REVA UNIVERSITY

Established as per the Section 2(f)
of the UGC Act, 1956
Approved by AICTE, COA and BCI,
New Delhi

SUSTAINABLE SOLAR ENERGY TECHNOLOGIES

Department of Chemistry, School of Applied sciences

OPEN ELECTIVE

SUSTAINABLE SOLAR ENERGY TECHNOLOGIES

COURSE CODE: B24ASO603

CREDIT : 3

SYLLABUS-CHAPTER 6

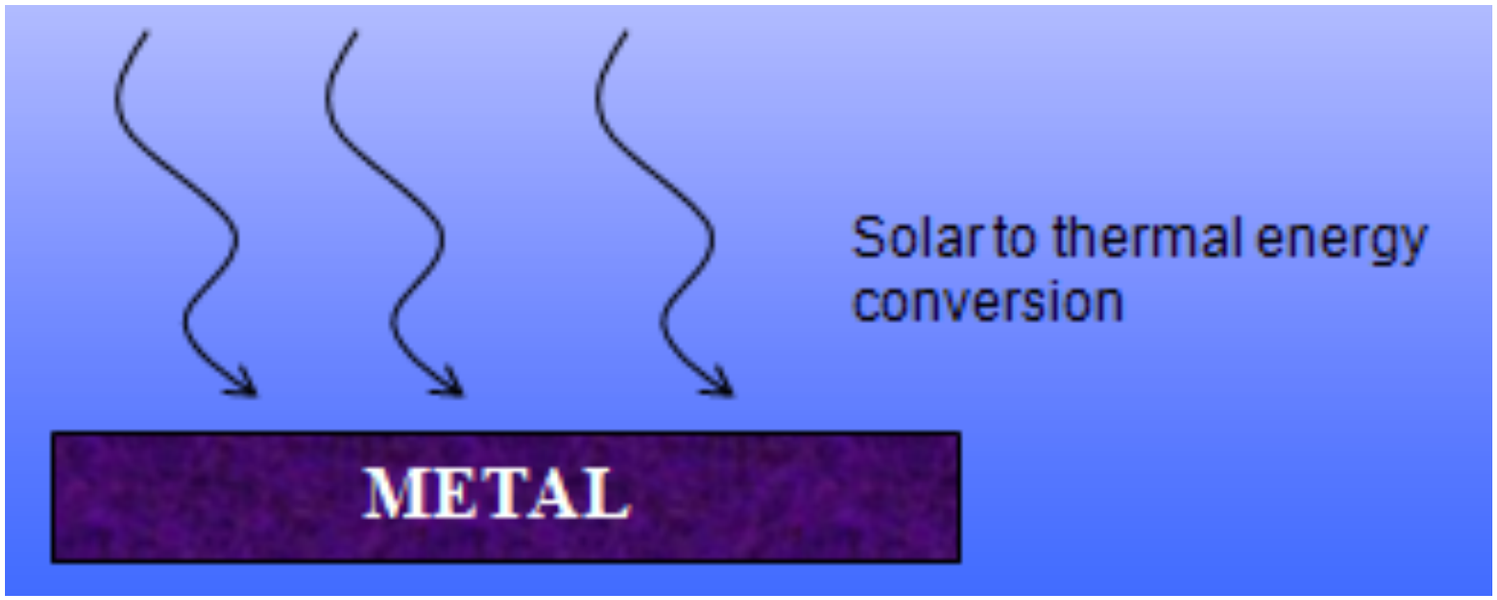
Solar to thermal technologies: Solar to thermal conversion (heating and cooling), solar thermal energy storage, solar collector, selective coatings, Solar-thermoelectric generator, solar-thermo mechanical systems, heat collection systems, solar-thermal plant, solar-gas, solar-pond, solar greenhouse solar seawater desalinations.

