Sustainable Energy:

(*) Solar Radiation:

→ Solar Radiation is also called solar resource or sunlight.
→ It is a general term for electromagnetic radiation emitted by the sun.
→ Solar radiation can be captured and converted into useful forms of energy, such as heat and electricity, using a variety of technologies.
→ Solar radiation is the energy emitted by the sun which is sent in all directions through space.
→ It is also directly and indirectly responsible for common phenomenon such as photosynthesis.
→ The sun emits energy in the form of short wave radiation, which is weakened in the atmosphere by the presence of clouds and absorbed by gas molecules.
→ Solar radiation is measured by means of a pyranometer. Measured in watts per square metre (W/m^2).

Types of solar Radiation: Depending on the form in which it reaches the earth:

① Direct solar radiation:
→ Radiation which penetrates the atmosphere
→ Reaches the Earth's surface without dispersing at all on the way.
→ Also called beam radiation or direct beam radiation.
→ Radiation travels from the sun to the earth's surface in a straight line.

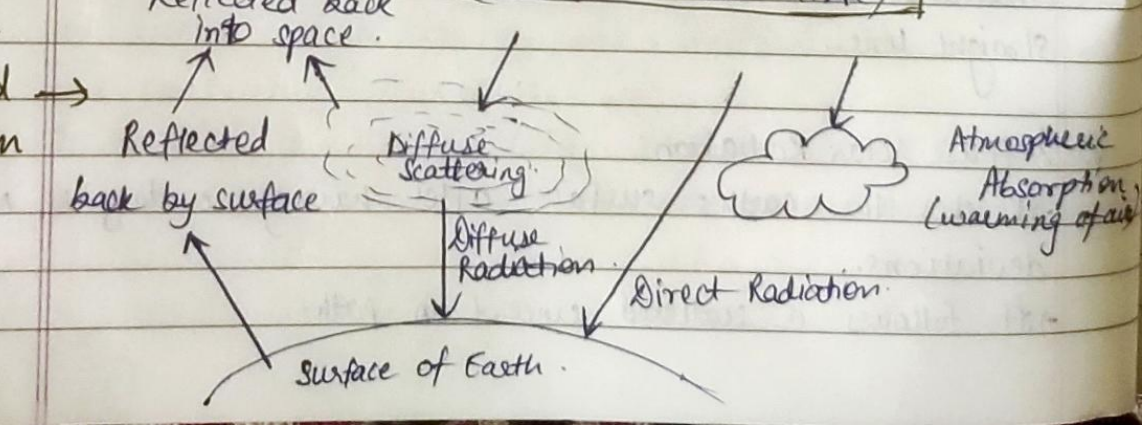
② Diffuse Solar Radiation:
→ Reaches the earth's surface after having undergone multiple deviations.
→ It follows a scattered, uncertain path.

③. Reflected Solar Radiation:
→ Fraction of solar radiation that is reflected by the earth's surface.
→ This phenomenon is called albedo effect.

Depending on Types of light:
① Infrared Rays: Longer wavelength than visible light, they emit heat.
② Visible rays: They emit light; perceived by human eye.
③ Ultraviolet (UV) rays: Invisible to Human eyes, have the most serious impact on skin. Further divided into Ultraviolet A, Ultraviolet B & Ultraviolet C.

(*). Solar Constant:
→ Total radiation energy received from the Sun per unit of time per unit area on a surface perpendicular to Sun's rays and at Earth's mean distance from Sun
→ It is most accurately measured from satellites.
→ The value of the constant is approximately 1.356 kilowatts per square metre.

Solar Constant = Energy / (Unit area × unit time)



(*) Solar Angles / Sun Angles:

① Angle of latitude: Angle between a line that points from the center of the Earth to a location on the Earth's surface and a line that points from the center of earth to equator. Denoted by φ.

② Inclination Angle: Describes the tilt of PV cell compared to a horizontally mounted PV cell.

③ Zenith angle (θ_z): The angle between the line that points to the Sun and the vertical. It is just where the sun is in the sky.

④ Solar Azimuth Angle (γ_s): Angle that points to the sun and south. Only measured in Horizontal plane.

⑤ Tilt angle or slope: Angles at which solar panels are mounted to face the Sun.

