UNIT II - NON-CONCENTRATING COLLECTORS
Types and classification of solar collectors - terminology related to flat plate collectors - evacuated collectors-Heat transfer processes and efficiency of a solar collector -solar drying- solar desalination- solar mechanical cooling- solar desiccant cooling- heat pump

1. Types and Classification of Solar Collectors

Solar collectors are devices that absorb solar radiation and convert it into useful heat energy.

They are classified as follows:

(A) Based on Concentration Ratio

Type	Concentration Ratio	Example
Non-Concentrating Collector	1:1	Flat plate collector, Evacuated tube collector
Concentrating Collector	>1	Parabolic trough, Fresnel lens

(B) Based on Medium of Heat Transfer

Type	Heat Transfer Medium	Example
Liquid Collector	Water or oil	Solar water heaters
Air Collector	Air	Solar drying systems

(C) Based on Mode of Heat Transfer

Type	Heat Transfer Method	Example
Passive	Natural convection	Thermosiphon solar heater
Active	Pump or fan-driven	Forced circulation solar heater

Example:

A **flat plate collector (FPC)** is used for residential solar water heating because of its simple design and effectiveness.

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2. Flat Plate Collectors (FPCs)

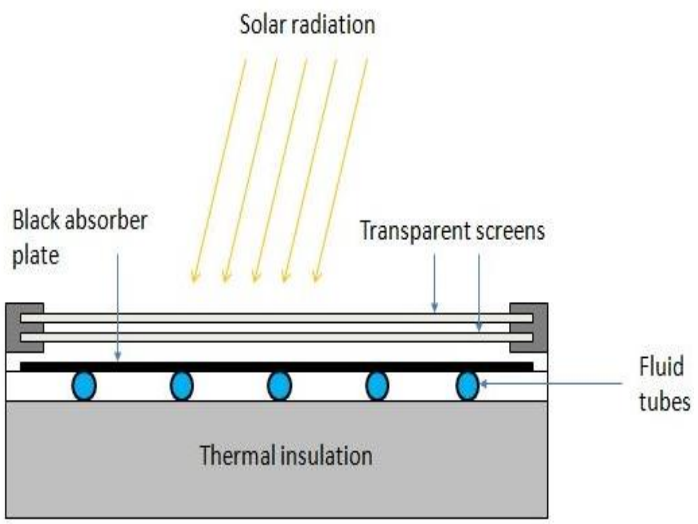
Flat Plate Collectors (FPCs) are one of the most commonly used **non-concentrating solar collectors** for harnessing solar thermal energy. They are widely used for heating applications such as **water heating, space heating, and industrial process heating**.

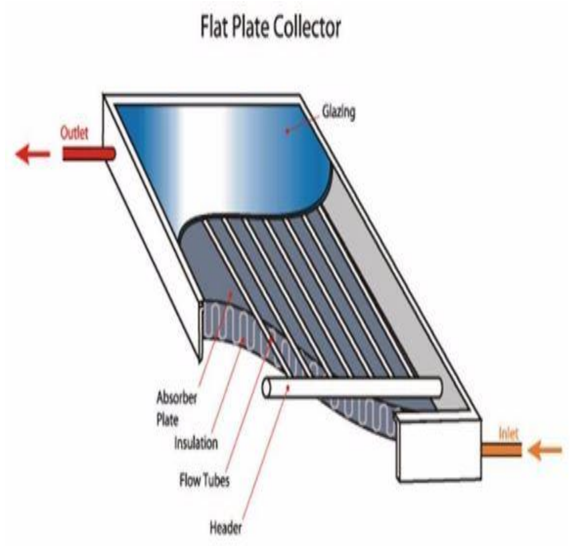
Principle of Flat Plate Collectors

Flat Plate Collectors work on the principle of **absorbing solar radiation and converting it into heat energy**, which is then transferred to a working fluid (water or air).

Basic Principles:

1. **Absorption of Solar Radiation:** The **absorber plate** absorbs sunlight and converts it into heat.
2. **Heat Transfer:** Heat is transferred to a **fluid (water or air)** flowing through tubes attached to the absorber plate.
3. **Minimizing Heat Loss:** A **transparent glass cover** reduces heat loss due to convection and radiation.
4. **Insulation:** A **thermal insulation layer** minimizes heat loss from the bottom and sides of the collector.
5. **Storage or Direct Use:** The heated fluid is either stored in an insulated tank or used immediately.





Construction of Flat Plate Collectors

A **Flat Plate Collector** consists of the following key components:

Component	Function
Absorber Plate	Collects and transfers solar energy to the working fluid
Transparent Cover (Glazing)	Reduces heat loss and allows sunlight to pass
Fluid Tubes (Heat Transport Tubes)	Carry the working fluid (water or air)

Component	Function
Insulation (Bottom and Sides)	Prevents heat loss from the collector
Casing/Enclosure	Provides mechanical support and protection from weather

Working of Flat Plate Collector

1. **Sunlight passes through the transparent glass cover** and strikes the absorber plate.
2. The **absorber plate absorbs solar radiation** and converts it into heat.
3. The **heat is transferred to a working fluid** (typically water or air) flowing through tubes attached to the absorber plate.
4. The **heated fluid exits the collector** and is either stored in an insulated tank or used directly.
5. **Insulation at the bottom and sides minimizes heat loss**, improving efficiency.

Types of Flat Plate Collectors

1. **Liquid Flat Plate Collectors:** Use **water or a heat transfer fluid** (glycol mixture) to absorb and transfer heat.
2. **Air Flat Plate Collectors:** Use **air as the heat transfer medium** and are commonly used for space heating and crop drying.

