glass mirrors, thickness about 3 mm, with suitable protective layer on back to minimize degradation of the reflective coating due to weathering.**
- **Reflectivity > 80%, minimum** <sup>MKM REN</sup>

- **Focal Point:** When dish is exposed to sun's rays at normal incidence, the size of the point where reflected rays get focused would be less or equal to the size of base area of the cooking pot.
- **Tracking Mechanism:** Manual or automatic, allowing unrestricted rotation of the dish along its horizontal and vertical axes enabling its adjustment in the normal direction to the sun's rays. Provision of locking arrangement to hold/fix the dish at a desired position. Equipped with an arrangement (may be in the form of a vertical pointer) to enable users to position the dish in a direction normal to the sun's rays.
- **Cooking vessel:** For dish of about 1.4 m dia, a pressure cooker of 5 l capacity with ISI mark may be provided. For other sizes, proportionately higher capacity of pressure cooker is to be provided. High temperature resistant black powder coating at the bottom to be provided.

# Indirect solar cooking

- The solar cooker with or without temporary heat storage has two basic units: a set of flat plate collectors and a cooking unit. The solar collector absorbs solar energy and transfers heat to a working fluid, usually a vegetable oil, which transports this heat to pots, where cooking is done. The cooking unit is made of cooking pots, a piping circuit that connect the solar collectors to the pots, control and direction valves, and a storage tank, which is added to the cooker if temporary heat storage is needed.



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- This cooker is based on a self circulating loop filled with peanut oil, carrying the energy from a flat collector (with lateral mirror panels) to the application (heat storage or cooking vessel) using peanut oil as a heat transfer fluid. The system enables cooking at 140°C.



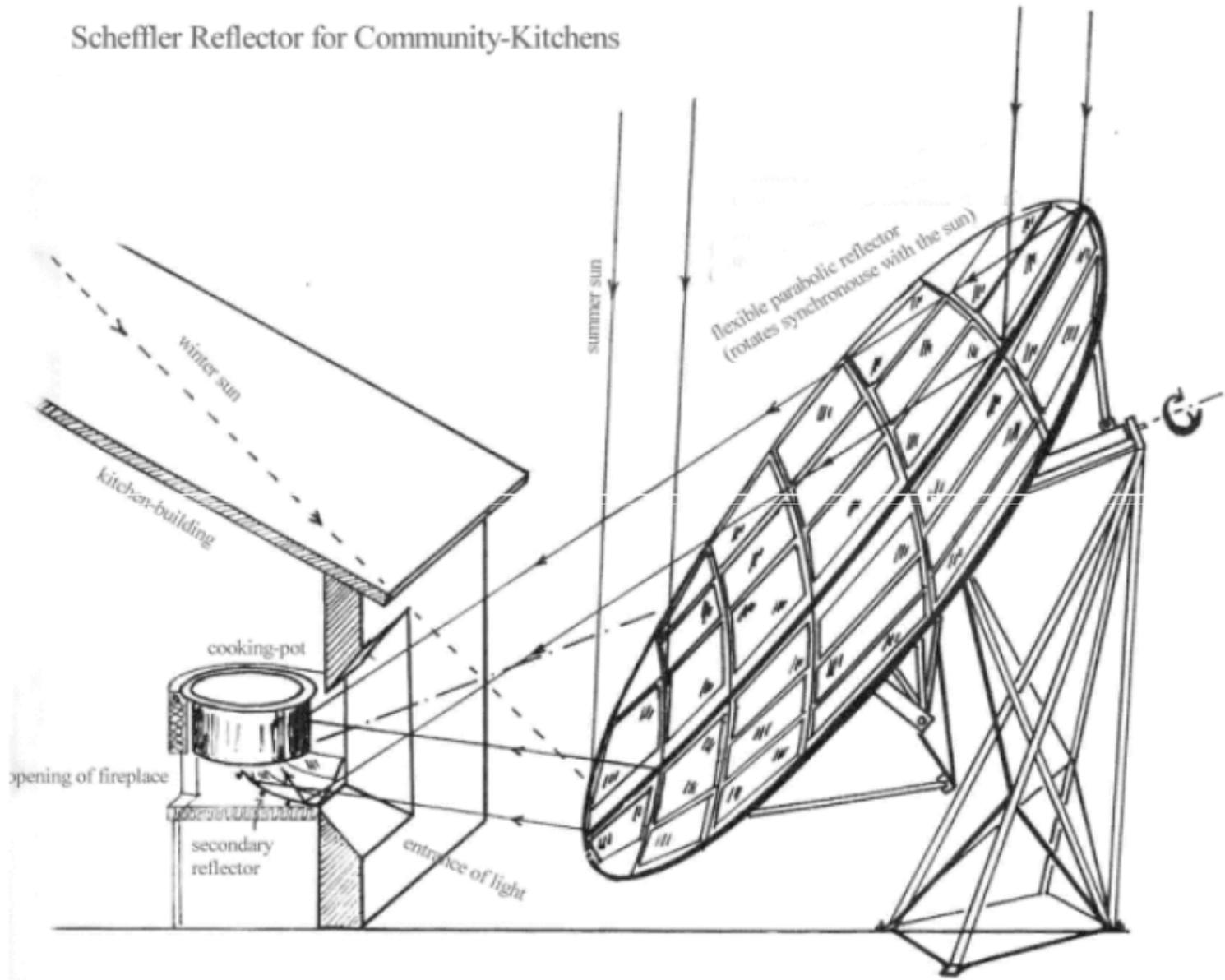
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# Community (Scheffler) Solar Cooker for Indoor Cooking