⑥ Angle of Incidence (θ): Angle between the line that points to the sun and the angle that points straight out of a PV panel. (line that is normal to the surface of the panel).

⑦ Surface Azimuth Angle (γ): Angle between the line that points straight out of a PV panel and south. Only measured in Horizontal plane.

⑧ Solar Altitude Angle (α_s): Angle between the line that points to the sun and the Horizontal. Complement of zenith angle. This angle is 0° at sunrise and sunset.

⑨ Hour angle (ω): Based on sun's angular displacement, east or west.

⑩ Declination angle (δ): Angle between the line that points to the sun from the equator and the line that points straight out from the equator.

(*). Solar Collectors:

→ Collectors are the starting point for the conversion of sunlight into energy.

→ They must be designed to efficiently concentrate light while minimizing installation & operational costs.

→ These devices are primarily used for active solar heating and allow for the heating of water for personal use.

→ Generally mounted on a roof.

→ Types of solar collectors:

ⓐ. Flat Plate Collectors

ⓑ. Concentrating Collectors.

①. Flat Plate Collectors:

→ Simple metal boxes with some kind of transparent cover on top.

→ The sides and bottom are covered with insulation to minimize heat loss.

→ Solar radiation passes through transparent material and hits the absorber plate.

→ This plate heats up, transferring the heat to either water or air that is held b/w these two plates.

→ Sometimes absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint.

→ It requires little maintenance.

②. Concentrating Collectors:

→ They reflect or refract the incident solar radiation.

→ It comprises a receiver, where radiation is absorbed and converted to some other form of energy. and a concentrator that directs beam radiation

onto the receiver.

→ They provide energy at higher temperature than flat plate collector.

→ They redirect solar radiation into an absorber and usually require tracking of the sun.

→ Higher efficiency. High initial cost.

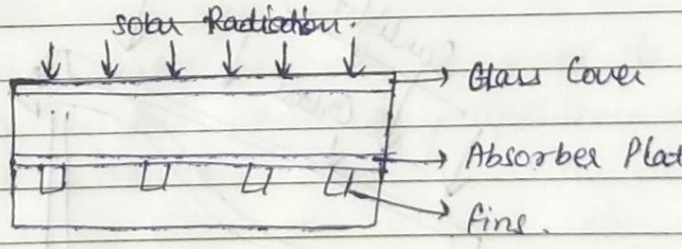
Liquid based Solar Collector: Solar collector that uses sunlight to heat a liquid that is circulating in a 'solar loop'.
The solar loop transfers the thermal energy from collectors to a thermal storage tank.
(Similar to flat plate collector).

(X) Solar Air Heaters:

→ The energy from the sun is captured by an absorbing medium and used to heat air.

→ It is a renewable air heating technology used to heat or condition air.

→ Most cost effective out of all solar technologies.



Types: ①. Porous (Air flow through absorber plates).
② Non-Porous. (No air flow through absorber plates)

(*) Solar Dryer:

→ Another technology to harness the solar energy that is used to dry fruits, vegetables & crops for preservation.

→ Two types: direct and indirect.

→ In direct, the substance that is to be dehydrated is exposed to sunlight in a vast field.

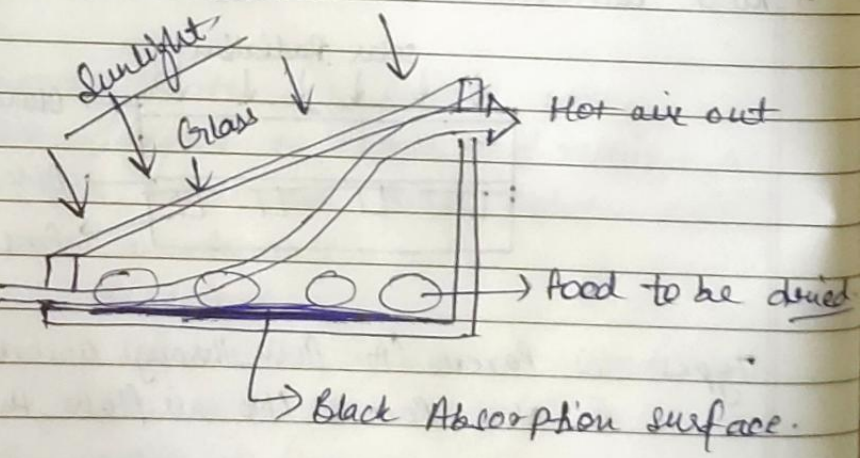
→ Indirect solar dryers consist of an insulated box coated inside with a black absorption surface, an air inlet and an air outlet & a single or double glazed glass.