Advantages of Flat Plate Collectors

Advantage	Description
Simple Design	No complex tracking systems required
Low Maintenance	Fewer moving parts compared to concentrating collectors
Works in Diffused Radiation	Functions even on cloudy days with reduced efficiency
Durability	Long lifespan (15-25 years) with proper maintenance
Suitable for Domestic and Industrial Use	Can be installed for residential water heating and industrial applications
Non-Toxic & Environmentally Friendly	Uses natural solar energy without harmful emissions

Disadvantages of Flat Plate Collectors

Disadvantage	Description
Lower Efficiency	50-60% efficiency, lower than evacuated tube collectors
Heat Losses	Higher losses due to convection and radiation, especially in cold climates
Bulkier Design	Requires more space compared to concentrating collectors
Limited Temperature Range	Typically heats fluids up to **80°C**, not suitable for high-temperature applications
Prone to Freezing	Water inside tubes may freeze in cold climates, requiring antifreeze solutions

Applications of Flat Plate Collectors

Application	Example
Solar Water Heating	Domestic water heaters for homes and apartments
Space Heating	Heating systems in homes, offices, and greenhouses
Industrial Process Heat	Preheating water for boilers in industries
Solar Cooking	Solar ovens and food drying applications
Swimming Pool Heating	Maintaining pool water temperature using solar energy
Agricultural Drying	Drying crops, fruits, and fish using solar-heated air

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Example Calculation of Heat Gain in an FPC

Given Data:

- Solar radiation = **800 W/m²**
- Collector area = **2 m²**
- Collector efficiency = **60%**

Heat Absorbed:

$$Q = \text{Solar Radiation} \times \text{Area} \times \text{Efficiency}$$

$$Q = 800 \times 2 \times 0.6 = 960 \text{ W}$$

Thus, the **collector delivers 960 W** of heat energy.

Flat Plate Collectors are a **widely used, cost-effective, and durable** solution for capturing solar energy. Although they have some limitations in terms of efficiency and heat loss, they remain an essential part of **solar thermal applications worldwide**.

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3. Evacuated Tube Collectors (ETCs)

Evacuated Tube Collectors (ETCs) are **advanced non-concentrating solar collectors** that provide **higher efficiency** than Flat Plate Collectors (FPCs). They use vacuum-sealed glass tubes to **minimize heat loss**, making them ideal for applications requiring high temperatures, such as **solar water heating and industrial heating systems**.

Principle of Evacuated Tube Collectors

ETCs work on the principle of **heat absorption and vacuum insulation**:

1. **Absorption of Solar Energy:** A special **coated absorber tube** inside each evacuated glass tube absorbs solar radiation.
2. **Vacuum Insulation:** The vacuum between the two glass layers **prevents heat loss** due to conduction and convection.
3. **Heat Transfer:** The absorbed heat is transferred to a working fluid (water or antifreeze) circulating through a **manifold or heat pipe system**.
4. **Utilization or Storage:** The heated fluid is either stored in an **insulated tank** or used directly.

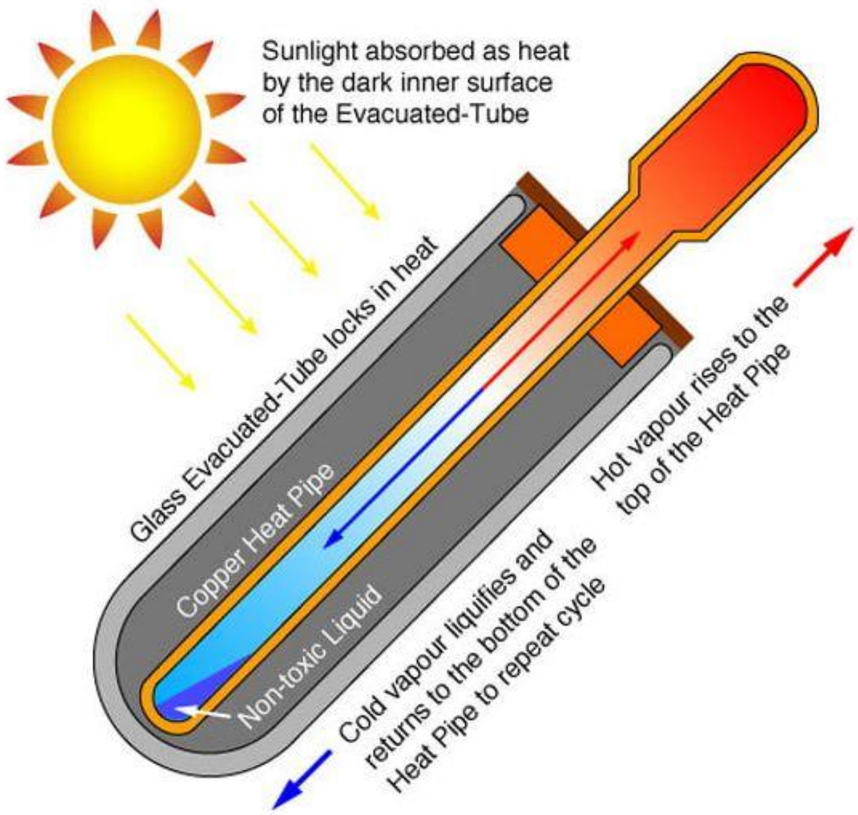
Key Principle:

Higher Absorption + Lower Heat Loss = Greater Efficiency

Construction of an ETC

An ETC consists of multiple **evacuated glass tubes** arranged in parallel, connected to a **manifold**.