SOLAR THERMAL ENERGY

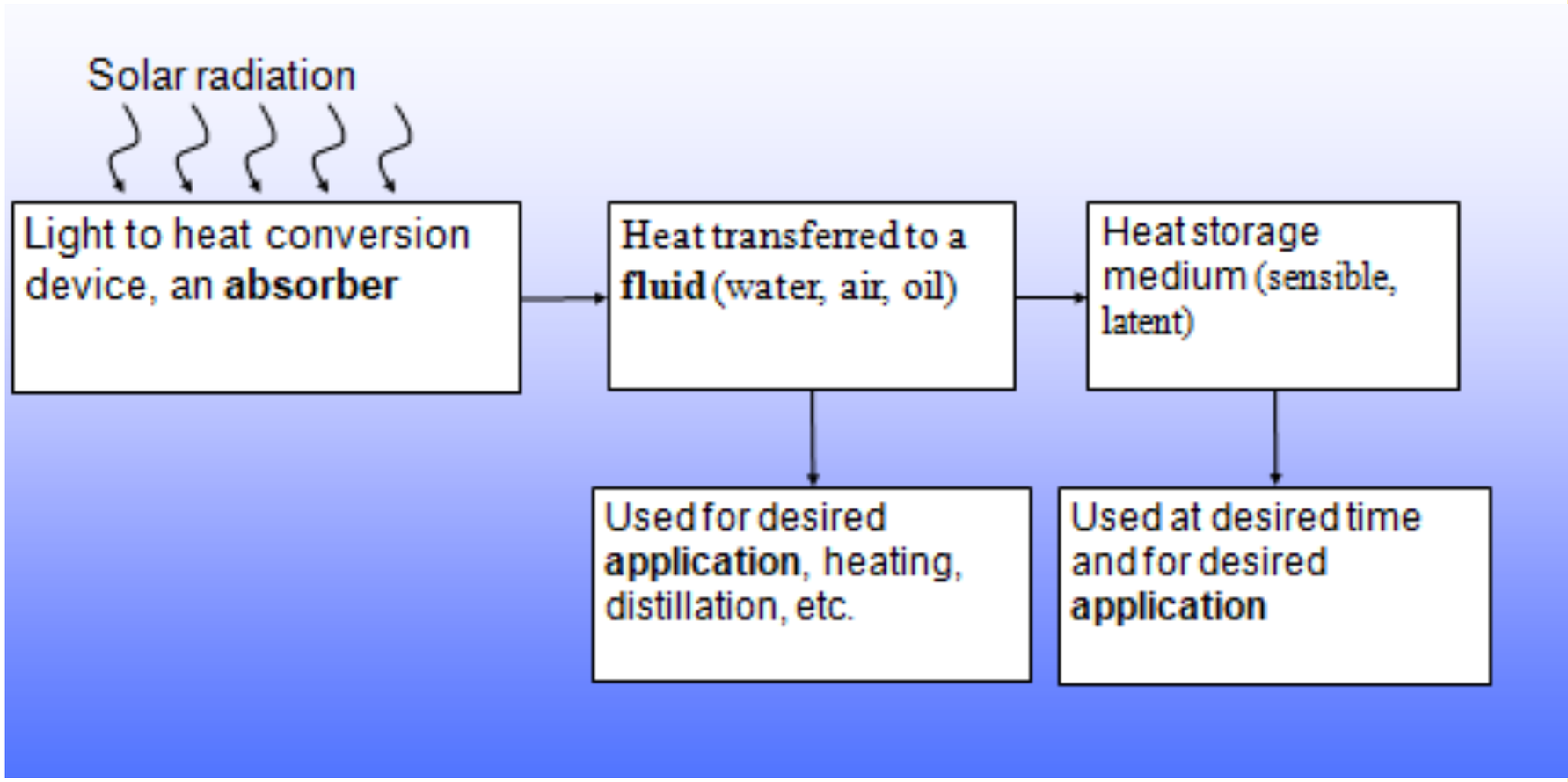
- Solar thermal technology uses the sun's energy, to generate low-cost, environmentally friendly thermal energy.
- This energy is used to heat water or other fluids, which can be used to generate electricity.
- Solar thermal systems differ from solar PV systems, which generate electricity directly.
- Solar thermal collectors on a roof, shade structure or other location absorb solar energy.
- Solar fluid circulated through the collectors by a pump delivers heat to a water storage tank.
- For hot water use, solar-heated water in the storage tank feeds the water-heating system thereby reducing energy bill for heating.

SOLAR THERMAL ENERGY CONVERSION: PRINCIPLE

- Material having very small or zero band gap energy are required.
- All the energy of the incoming photon should get converted to
- Kinetic energy → high thermal velocity → greater collision →loss of energy as heat → radiation to heat conversion takes place
- Metal are suitable as an absorber.



SOLAR THERMAL ENERGY CONVERSION: PRINCIPLE



1. **Collection**: Solar collectors (usually flat-plate or evacuated tube collectors) absorb sunlight.
2. **Absorption**: The solar radiation is absorbed by a **black surface** inside the collector, which gets hot.
3. **Heat Transfer**: This heat is transferred to a working fluid (like water or air) that flows through pipes or tubes.
4. **Usage**: The heated fluid is then used for various purposes — heating buildings, water heating, or even powering turbines.

DIFFERENCE B/W SOLAR THERMAL ENERGY AND SOLAR PV ENERGY CONVERSION

- Solar PV Energy is the direct conversion of solar radiant energy into electrical energy.
- It uses the photovoltaic effect . This happens due excitation of the electron and hole pairs when the light falls on it.
- It is a direct method of energy conversion.
- Solar Thermal energy is indirect method of power conversion.
- It is used to heat up some fluid to generate mechanical power which in turn produces electricity.

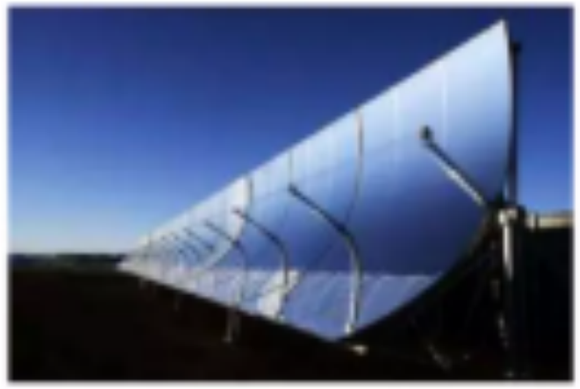
SOLAR TO THERMAL CONVERSION

- **Solar thermal** power generation systems use mirrors to collect sunlight and produce steam by solar heat to drive turbines for generating power.
- This system generates power by rotating turbines like thermal and nuclear power plants, and therefore, is suitable for large-scale power generation.