- Wolfgang Sheffler and his colleagues have installed more than 200 community solar cookers since 1986, mostly in India
- A concentrating primary reflector tracks the movement of the sun, focusing sunlight on a motionless cooking place in a nearby shed. The focused light heats a very large pot
- The optical system of Scheffler's community solar cooker forms a *heliostat*
- *Heliostat* : "an instrument which will reflect the rays of the sun in a fixed direction notwithstanding the motion of the sun. The optical apparatus generally consists of a mirror mounted on an axis parallel to the axis of the earth, and rotated with the same angular velocity as the sun."

- Each morning, the operator rotates the primary reflector back to a starting position in which the secondary reflector is illuminated, and starts the clockwork.
- Every few days the operator adjusts the angle between the axis of rotation and the reflector to accommodate the seasonal variation in the height of the sun. Once the secondary reflector is illuminated and the clockwork is in motion, the spot of focused light remains on the secondary reflector all day.
- **The shape of the primary reflector approximates a paraboloid. The seasonal variation in the height of the sun requires changing not only the angle between the primary reflector and its axis of rotation, but also the shape of the reflector. The geometry of the framework supporting the reflecting surface is designed so that the action of changing the angle between the primary reflector and its axis of rotation produces forces which squeeze or stretch the primary reflector to produce the necessary changes of shape. The primary reflector comprises a number of facets, usually flat glass mirrors. A concrete pad and a welded steel space frame provide support for the primary reflector. The area of the primary reflector in the configuration shown above is usually about 7 square meters, delivering approximately 2 kW to the cooking pot. In an alternative configuration, a smaller primary reflector is arranged to reflect upwards along the axis of rotation, eliminating the need for a secondary reflector.**

# Scheffler Reflector for Community-Kitchens



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## Some Data on Scheffler-Reflector

- Maximum temperature reached at focal-point :1020°C
- Maximum optical efficiency (reflector-surface from clear-glass/ordinary glass) :75 to 84%
- Average cooking-power at 700W/m<sup>2</sup> insolation, with normal glass-mirrors (8m<sup>2</sup> Reflector) :1.7 to 2.5 Kw
- Largest number of people catered for by one kitchen :18000
- Example: **The construction of the worlds largest solar-kitchen in Mount Abu, Rajasthan, by the Brahma Kumaris. ( 800m<sup>2</sup> of Reflector surface + steam system +back-up boiler**



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## Advantages and disadvantages of different types of solar cookers