Component	Function
Outer Glass Tube	Protects the system, allows sunlight to pass
Inner Glass Tube (Absorber Tube)	Absorbs solar radiation and converts it into heat
Vacuum Layer	Reduces heat loss due to convection and conduction
Heat Pipe (in some designs)	Transfers heat to the working fluid efficiently
Manifold/Header Pipe	Collects heat from multiple tubes and transfers it to the system



Working of an ETC

1. **Sunlight enters the evacuated glass tubes** and is absorbed by the **inner coated absorber tube**.
2. The **absorber tube transfers heat** to the working fluid (water or antifreeze solution).
3. The vacuum between the glass tubes **prevents heat loss**, maintaining high efficiency.
4. The heated fluid flows into the **manifold/header pipe**, where it is either stored or circulated for direct use.
5. **A pump (in active systems) or thermosiphon effect (in passive systems)** helps circulate the fluid.

Types of Evacuated Tube Collectors

Type	Working Mechanism	Application
Direct Flow ETC	Water or fluid flows directly through the tubes	Domestic water heating
Heat Pipe ETC	A heat pipe transfers heat to the manifold without direct water contact	Industrial heating, cold climates

Key Difference:

- **Direct Flow ETCs** are simple and used for residential water heating.
- **Heat Pipe ETCs** are **freeze-resistant** and better for industrial applications.

Advantages of Evacuated Tube Collectors

Advantage	Description
Higher Efficiency	70-80% efficiency, compared to 50-60% for FPCs
Low Heat Loss	Vacuum insulation minimizes convection and conduction losses
Works in Cold Climates	Functions well in winter and at low temperatures
High Temperature Output	Can heat water up to 150°C, compared to ~80°C for FPCs
Better Performance in Cloudy Weather	Works well even with diffused solar radiation
Durability	Tubes can be individually replaced if damaged

Disadvantages of Evacuated Tube Collectors

Disadvantage	Description
Higher Cost	More expensive than Flat Plate Collectors
Fragile Glass Tubes	Susceptible to damage from hail or impact
Requires Skilled Installation	Proper tilt and positioning needed for efficiency
Overheating Risk	High temperatures can cause scaling or steam formation

Applications of Evacuated Tube Collectors

Application	Example
Solar Water Heating	Domestic and commercial hot water systems
Industrial Process Heat	Preheating water for factories and boilers
Solar Space Heating	Heating systems for homes and buildings
Solar Cooling Systems	Used in absorption cooling technologies
Swimming Pool Heating	Heating pool water with solar energy
Solar Desalination	Provides heat for seawater desalination plants

Example Calculation of Heat Gain in an ETC

Given Data:

- Solar radiation = **900 W/m²**
- Collector area = **3 m²**
- Collector efficiency = **75%**

Heat Absorbed:

$$Q = \text{Solar Radiation} \times \text{Area} \times \text{Efficiency}$$

$$Q = 900 \times 3 \times 0.75 = 2025 \text{ W}$$

Thus, the **collector delivers 2025 W** of heat energy.

- Evacuated Tube Collectors **offer higher efficiency** and **better heat retention** than Flat Plate Collectors.
- They are **ideal for high-temperature applications** and **cold climates**.
- Despite their **higher cost**, their **long-term energy savings** and **durability** make them a preferred choice for solar heating applications.

Comparison: Evacuated Tube Collector vs. Flat Plate Collector

Feature	Flat Plate Collector (FPC)	Evacuated Tube Collector (ETC)
Efficiency	50–60%	70–80%
Heat Loss	High (convection & conduction)	Low (vacuum insulation)
Temperature Range	Up to 80°C	Up to 150°C
Performance in Cold Weather	Less effective	Highly effective
Durability	Stronger (rigid design)	Fragile (glass tubes can break)
Cost	Lower	Higher
Installation	Simple	Requires skilled installation

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4. Heat Transfer Processes and Efficiency of a Solar Collector

Heat transfer in solar collectors occurs through:

1. **Conduction:** Heat moves through solid materials (absorber plate).
2. **Convection:** Heat is transferred through fluids (air or water).
3. **Radiation:** Heat is emitted from hot surfaces.

Efficiency of a Solar Collector

The efficiency (η) of a solar collector is given by:

$$\eta = \text{Useful Heat Output} / \text{Solar Energy Input}$$

Example Calculation:

If a solar collector receives **1000 W/m²** of solar radiation and delivers **600 W/m²** of heat:

$$\eta = 600 / 1000 = 60\%$$

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5. Solar Drying

Solar drying uses solar energy to remove moisture from materials (e.g., food, timber).