SOLAR POWER GENERATIONS

- There are two main ways of generating energy from the sun:

1. Photovoltaic (PV) Converts sunlight directly into electricity.
2. Concentrating Solar Thermal (CST) Generate electricity indirectly.

Photovoltaic (PV)	Concentrating Solar Thermal (CST)
Converts sunlight directly into electricity. 	Generate electricity indirectly 

Components of a Solar Thermal System

1. **Solar Collector**: Captures solar energy.
2. **Heat Transfer Fluid**: Often water or glycol that transfers heat.
3. **Storage Tank**: Stores hot water or thermal energy.
4. **Heat Exchanger**: Transfers heat to the desired system (water/air).
5. **Controller & Pump** (in active systems): To regulate and circulate fluid.

Advantages

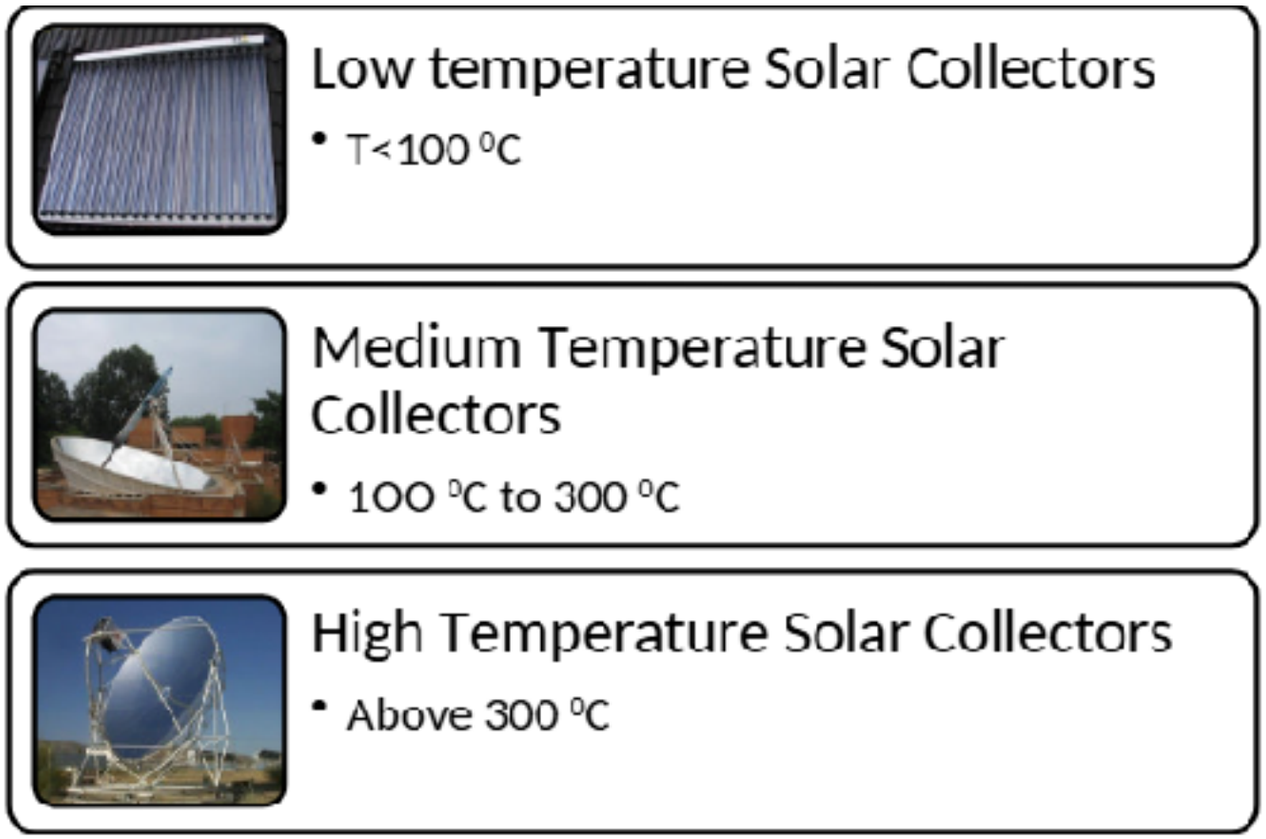
1. Renewable and sustainable
2. Reduces electricity/fuel bills
3. Environmentally friendly
4. Low maintenance (especially passive systems)

Limitations

1. Initial cost can be high
2. Efficiency depends on solar availability
3. Needs backup or hybrid systems in cloudy conditions