<i>Type of cooker</i>	<i>Advantages</i>	<i>Disadvantages</i>
Solar box cooker (solar oven)	<ul style="list-style-type: none"> <li>Uses both direct and diffuse radiation</li> <li>Requires little intervention by the user</li> <li>Very easy and safe to use</li> <li>Easy to construct</li> <li>High acceptance angle*</li> <li>High tolerance for tracking error</li> </ul>	<ul style="list-style-type: none"> <li>Widely divergent thermal performance (slow even cooking)</li> </ul>
Panel cooker	<ul style="list-style-type: none"> <li>Better performance than box cooker</li> </ul>	<ul style="list-style-type: none"> <li>Poor performance on cloudy conditions</li> <li>Relies more on reflected radiation</li> </ul>
Collector cooker	<ul style="list-style-type: none"> <li>Uses both diffuse and direct radiation</li> <li>Could used as a multicooker</li> <li>Higher cooking temperatures</li> <li>Simple, safe and convenient to use</li> </ul>	<ul style="list-style-type: none"> <li>Complicated to build</li> <li>Expensive</li> </ul>
Concentrating (reflector) cooker	<ul style="list-style-type: none"> <li>Quite efficient</li> <li>Can achieve extremely high temperatures (suitable for frying)</li> <li>Cooks quicker</li> </ul>	<ul style="list-style-type: none"> <li>Harder to make and use</li> <li>Requires the user's attention</li> <li>Strong reliance on direct beam</li> <li>Suffers from wind</li> <li>Low acceptance angle</li> <li>Relatively high cost</li> <li>Safety problems (burns or eye damage)</li> </ul>

# Cooking Power

- $P = (T_f - T_i)MC_v/600$

where:

- $P$  = cooking power (W)
- $T_f$  = final water temperature
- $T_i$  = initial water temperature
- $M$  = water mass (kg)
- $C_v$  = heat capacity (4186 Jkg<sup>-1</sup>K<sup>-1</sup>)

- **Standardizing cooking power.** Cooking power for each interval shall be corrected to a standard insolation of  $700 \text{ Wm}^{-2}$  by multiplying the interval observed cooking power by  $700 \text{ Wm}^{-2}$  and dividing by the interval average insolation recorded during the corresponding interval.
- $P_s = P_i(700/I_i)$
- where:
- $P_s =$  standardized cooking power (W)
- $P_i =$  interval cooking power (W)
- $I_i =$  interval solar insolation ( $\text{Wm}^{-2}$ )

$$n_c = \frac{(m_p c_p + m_w c_w) (\bar{T}_w - \bar{T}_a)}{A_c Q_c t}$$

where  $m_p$  and  $m_w$  represent mass of pot and water respectively;

and  $c_p$  and  $c_w$  represent specific heat capacity of the material (i.e. aluminum) of the pot ( $920\text{J/kg}^\circ\text{C}$ ) and water ( $4200\text{J/kg}^\circ\text{C}$ ) respectively;

$\bar{T}_w$  and  $\bar{T}_a$  stand for average water and ambient absolute temperatures respectively;

$A_c$  represents the area of the solar collector;

$Q_c$  represents the average global radiation intensity and  $t$  stands for the daily time period of investigation,

### Cooking performance of solar cooker

Sr.No.	Food material cooked	Quantity (gm)	Mixing Water (gm)	Cooking time required (min)
1.	Rice	100	200	70
2.	Potato	200	400	80
3.	Eggs	5 no.	200	85
4.	Pulses ( Tur dal)	100	200	110