Types of Solar Dryers:

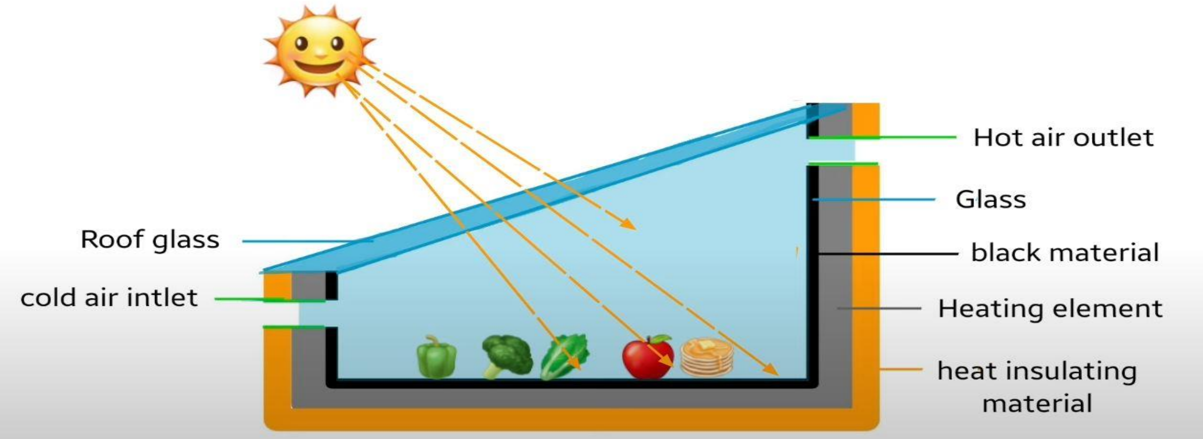
1. **Direct Solar Dryer:** Material is exposed directly to sunlight.
2. **Indirect Solar Dryer:** Uses a solar collector to heat air, which then dries the material.

Type	Mechanism	Example
Direct	Sunlight directly heats the object	Open-air drying of fruits
Indirect	Heated air is passed over the material	Solar timber drying

Example:

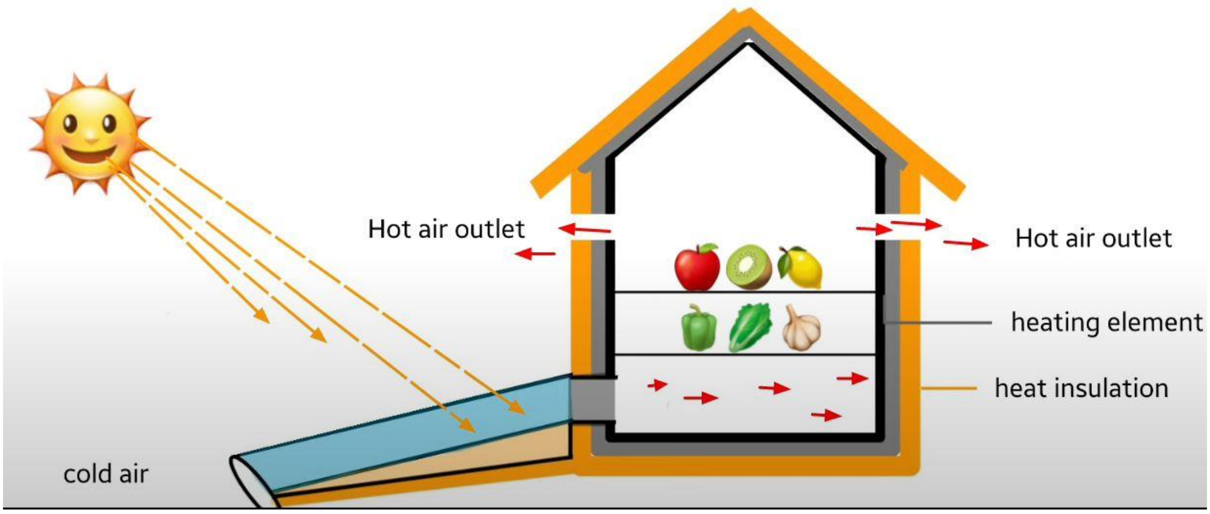
Solar fish dryers in coastal regions help preserve fish without electricity.

Direct Solar Dryer



- Food is directly exposed to sunlight inside a transparent-roof chamber.
- The black absorbing material helps increase drying efficiency.
- Suitable for drying herbs, spices, and small food items.

Indirect Solar Dryer



- Cold air is heated in a solar collector before being directed into a drying chamber.
- Moisture-laden air exits through the hot air outlet, promoting uniform drying.
- Best for drying fruits and vegetables.

Solar drying is a process that uses solar energy to remove moisture from materials, primarily food products, to enhance their shelf life and quality. The provided diagrams illustrate two different types of solar dryers.

Principle of Solar Drying

The principle of solar drying is based on the conversion of solar radiation into thermal energy, which heats the air. The heated air removes moisture from the food items placed inside the dryer. The moisture-laden hot air is then exhausted through an outlet, promoting continuous drying.

Working of Solar Dryers

Solar drying systems work by trapping solar radiation inside an insulated drying chamber. The working mechanism can be explained as follows:

1. **Solar Radiation Absorption**
    - Sunlight enters through a transparent cover (glass or plastic) and is absorbed by the black surface inside the dryer.

- The black surface converts the solar radiation into heat, increasing the temperature of the air inside.

2. **Air Circulation**
   - The cold air enters through the inlet.
   - As the air gets heated, it rises and moves towards the drying chamber where food products are placed.
3. **Moisture Removal**
   - The warm air absorbs moisture from the food.
   - The moisture-laden air is expelled through an outlet, ensuring a continuous drying process.
4. **Controlled Drying Environment**
   - The insulation within the system retains the heat and prevents excessive heat loss, making the drying process more efficient compared to open sun drying.

Advantages of Solar Drying

- **Energy Efficient**: Uses free and renewable solar energy, reducing dependency on electricity or fossil fuels.
- **Faster Drying**: Dries products faster than traditional open sun drying by trapping heat within the system.
- **Improved Hygiene**: Reduces contamination from dust, insects, and animals compared to open drying methods.
- **Preserves Nutrients**: Minimizes nutrient loss in food, maintaining quality.
- **Low Operating Cost**: Once installed, the operational cost is minimal since it mainly relies on sunlight.