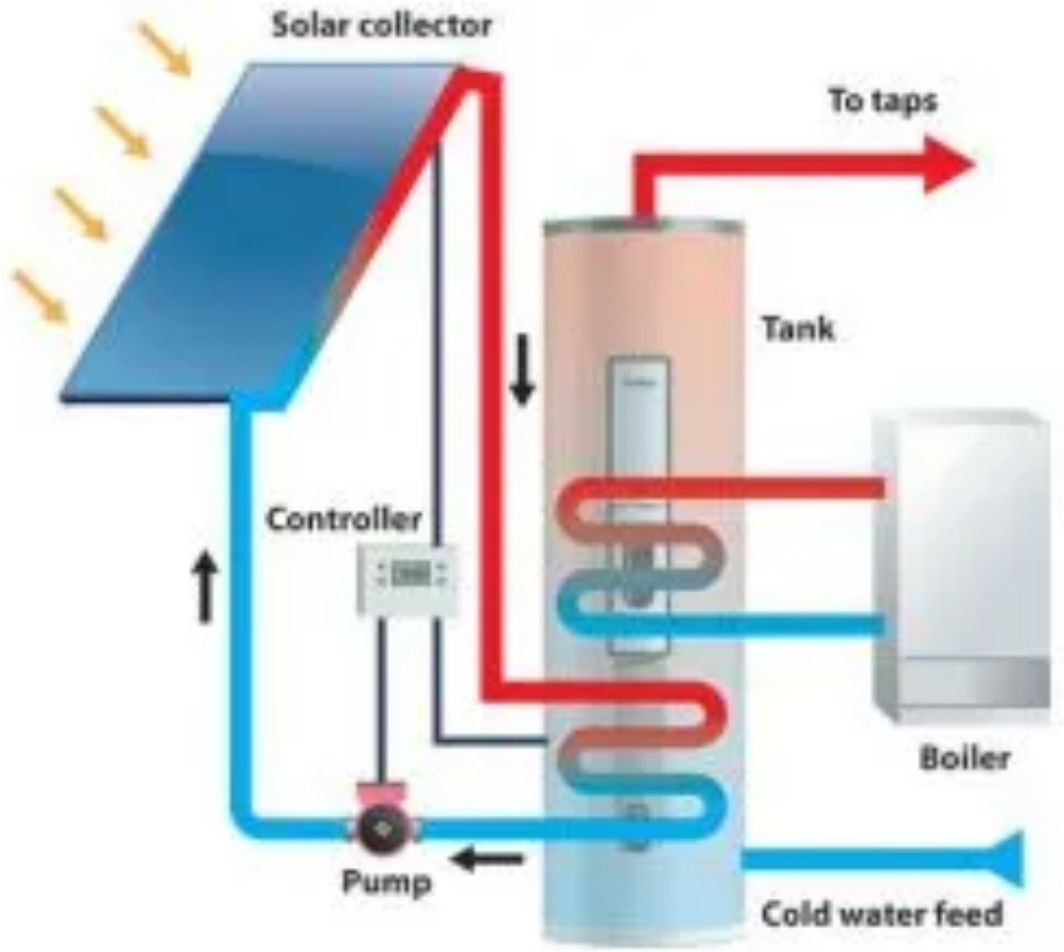
SOLAR COLLECTORS

- The collector is the main component of a solar thermal system.
- Solar collectors are devices that capture and convert solar energy into usable heat. They are commonly used in solar thermal systems to heat water, air, or other fluids for domestic, commercial, and industrial applications.
- Solar collectors are distinguished as low, medium, high temperature heat exchangers.



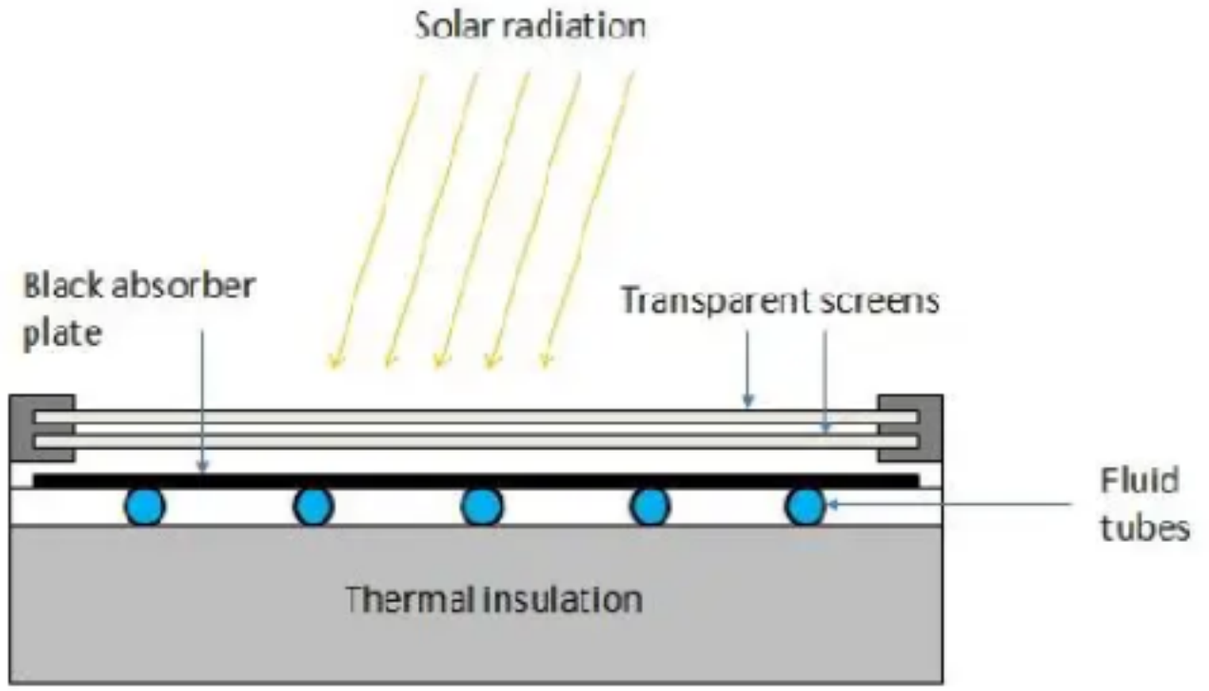
SOLAR THERMAL SYSTEM-HEAT COLLECTION SYSTEM