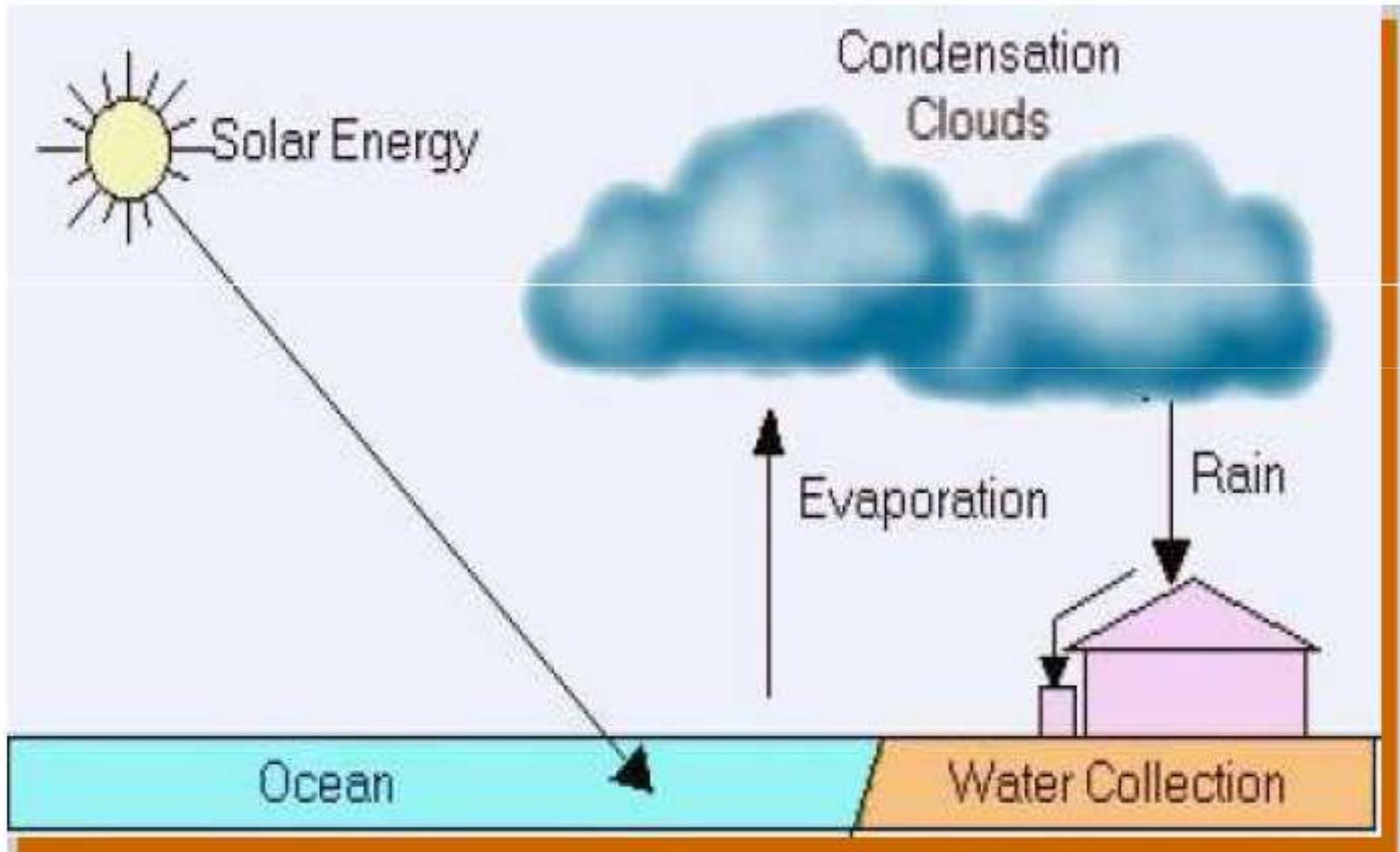
# **solar distillation**

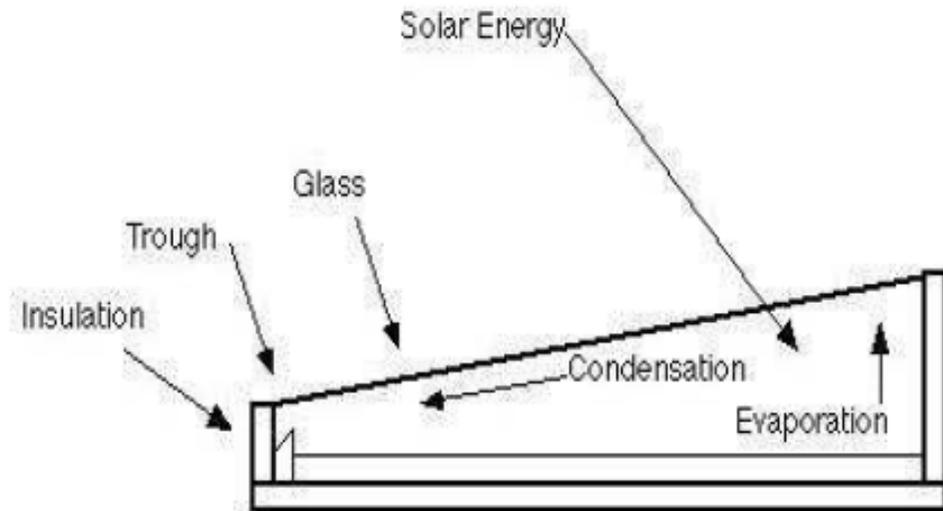