→ The inlet air hole is at lower side for the entrance of cold air.

→ The outlet is at the upper side of opposite wall.

→ The sunlight coming throug the glazing keeps the inner environment warm, which dehydrates the substance.

→ The cold air takes the hot air enriched with moisture from the box and the air is ventilated through hot air outlet.



(X) Storage of Solar Energy:

→ Storage refers to technologies that can capture electricity, store it as a form of Energy and then release it for use when it is needed.

→ Using Energy Storage is not 100% efficient. Some energy is always lost in converting and retrieving it.

→ Storage can increase system efficiency.

→ Storage facilities differ in both, energy capacity, which is the total amount of energy that can be stored and power capacity, which is the amount of Energy that can be released.

→ Benefits of Storing Solar Energy:

① Balancing electricity loads: If electricity isn't stored, then it has to be used at the moment it is generated.

② Filling in the gaps: Provides consistent energy flow during brief disruptions in generators.

③ Energy resilience: Solar energy storage creates a protective bubble during disruptive events.

④ Saving from electric bills: By using solar energy, you consume your own power.

⑤ Large solar batteries can be used to charge electric vehicles and turn any appliance into a "solar-powered" device.

Types of Energy storage:

① Pumped Storage Hydropower: Based on water. Electric energy is used to pump water uphill into a reservoir when energy demand is low. Later, the water can be allowed to

flow back downhill and generate electricity when demand is high.

③. Electrochemical Storage: Electrochemical batteries found in laptops and mobile phones.

④. Thermal Energy storage: Technology in which a fluid, such as water or molten salt or other material is used to store heat. This thermal storage material is then stored in an insulated tank until the energy is needed.

⑤. Flywheel Storage: Flywheel is a heavy wheel attached to a rotating shaft. The energy can be extracted by attaching the wheel to electrical generator. They can't store a lot of Energy.

⑥. Solar fuels: Solar power can be used to create new fuels that can be combusted (burned) or consumed to provide energy, effectively storing the energy in chemical bonds.

⑦. Virtual Storage: By heating or cooling a building before anticipated peak of electric demand, the building can "store" that thermal energy so it doesn't need to consume energy later in the day.

⑧. Thermal Storage:

→ Heating or cooling the medium to use the energy when needed later.

→ For eg, using a water tank for heat storage, where the water is heated at times when there is a lot of energy, and the energy is then stored in the water for use when energy is less plentiful.

→ Can also be used to balance energy consumption between day and night.

→ Divided in 3 types:

ⓐ · Sensible heat : use water or rock for storing & releasing heat energy.

ⓑ · latent heat : Depends upon the changing state of a medium.

ⓒ · Thermochemical heat : Systems based on chemical reactions.

→ Key benefits:

① Reduces peak demand and level demand by storing energy when there is less demand and relasing when there is high demand.

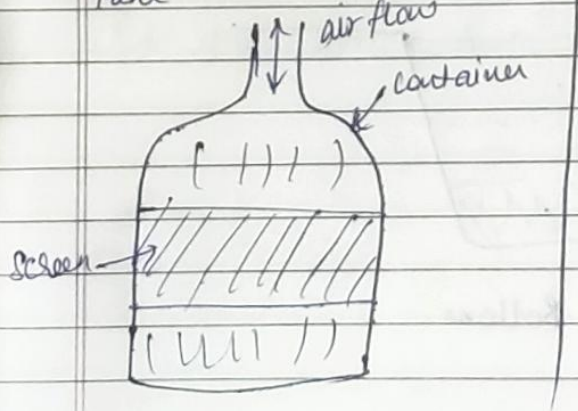
② · Reduce CO_2 emissions and costs by making sure that the energy is used when it is cheaper and there is more renewable energy in the mix.

③ · Increases the overall energy efficiency of energy systems.

→ A material gains energy when increasing its temperature and loses it when decreasing.