- The collector contains specially coated reinforced glass pipes to capture the radiation emitted from the sun, which can then be transferred into heat.
- The pipes themselves will be embedded in an insulated container to prevent heat energy being lost. The heat transfer fluid in the pipes will include eco-friendly antifreeze and will circulate through the collector and hot water tank.



•The whole system is operated from a solar thermal controller which is automated. When the temperature at the collectors rises to a specific temperature above the temperature in the storage tank, the controller will automatically switch on the pump and the transfer fluid heated in the collector will be sent to the hot water tank.

FLAT PLATE SOLAR ENERGY COLLECTORS



A flat-plate solar collector is a widely used and well-studied technology for solar-powered domestic hot water systems A black absorbing surface (absorber) inside the flat plate collectors absorbs solar radiation and transfers the energy to water flowing through it.:

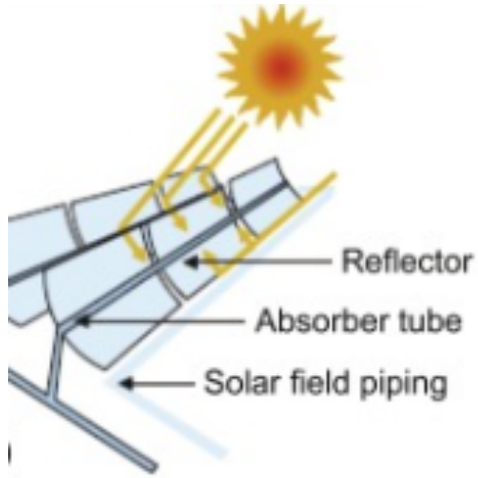
1. **Black surface**: Absorbs solar energy
2. **Glazing cover**: Transparent layer that allows sunlight in but prevents heat loss
3. **Tubes**: Carry the heating fluid to transfer the heat
4. **Support structure**: Holds and protects the components
5. **Insulation**: Reduces heat loss from the sides and bottom

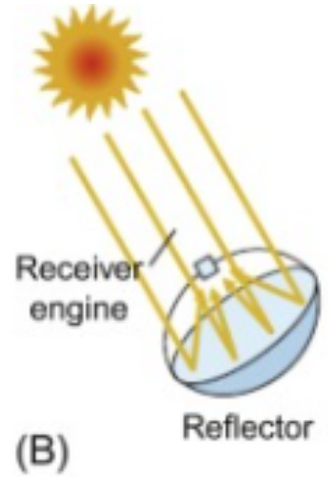
CONCENTRATING SOLAR-THERMAL POWER PLANTS

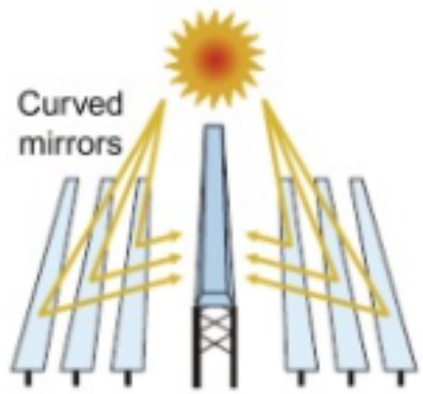
These plants use mirrors to reflect and focus sunlight onto a receiver, converting it to heat for electricity generation. There are two main types:

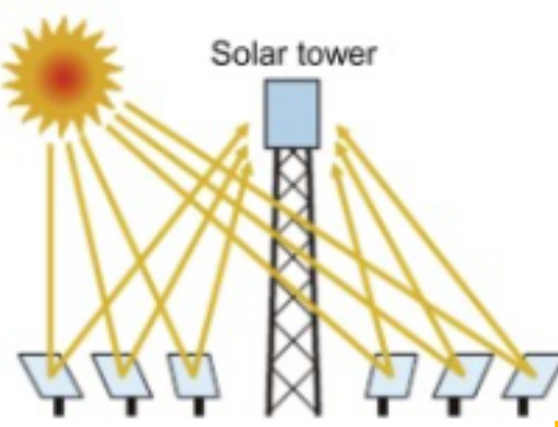
1. **Tower (central receiver) plants**: Use heliostats—mirrors that track the sun on two axes—to focus sunlight onto a receiver at the top of a tower. Each heliostat has its own base, foundation, and motor.