Disadvantages of Solar Drying

- **Weather Dependent**: Efficiency is reduced during cloudy or rainy days.
- **Initial Investment**: Requires an initial setup cost for constructing the dryer.
- **Limited Capacity**: The amount of food that can be dried at a time is limited by the dryer’s size.
- **Temperature Control Issues**: Requires monitoring to prevent overheating or uneven drying.

Applications of Solar Drying

- **Food Preservation**: Drying fruits, vegetables, grains, spices, and meat to extend shelf life.
- **Herbal and Medicinal Plants**: Used in drying herbs and medicinal plants while preserving their essential oils.
- **Agricultural Products**: Drying crops like coffee beans, cocoa, and nuts.
- **Fish and Meat Drying**: Helps in preserving fish and meat for long-term storage.
- **Industrial Uses**: Can be applied in drying wood, textiles, and other industrial products.

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6. Solar Desalination

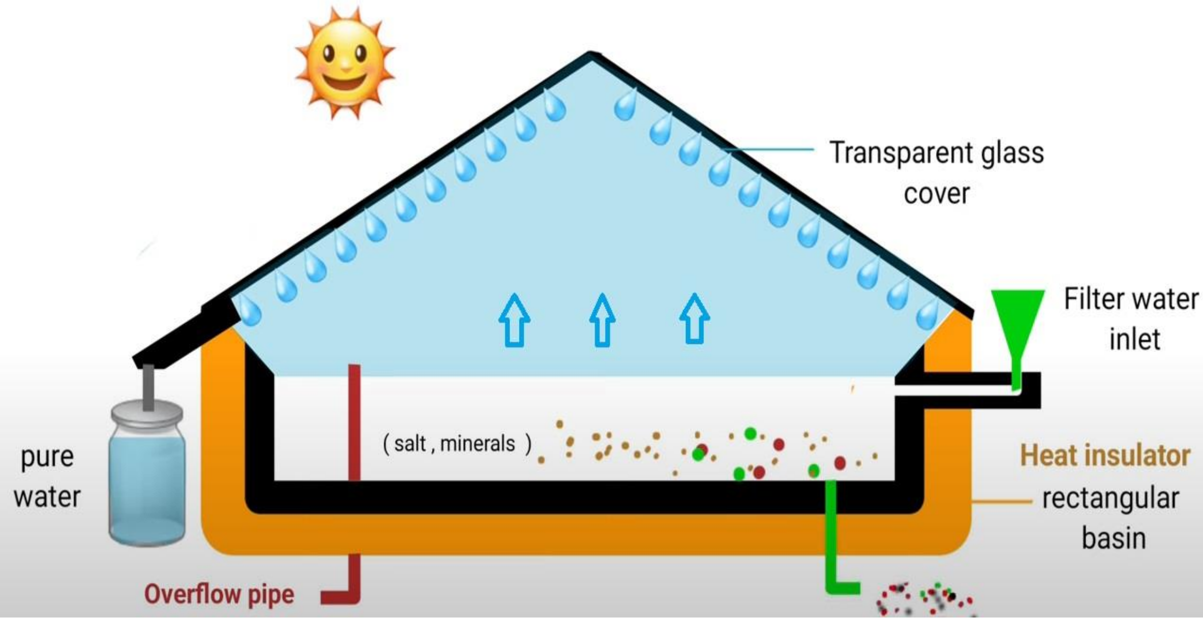
Solar desalination removes salt from sea water using solar energy.

Types of Solar Desalination Systems:

1. **Solar Still:** Uses sunlight to evaporate water, leaving salt behind.
2. **Multi-Effect Distillation (MED):** Uses solar heat in multiple evaporation-condensation stages.

Example:

A **solar still** can produce **5 liters of freshwater per day per square meter** in sunny regions.



This technology is particularly useful in regions facing water scarcity and high salinity levels in natural water sources. The **solar desalination system**, which is used to convert saline or contaminated water into fresh, drinkable water using solar energy.

Principle of Solar Desalination

Solar desalination is based on the natural process of **evaporation and condensation**. It mimics the water cycle:

- Solar radiation heats saline water, causing it to evaporate.
- The evaporated water condenses on a cooler surface, leaving behind salts and impurities.
- The condensed pure water is collected separately.

Working of Solar Desalination

The working process of the solar desalination system, as shown in the diagram, is as follows:

1. **Water Inlet & Basin Heating:**
    - Saline or impure water enters through the **filter water inlet** into a **rectangular basin** lined with a **heat insulator** to prevent heat loss.
    - A **transparent glass cover** allows sunlight to enter, heating the water inside.
2. **Evaporation Process:**
    - Sunlight increases the temperature of the water, causing it to evaporate.
    - As the water evaporates, dissolved **salts, minerals, and impurities** remain in the basin.
3. **Condensation & Collection:**
    - The water vapour rises and comes into contact with the **inner surface of the glass cover**, which is cooler.
    - The vapour condenses into droplets of pure water.
    - The condensed water flows down the inclined glass surface and is collected through an **outlet**, storing pure water separately.
4. **Waste Disposal:**
    - The residual salts and impurities settle at the bottom of the basin.
    - The **overflow pipe** helps in draining excess waste water and cleaning the basin.

Advantages of Solar Desalination

- **Renewable Energy Source**: Uses abundant and free solar energy.
- **Eco-friendly**: No harmful emissions or pollutants.
- **Low Maintenance**: Simple design with minimal moving parts.
- **Self-Sustainable**: Works independently in remote or off-grid areas.
- **Cost-Effective**: No fuel cost; only an initial setup investment.