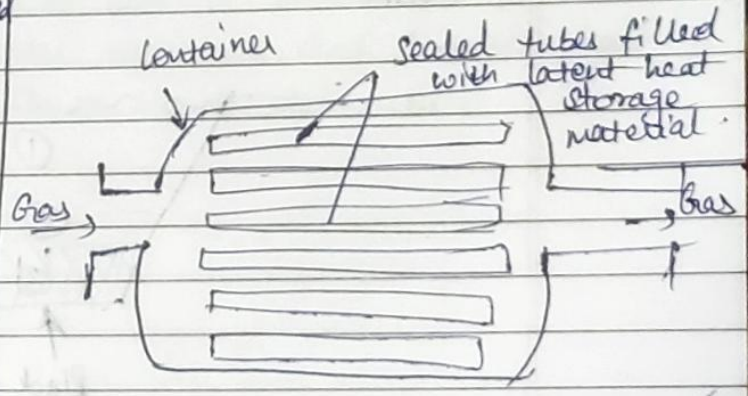
Sensible Heat Storage.

→ Heat transfer fluid - water
→ Inexpensive, easy to store
→ Easily available.
→ High thermal storage capacity.
→ Water stored in highly insulated tank.



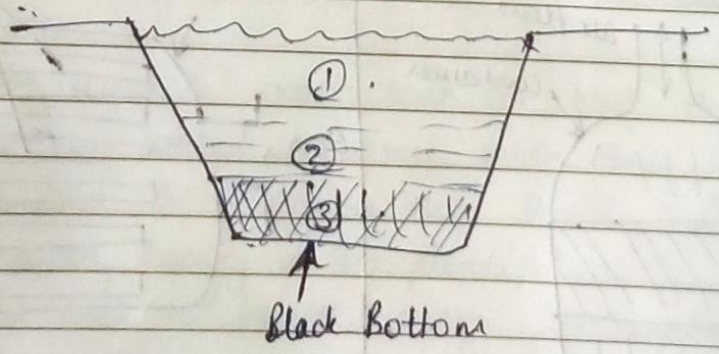
Latent Heat Storage.

→ Heat material melts storage.
→ High latent heat effect.
→ low cost, non toxic, inflammable
→ High thermal conductivity.



Solar Pond:

→ Artificial pond that uses solar energy to provide heating, cooling or desalination for industry, water treatment, or agriculture.
→ Efficient way of harvesting solar energy.
→ Cost effective.
→ It requires constant maintenance and a large area of land.
→ Human-made bodies of water that use sun's heat.
→ They store the collected heat instead of transferring it through fluids or devices.
→ Solar Ponds have 3 layers: Top zone, Gradient zone, Bottom zone.
ⓐ Top zone: Sun activated heating portion of Solar Pond.
ⓑ Bottom zone: located in the bottom. Absorbs solar Ponds heat.
ⓒ Gradient zone: Middle zone. Absorbs energy from top zone and transfers to bottom zone.
→ Energy derived from solar pond is more cost-effective.
→ Safe for the environment as it does not emit harmful toxins and pollutants.
→ Requires high level of solar Energy Input.
→ Needs to be supplied with an Extensive reservoir of water.



(*). Solar Water Heaters:

→ Device that helps in heating water by using energy from the Sun.

→ water is easily heated to a temperature of 60-80°C.

→ Solar water heaters of 100-300 litres capacity are suited for domestic use.

→ working:

① The Sun's rays fall on a collector panel.

② A black absorbing surface inside the collector absorbs solar radiation and transfers heat energy to water flowing through it.

③ Heated water is collected in a tank which is insulated to prevent heat loss.

→ Main components:

① Solar collector (to collect solar Energy).

② Insulated tank (to store hot water).

→ Types: ① Flat plate Solar water Heater: A black absorbing surface absorbs solar radiation and transfers energy to the water flowing through it.

② Evacuated Tube Collector (ETC) Based Solar Water Heater: Made of double layer glass tubes evacuated for providing insulation. Outer wall of tube is coated with absorbing material. This absorbs solar radiation and transfer heat to the water that flows inside the tube.