2. **Parabolic trough plants**: Use curved mirrors arranged in troughs that follow the sun in one direction and focus sunlight onto a linear receiver pipe.









SOLAR HEATING

1. Solar Water Heating

a. **Flat Plate Collectors**: Absorb solar radiation using a dark flat-plate surface and transfer it to water.

b. **Evacuated Tube Collectors**: Use vacuum-sealed tubes to minimize heat loss and are more efficient in colder climates.

c. **Thermosiphon Systems**: Use natural convection to circulate water between the collector and the storage tank.

2. Solar Space Heating

a. **Passive Solar Heating**: Involves building design elements (like large south-facing windows and thermal mass) that naturally capture and store heat.

b. **Active Solar Heating**: Uses mechanical components like pumps or fans to distribute heat.

SOLAR COOLING - SOLAR THERMAL COOLING (THERMO-MECHANICAL FOR COOLING)

1. Absorption Chillers

- Use solar-heated water to drive a chemical process that produces cooling.
- Typically use a lithium bromide-water or ammonia-water cycle.
- Best suited for large buildings or industrial use.

2. Desiccant Cooling

- Uses materials that absorb moisture from air (desiccants), which are then regenerated (dried) using solar heat.
- Good for humid climates.

3. Solar-Powered Adsorption Cooling

- Involves the use of solar heat to regenerate adsorbent materials that capture and release refrigerants in cycles.

SOLAR THERMAL COOLING SYSTEMS

Advantages of thermal Cooling systems

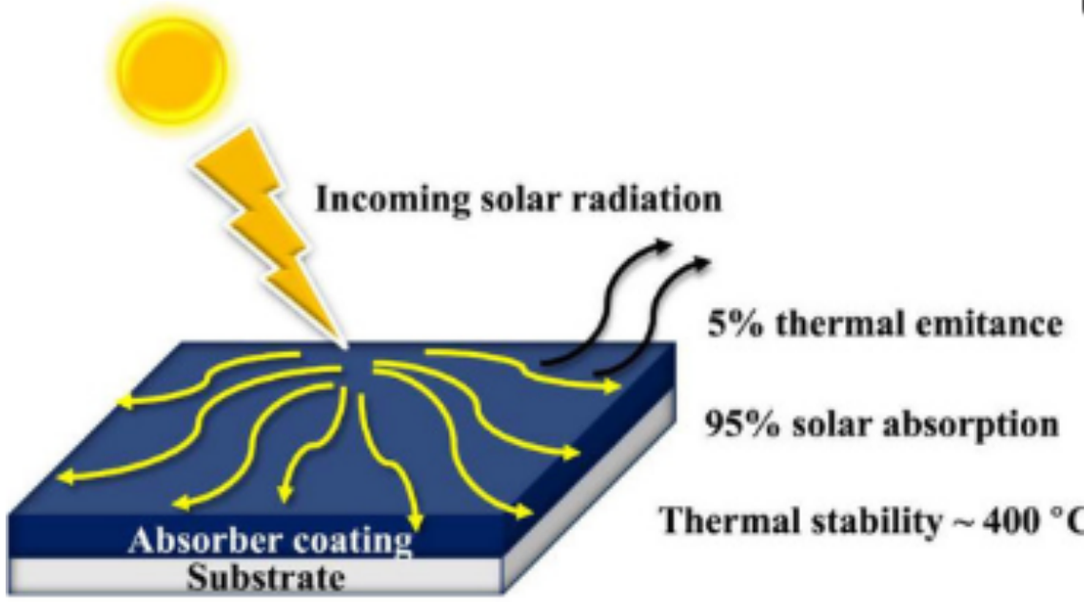
- The availability of high solar radiation during the time when cooling is needed the applicability of thermal energy as driving energy.
- Low operating costs and low electrical power rating, Durability and environmental compatibility.
- **The disadvantage of solar cooling systems -** high installation costs, the space needed for heat storage and the additional backup system necessary.

SELECTIVE COATINGS

These coatings are applied to the surface of the absorber plate in collectors to **maximize absorption and minimize emission**. These are essential for improving **thermal efficiency**, at higher operating temperatures.