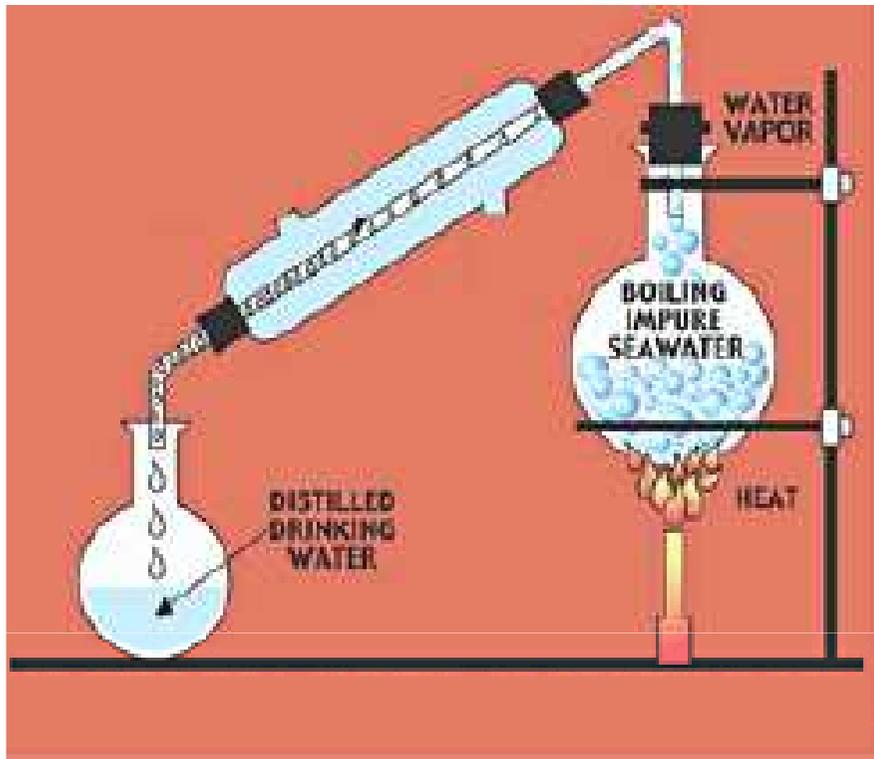
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# Why water distillation solar