(*) Solar Distillation

→ Solar Distillation unit is a system that distillates the contaminated water by using solar irradiative energy obtained from the sun

→ It can be used to remove salts from water

→ Basic design consists of a shallow trough (covered)

→ Water evaporates from the trough and condenses on a plate over the trough

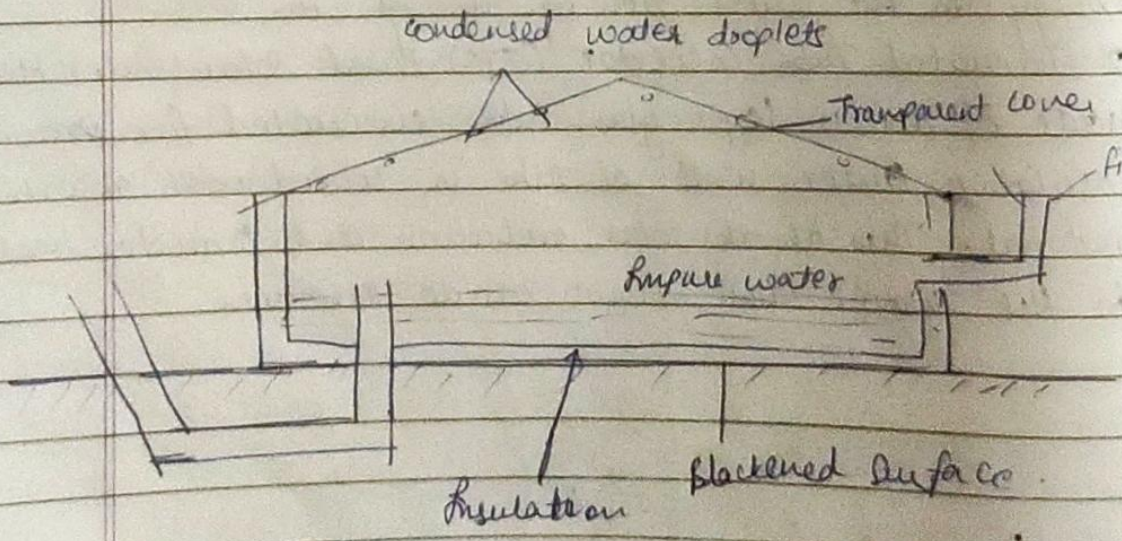
→ For high efficiency, one should have high solar radiation, high temperature, low wind and small condenser surface

→ Drawbacks are high initial costs and intermittent use of sun

→ Simple designs are preferred because they are easy to maintain and cost effective.

→ Process of removing salts and other impurities using the energy of sun to get pure drinking water

→ Solar energy is used to evaporate the water and its condense is collected within the same closed system.



(*) Solar Heating and Cooling of Buildings

→ Conventional heating and cooling systems are responsible for a large amount of carbon dioxide release into the environment

→ They are also responsible for the release of harmful refrigerants that cause greenhouse effect and ozone layer depletion

→ Solar radiation is a clean form of Energy which is required for almost all natural processes on the Earth.