Properties:

1. **High solar absorptance** (α): captures more sunlight
2. **Low thermal emittance** (ε): reduces re-radiation of heat
3. **Black chrome, black nickel**
4. **Tin oxide (SnO_2) on aluminum**
5. **Cermet coatings** (ceramic-metal composite)

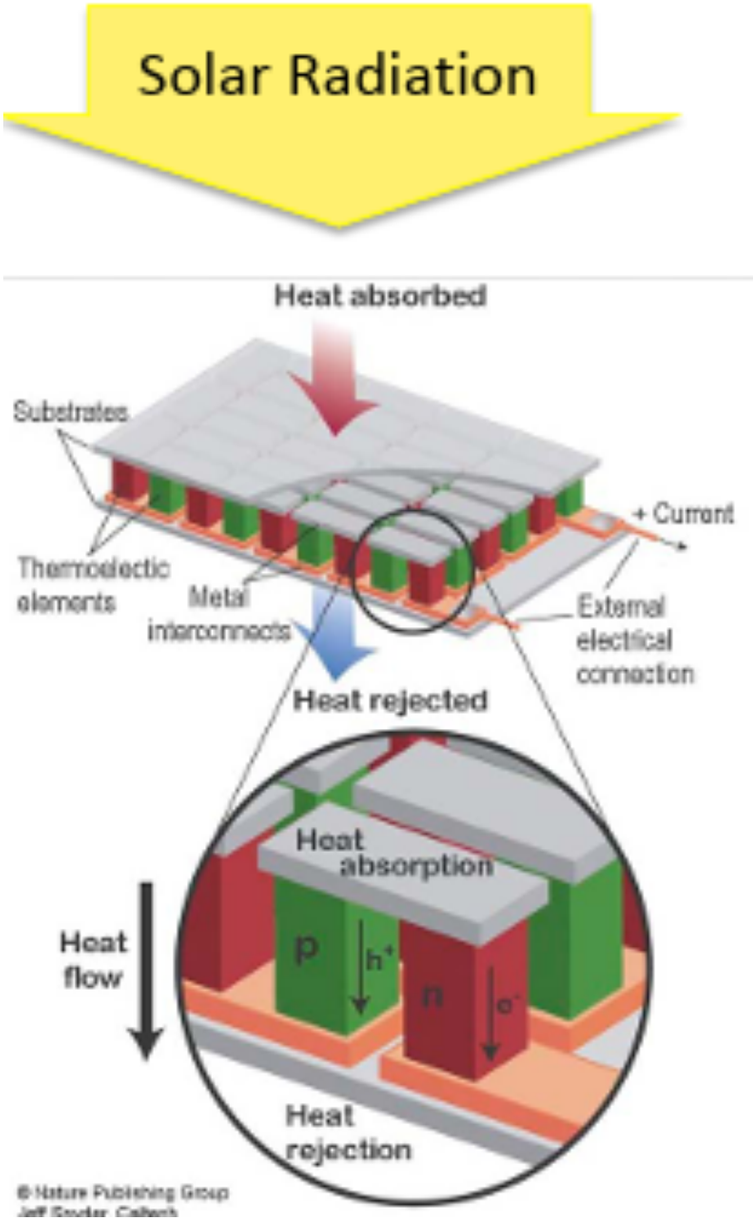


SOLAR THERMOELECTRIC GENERATOR

These devices convert heat from the sun directly into electricity using the Seebeck effect.

A **Solar Thermoelectric Generator** combines:

1. A **solar collector** that focuses or absorbs sunlight to generate heat
2. A **thermoelectric module** that converts that heat into electricity via a temperature gradient.



How It Works: The Seebeck Effect

- When two different conductors or semiconductors are joined at two points and those junctions are kept at different temperatures, a voltage is generated.
- The voltage is proportional to the temperature difference between the hot and cold sides.

$$Heat \rightarrow TemperatureGradient \rightarrow ElectricalVoltage \rightarrow Current$$

SOLAR-THERMO MECHANICAL SYSTEMS

They use thermal energy from the sun to drive a mechanical engine, such as a turbine or piston-based system. These systems are a core part of concentrated solar power technology.

Types of Solar-Thermo Mechanical Systems

1. Solar Stirling Engines

- Closed-cycle, external combustion engine
- Uses solar heat to expand and contract gas (usually **helium or hydrogen**) in a sealed system
- Moves pistons → turns a crankshaft → generates power

2. Solar Rankine Cycle Systems

- Works like a **steam power plant** using solar thermal input
- Heat from solar collectors boils a **working fluid.**
- Vapor spins a **turbine**, then condenses and recirculates.

Pros:

- Scalable from kilowatts to megawatts
- Can store thermal energy for night-time operation

3. Solar Brayton Cycle

- Similar to a gas turbine
- Air is compressed, heated by concentrated solar energy, and expanded in a turbine
- Used in **hybrid CSP systems** (can combine solar + gas combustion)

Pros:

- Can run continuously with hybrid fuels
- Simple and robust cycle

HEAT COLLECTION SYSTEM

The system that captures solar radiation, converts it into thermal energy (heat), then transfers and stores that heat for later use.

Types of Solar Heat Collection Systems

1. **Non-Concentrating Collectors c**aptures sunlight directly without focusing it.

a. **Flat Plate u**sed for water heating, space heating. Efficiency: ~30–60%.

b. **Evacuated Tube Collectors** used for cold climates, high-temp water heating. Efficiency: ~50–70%.

c. **Unglazed Collectors** used for pool heating or low-temp applications.