Disadvantages of Solar Desalination

- **Slow Process**: Evaporation and condensation take time.
- **Weather Dependent**: Efficiency reduces on cloudy days or at night.
- **Limited Output**: Small-scale production; not suitable for large-scale desalination.
- **Initial Cost**: Setup cost can be high for larger systems.

Applications of Solar Desalination

- **Drinking Water Production**: Converts seawater or brackish water into potable water.
- **Remote and Rural Areas**: Provides clean water in off-grid locations.
- **Disaster Relief**: Emergency water supply in disaster-struck regions.
- **Agriculture and Irrigation**: Purifies water for farming.
- **Industrial Use**: Can be applied in small-scale industries requiring pure water.

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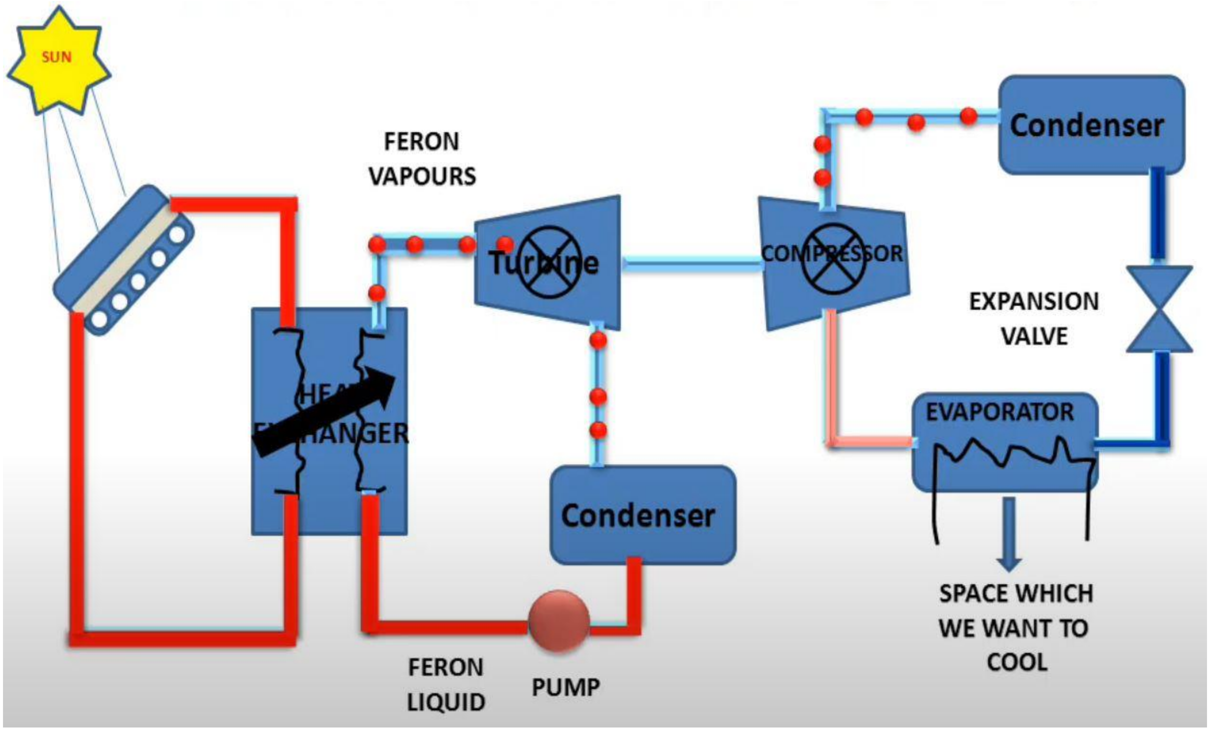
7. Solar Mechanical Cooling

This method uses solar energy to power **mechanical cooling systems** such as:

- **Solar Absorption Cooling** (Li-Br & Ammonia-Water systems).
- **Solar-Powered Vapor Compression Systems** (conventional refrigeration with solar electricity).

Example:

A **solar air conditioning system** uses a **solar-powered compressor** to cool buildings.



This **solar-assisted cooling** system is a promising alternative for reducing energy consumption while maintaining cooling efficiency. The above diagram represents a **solar-powered mechanical cooling system**, which integrates solar energy into a refrigeration cycle to provide cooling. This system is beneficial for reducing dependency on conventional electricity and enhancing energy efficiency.

Principle of Solar Mechanical Cooling

Solar mechanical cooling works on the principle of the **vapour compression refrigeration cycle**, but instead of using electricity as the primary energy source, it utilizes **solar thermal energy**.

- **Solar heat** is used to drive a heat exchanger, which produces refrigerant vapours.
- The refrigerant follows a **compression-expansion cycle** to absorb heat from a given space and dissipate it elsewhere.

Working of Solar Mechanical Cooling System

Step-by-Step Process:

1. **Solar Energy Collection:**
    - A **solar collector** absorbs sunlight and heats a working fluid (possibly refrigerant or water).
    - The heated fluid is transferred to a **heat exchanger**, where it vaporizes the refrigerant (Freon Vapours).
2. **Refrigeration Cycle Activation:**
    - The vaporized refrigerant passes through a **turbine**, which may extract some mechanical work.
    - The refrigerant then enters a **compressor**, where it is further compressed to increase pressure and temperature.
3. **Heat Dissipation in Condenser:**
    - The **condenser** removes heat from the high-pressure refrigerant, converting it back into liquid.
    - This step releases heat into the surroundings (e.g., air or water cooling).
4. **Expansion & Cooling Effect:**
    - The high-pressure liquid refrigerant passes through an **expansion valve**, which reduces its pressure and temperature.