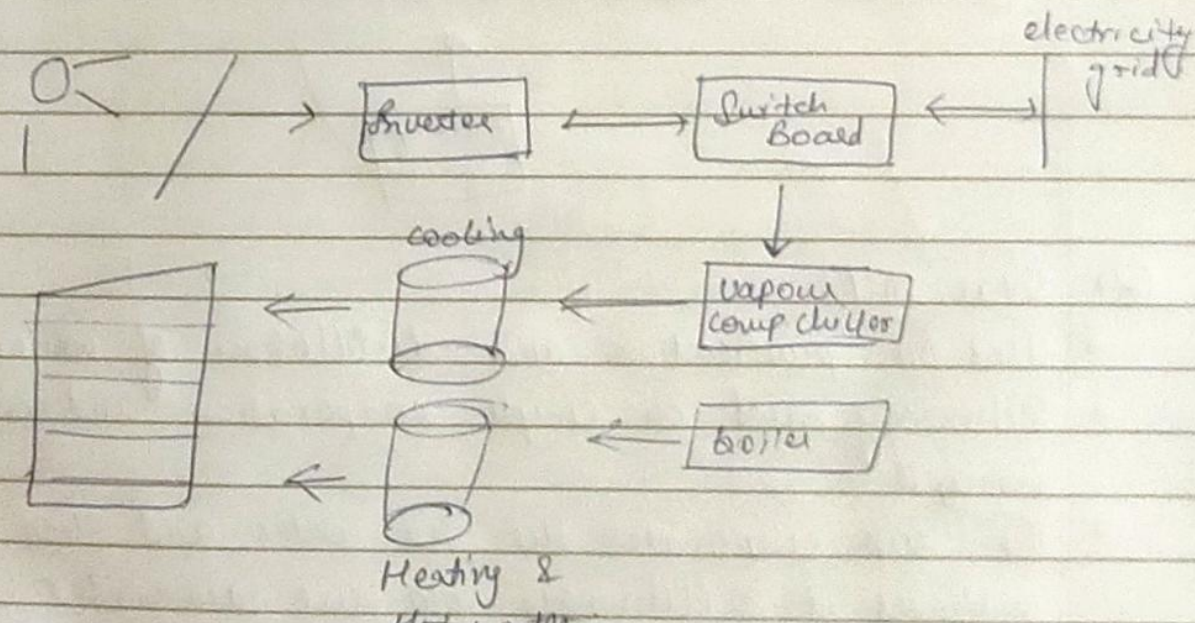
→ 2 main technologies used are

① photovoltaic Systems

② Solar thermal collector Systems.

(*) Photovoltaic Systems: A normal boiler is used for heating and hot water production

A vapour compression chiller is used for cooling.



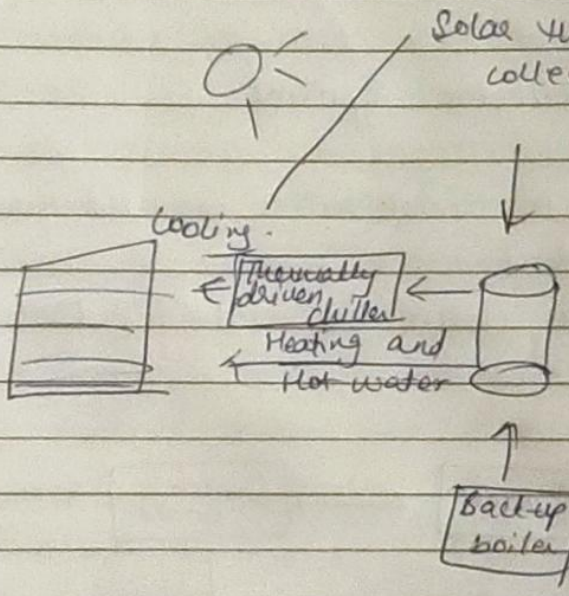
(*) Solar Thermal Collector Systems:

→ Most common way to cover hot water loads in buildings.

→ Can be used for cooling by integrating a thermally driven cooling device.

→ A back up boiler is used for both, heating and cooling.

→ A vapour compression chiller is used as a backup device for cooling.



(*) Solar still:

→ Used for purification and distillation of water.

→ Technology based on simple evaporation and condensate principle.

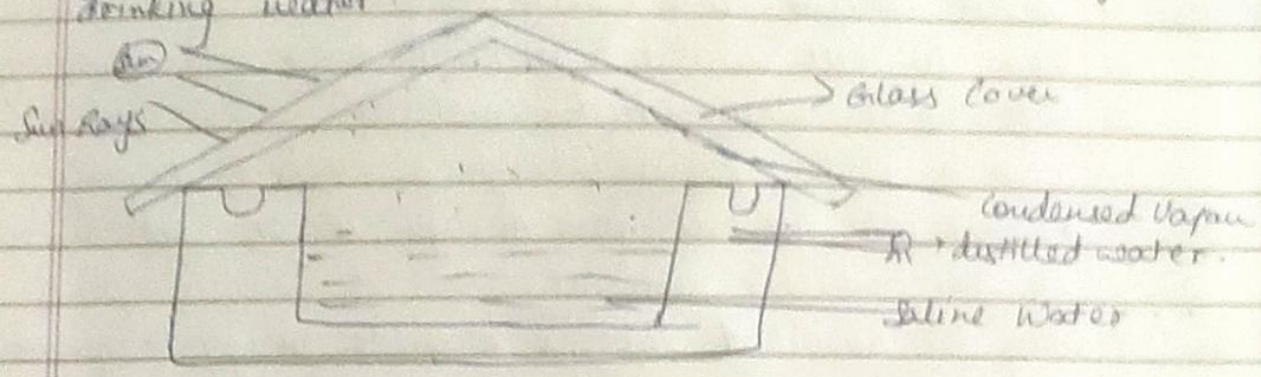
→ The sun evaporates the sea water and then condenses it to eliminate into pure rain water.