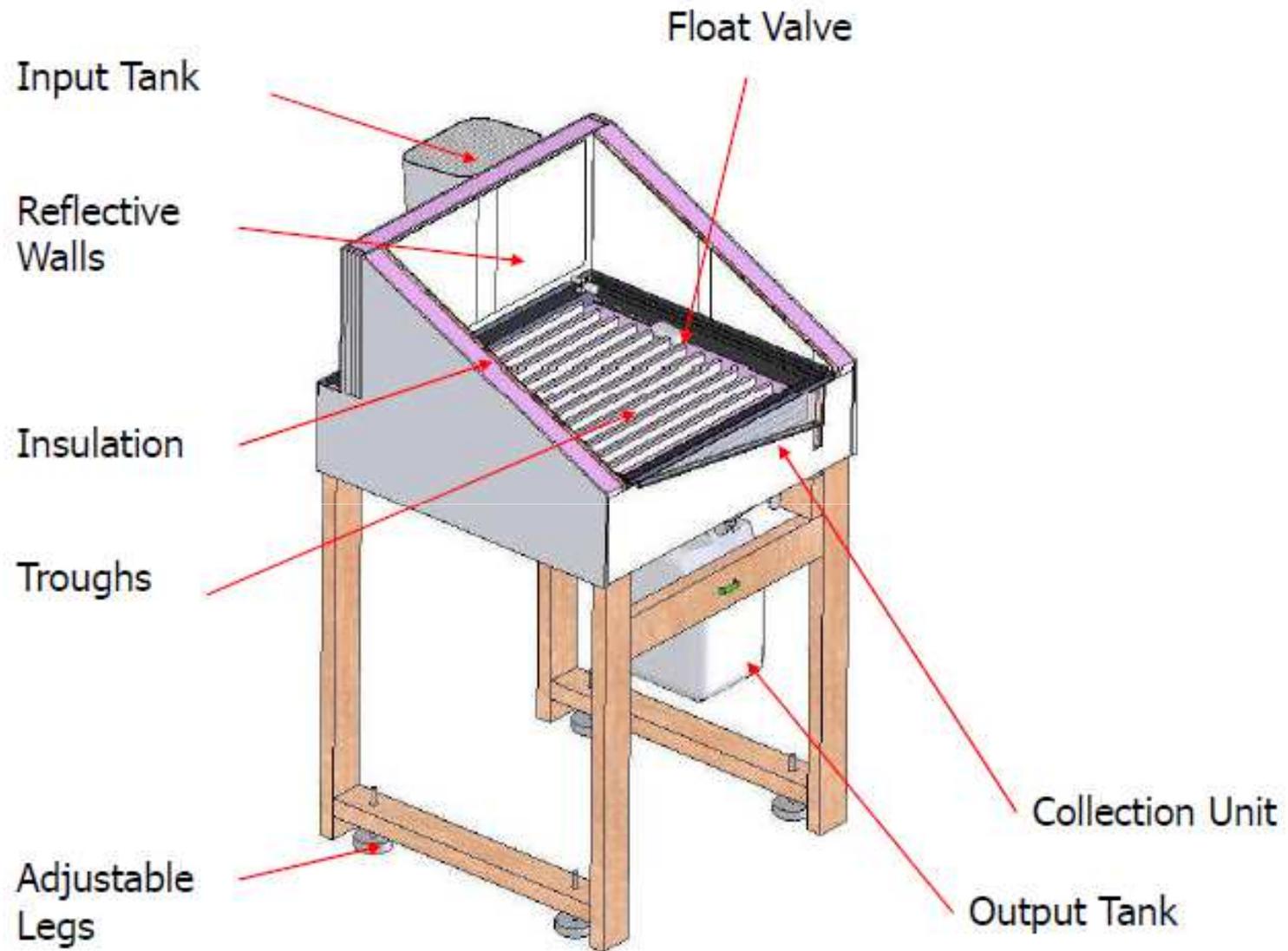
- Over 1 billion people without access to clean water worldwide
- Clean water essential to stop spread of disease & improve overall health
- Process that removes impurities & contaminants
- Solar energy = untapped resource