    - This low-pressure refrigerant enters the **evaporator**, where it absorbs heat from the **space to be cooled**, creating a cooling effect.

5. **Recirculation of Refrigerant:**
    - The refrigerant, now in a low-pressure vapour state, returns to the **heat exchanger**, where the cycle repeats.
    - A **pump** is used to circulate the working fluid back to the solar collector.

Advantages of Solar Mechanical Cooling

- **Energy Efficient:** Uses solar energy, reducing electricity consumption.
- **Environmentally Friendly:** Lower carbon footprint compared to conventional cooling.
- **Cost Savings:** Reduced operational costs due to free solar energy.
- **Sustainable Solution:** Works well in hot and sunny climates, where cooling demand is high.
- **Reduced Grid Dependency:** Ideal for remote or off-grid areas.

Disadvantages of Solar Mechanical Cooling

- **High Initial Cost:** Requires expensive solar collectors, heat exchangers, and compressors.
- **Weather Dependency:** Performance decreases in cloudy or rainy conditions.
- **Complex System:** Requires skilled maintenance and monitoring.
- **Lower Efficiency:** Compared to conventional ACs, efficiency may be lower without proper solar exposure.

Applications of Solar Mechanical Cooling

- **Residential and Commercial Buildings:** Reduces energy costs for air conditioning.
- **Industrial Cooling:** Used in factories requiring temperature regulation.
- **Refrigeration Units:** Ideal for cold storage and food preservation.
- **Off-grid Cooling Solutions:** Useful in remote or rural areas with limited electricity access.
- **Data Centres:** Helps in energy-efficient cooling for IT infrastructure.

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8. Solar Desiccant Cooling

Desiccant cooling removes humidity from the air using **moisture-absorbing materials** (e.g., silica gel).

Working Principle:

1. **Desiccant absorbs moisture from humid air.**
2. **Solar heat regenerates the desiccant for reuse.**

Example:

Solar desiccant cooling is used in **large commercial HVAC systems**.

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9. Heat Pump

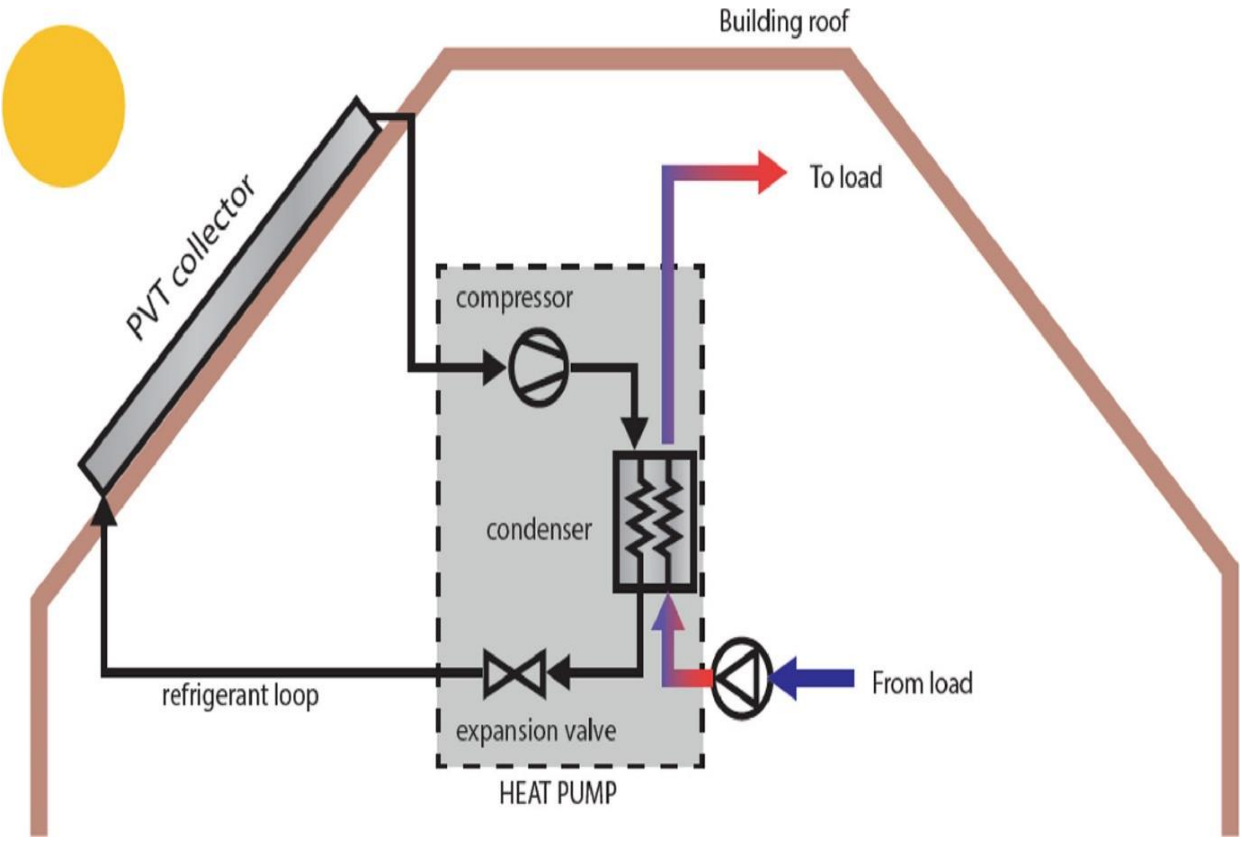
A **heat pump** transfers heat from a low-temperature source to a high-temperature sink using solar energy.