→ Saline water is fed into the tank which is exposed to

→ The black bottom absorbs solar energy and gets heated.

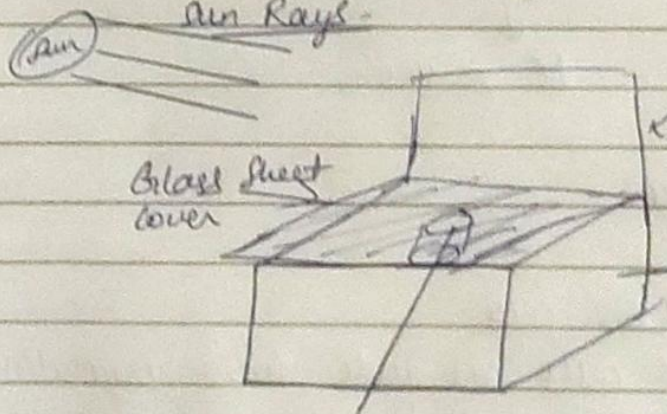
→ This heat evaporates the tank water which condenses

glass sheet and finally converts it into drops of drinking water.



(ii) Solar Cooker:

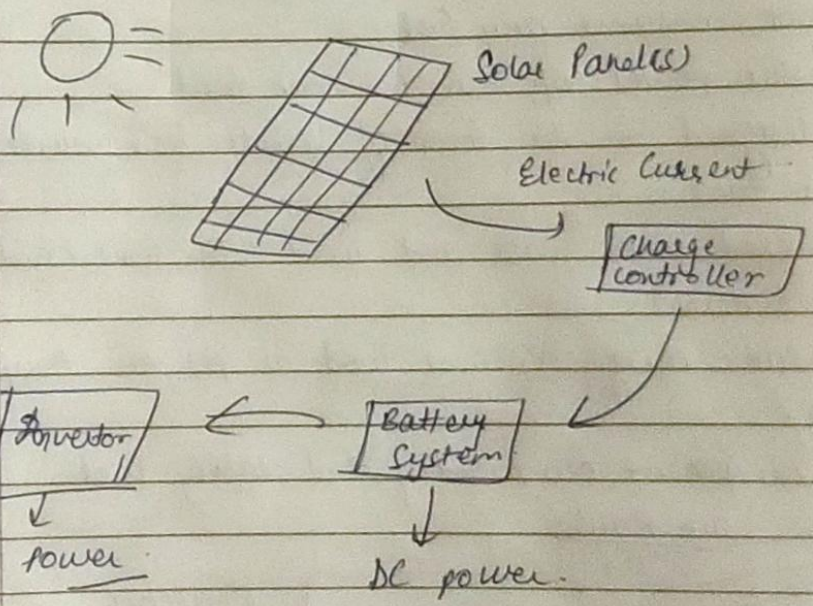
→ One of the simplest utensils used to cook food.
→ It doesn't use fire and it is enviornment friendly.
→ It does not consume any fuel.
→ Harnesses the power of sun to cook food.
→ Usually designed in the form of simple box where you place your food.
→ Box is covered with glass and lined with some kind of reflective material
→ It uses sun's energy to cook food as per the temperature you want.
→ They are inexpensive, eco friendly and easily used.



Containers Having food to be cooked.

(*) Photo Voltaic cells:

→ Convert sunlight into electricity.
→ Some PV cells convert artificial light into electricity
→ Made up of semiconductor material.
→ When a photon passes through a PV cell, it may reflect off the cell, pass through it or get absorbed by semiconductor material.
→ Only the absorbed photons provide energy to generate electricity.
→ When the semiconductor material absorbs enough sunlight electrons are dislodged from material's atoms.