## ***Distillation is same as Rainwater Process***





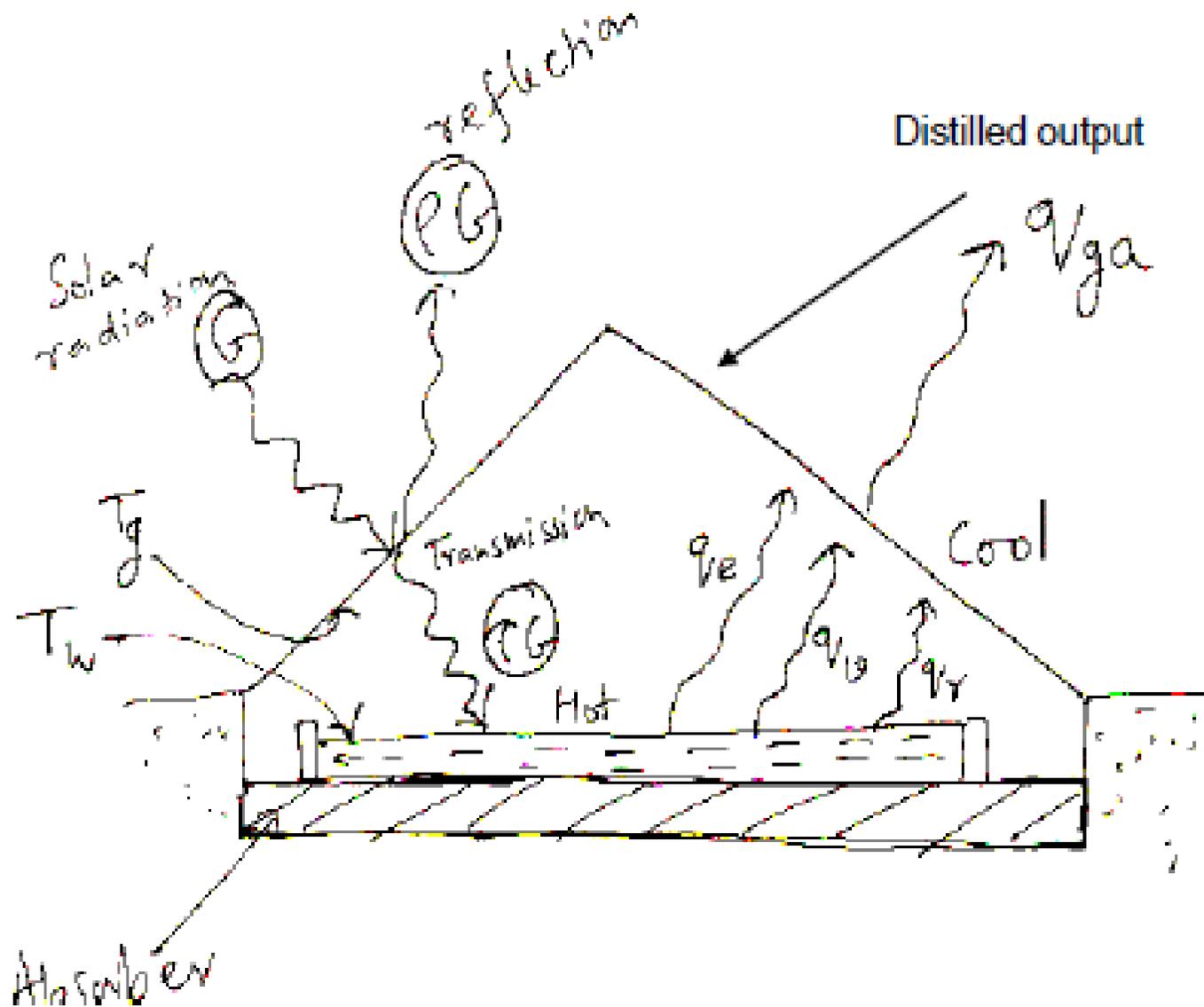
- Heat water to point of vaporization
- Water vapor condenses on cooler surfaces
  - Condensate runs off into collection bin



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# Working principle

- Internally blackened basin contains shallow depth of impure ( or saline ) water. A transparent vapour- tight cover encloses the basin with a slope towards the collection channel.
- Operation: Absorbed solar energy evaporates some of the water which condenses on the cooler cover and is collected as the distilled output.



The fraction of the heat going into evaporation is independent of  $(T_w - T_g)$  but increases strongly with the water temperature

- $Q_s = m_w c_p \Delta T,$

$Q_s$  is sensible heat (k Joules),

$m_w$  is the mass of water

$c_p$  is the specific heat at constant pressure (For water = 4.187 k Joules. kg<sup>-1</sup>. K<sup>-1</sup>)

$\Delta T$  is the change in temperature (°K) for a specific time.

- $Q_L = m L_{fg}$ ,
- $Q_L$  is the latent heat (k Joules),
- $m$  is the quantity of water evaporated (kg) in specific period of time and
- $L_{fg}$  is the specific latent heat of vaporization (For water = 2240 k Joules.kg<sup>-1</sup>)

- Example:

The insolation of the place is about  $20 \text{ MJ m}^{-2}$  per day. The latent heat of evaporation of water is  $2.4 \text{ MJ/kg}$ . Assuming all the solar heat is available for evaporation and all the evaporated water is collected, calculate the output of the still.

- Solution:

The production will be  $20 \text{ MJ m}^{-2}$  per day /  $2.4 \text{ MJ/kg} = 8.3 \text{ kg per day per m}^2$ . In practice, the maximum achievable production is 60% of the above value  $\sim 5 \text{ kg/day/m}^2 = 5 \text{ litre per day per m}^2$

$$Q = \frac{E \times G \times A}{2.3}$$

where:

Q = daily output of distilled water (litres/day)

E = overall efficiency

G = daily global solar irradiation (MJ/m<sup>2</sup>)

A = aperture area of the still ie, the plan areas for a simple basin still (m<sup>2</sup>)