Working Principle:

- Uses a **working fluid** to extract heat from the environment.
- A **compressor** increases temperature and delivers heat to the required area.

Example:

A **solar-assisted heat pump** provides hot water for buildings with high efficiency.



The above diagram illustrates a **heat pump system** integrated with a **Photovoltaic-Thermal (PVT) collector**, which utilizes solar energy to assist in heating or cooling applications. This setup improves efficiency by harnessing solar energy to power the refrigerant loop of the heat pump.

Principle of Heat Pump System

A **heat pump** works on the principle of the **vapour compression refrigeration cycle** but in reverse, transferring heat from a lower-temperature source to a higher-temperature sink.

- The system absorbs heat from the surrounding environment (air, water, or ground) and **pumps** it to a desired location using a refrigerant cycle.
- The **Photovoltaic-Thermal (PVT) collector** in this system helps improve efficiency by preheating the refrigerant, reducing electrical energy consumption.

Working of the Heat Pump System

Step-by-Step Process:

1. **Solar Energy Collection via PVT Collector:**
    - The **PVT collector** absorbs sunlight and transfers thermal energy to the refrigerant in the **refrigerant loop**.
    - This helps reduce the work required by the compressor, improving efficiency.
2. **Heat Absorption from Load:**
    - The **evaporator** extracts heat from the source (air, water, or ground).
    - The refrigerant absorbs this heat and evaporates into a low-pressure gas.
3. **Compression:**
    - The refrigerant gas enters the **compressor**, where it is compressed to a high-pressure, high-temperature state.
    - This compression increases the temperature of the refrigerant.
4. **Heat Release in Condenser:**
    - The **condenser** releases the absorbed heat to the target area (building, water, or another system).
    - This heat is used for space heating, water heating, or other applications.
5. **Expansion & Recirculation:**
    - The refrigerant passes through the **expansion valve**, reducing its pressure and temperature.

- The low-pressure refrigerant then re-enters the evaporator, where it absorbs heat again, repeating the cycle.

Advantages of Heat Pump System

- **Energy Efficient:** Uses ambient heat and solar energy, reducing electricity consumption.
- **Dual Functionality:** Can provide both heating and cooling.
- **Eco-Friendly:** Lowers carbon emissions compared to conventional heating systems.
- **Long-Term Cost Savings:** Although the initial cost is high, operational costs are lower due to energy savings.
- **Sustainable Solution:** Works efficiently in various climates, especially when combined with solar energy.

Disadvantages of Heat Pump System

- **High Initial Cost:** Requires investment in a heat pump, solar PVT collector, and installation.
- **Weather Dependency:** Performance may drop in extreme cold climates without an additional energy source.
- **Complex Installation:** Requires professional setup and maintenance.
- **Requires Space:** Needs outdoor units, refrigerant loops, and solar collectors for efficient operation.

Applications of Heat Pump System

- **Residential Heating & Cooling:** Used in homes to provide efficient year-round climate control.
- **Industrial Processes:** Supports temperature regulation in various industries.
- **Water Heating:** Can be used for domestic and commercial hot water systems.
- **Geothermal Applications:** Works with ground-source heat pumps for enhanced efficiency.
- **Solar-Assisted Heating:** Ideal for sustainable building designs integrating renewable energy.

The **solar-assisted heat pump system** is an excellent energy-efficient solution for heating and cooling applications. The integration of a **PVT collector** further enhances the performance by reducing the workload on the compressor.

Overview of Non-concentrating collectors

- **Non-concentrating collectors** (FPCs, ETCs) are widely used for domestic and industrial solar heating.
- **Evacuated tube collectors** are more efficient but costlier than flat plate collectors.
- **Solar drying, desalination, cooling, and heat pumps** are practical applications of solar thermal energy.

End Semester Questions

PART A (2 Marks Questions)

1. Predict the problems associated with tapping solar energy. **(April / May 2022)**
2. Contrast the need for solar mechanical cooling in the future. **(April / May 2022)**
3. Confer the three types of solar energy collectors with a utilization range. **(April / May 2023)**
4. List down the applications of solar drying. **(April / May 2023)**
5. Compare the different types of non-concentrating collectors used. **(April / May 2024)**
6. Recall the working principle of a heat pump. **(April / May 2024)**

PART B

1. Interpret the need and the working principle of indirect solar driers along its usage in real time. **(April / May 2022)**
2. Compare the working principle of Evacuated Solar Collectors over flat plate collectors with its advantages and disadvantages. **(April / May 2022)**
3. (i) Construct the concentrating collectors and explain the function of its components with a neat sketch. (10 Marks) **(April / May 2023)**

   (ii) Enlighten the working of a solar heat pump with its real-time application. (6 Marks)
4. (i) Elucidate the implementation of a solar desalination system with a neat layout. (10 Marks)

   (ii) Short note on solar mechanical cooling. (6 Marks) **(April / May 2023)**
5. Contrast the difference between a solar collector and a solar panel. Give a general description and design characteristics of a flat plate collector, giving a neat sketch. **(April / May 2024)**
6. What is meant by solar cooling? Examine the principle and operations of solar mechanical cooling and solar desiccant cooling. **(April / May 2024)**