→ Types: 3 types:

① Crystalline Silicon cells:
→ Around 90% of cells are made from Crystalline Silicon
→ Single crystals are used to make mono crystalline solar panels and cells while multiple crystals are

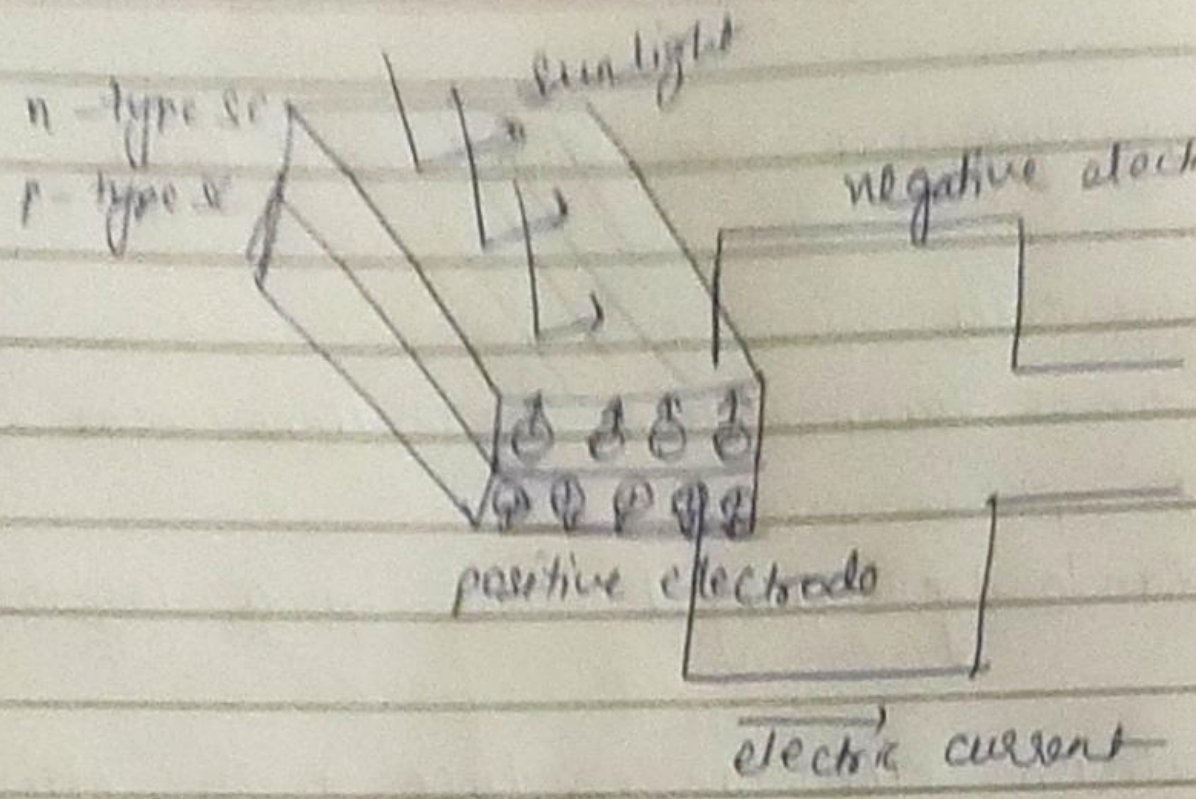
used for polycrystalline solar panels and cells.

② Thin film Solar Cells.
→ Around 100 times thinner from Crystalline solar cells
→ Made from amorphous silicon.
→ Atoms are Randomly arranged than in a Crystalline structure.
→ Crystalline silicon cells can produce a 20% efficiency, these film cells only reach around 7% efficiency.

③ Third Generation Solar Cells:
→ latest solar cell technologies combine best features of both the previous cells.
→ Provides High efficiency.
→ Cheaper, more efficient and more practical.
→ Provide around 30% efficiency.

(*) Characteristics and Working Principle of PV cells.

Working:
→ Based on Photovoltaic Effect.
→ Current or voltage is generated when exposed to light.
→ A depletion layer is formed at the junction of N type and P type semiconductor material.
→ When the light energy of the sun rays fall on the solar panel, The photons give energy to electrons and holes.
→ The electrons and holes move to a higher level which is Conduction band.
→ Electrons move towards N type and holes move towards P type and form a battery.
→ This movement forms electric current.



→ VI Characteristics.