2. **Concentrating Collectors** Focus sunlight onto a small area to reach high temperatures — ideal for power generation.

a. **Parabolic Trough Collectors** used in CSP plants with Rankine cycles.

b. **Parabolic Dish Collectors:** Extremely high temperatures (700–1000°C). Often used with **Stirling engines.**

c. **Solar Power Towers (Heliostat Fields):** Stores energy for 24/7 electricity generation.

SOLAR-THERMAL PLANT

Also known as Concentrated Solar Power (CSP) Plant

Working Principle: Uses mirrors or lenses to concentrate sunlight onto a small area to generate heat. This heat is used to produce steam that drives a turbine to generate electricity.

Key Components:

1. Solar collectors (heliostats/parabolic troughs)
2. Heat transfer fluid (e.g., molten salt or oil)
3. Heat exchanger and steam turbine

Types:

1. Parabolic Trough Systems
2. Solar Power Towers
3. Dish Stirling Systems

Applications: Large-scale power generation, often with thermal storage for night-time use.

SOLAR-GAS HYBRID SYSTEM

Solar-assisted gas turbine or solar hybrid power plant

Working Principle: Combines solar energy with a gas-based power system. Solar collectors preheat the air or working fluid before it enters a gas turbine or internal combustion engine.

Advantages:

1. Reduces fossil fuel consumption
2. Increases efficiency
3. Provides continuous power (solar + gas backup)

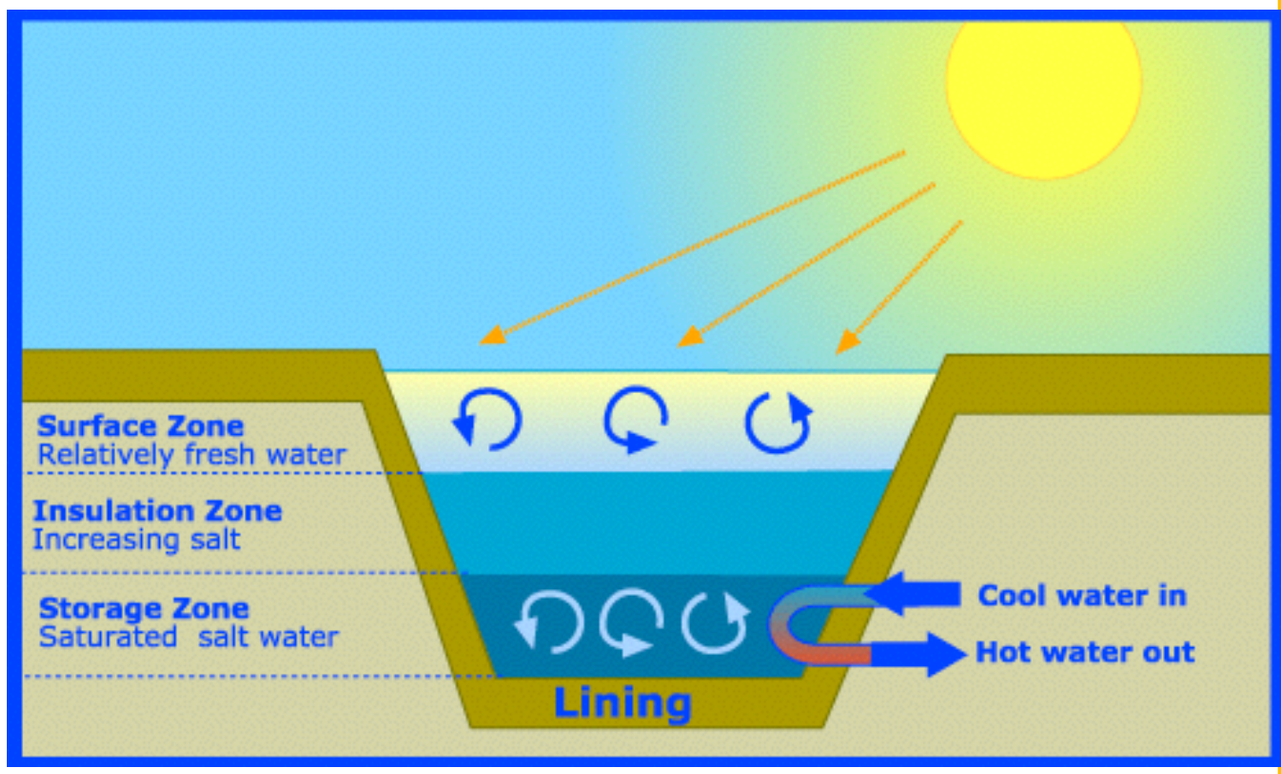
Use Case: Industrial applications or power plants where solar energy supplements natural gas-based power.

SOLAR POND

Working Principle: A solar pond is a pool of saltwater that collects and stores solar thermal energy. It consists of layers of water with different salt concentrations (salinity gradient) that trap heat in the bottom layer.

Key Features:

1. Bottom layer can reach 85–90°C
2. Acts as both collector and storage system



Applications:

1. Low-temperature industrial heat
2. Water desalination
3. Rural power generation

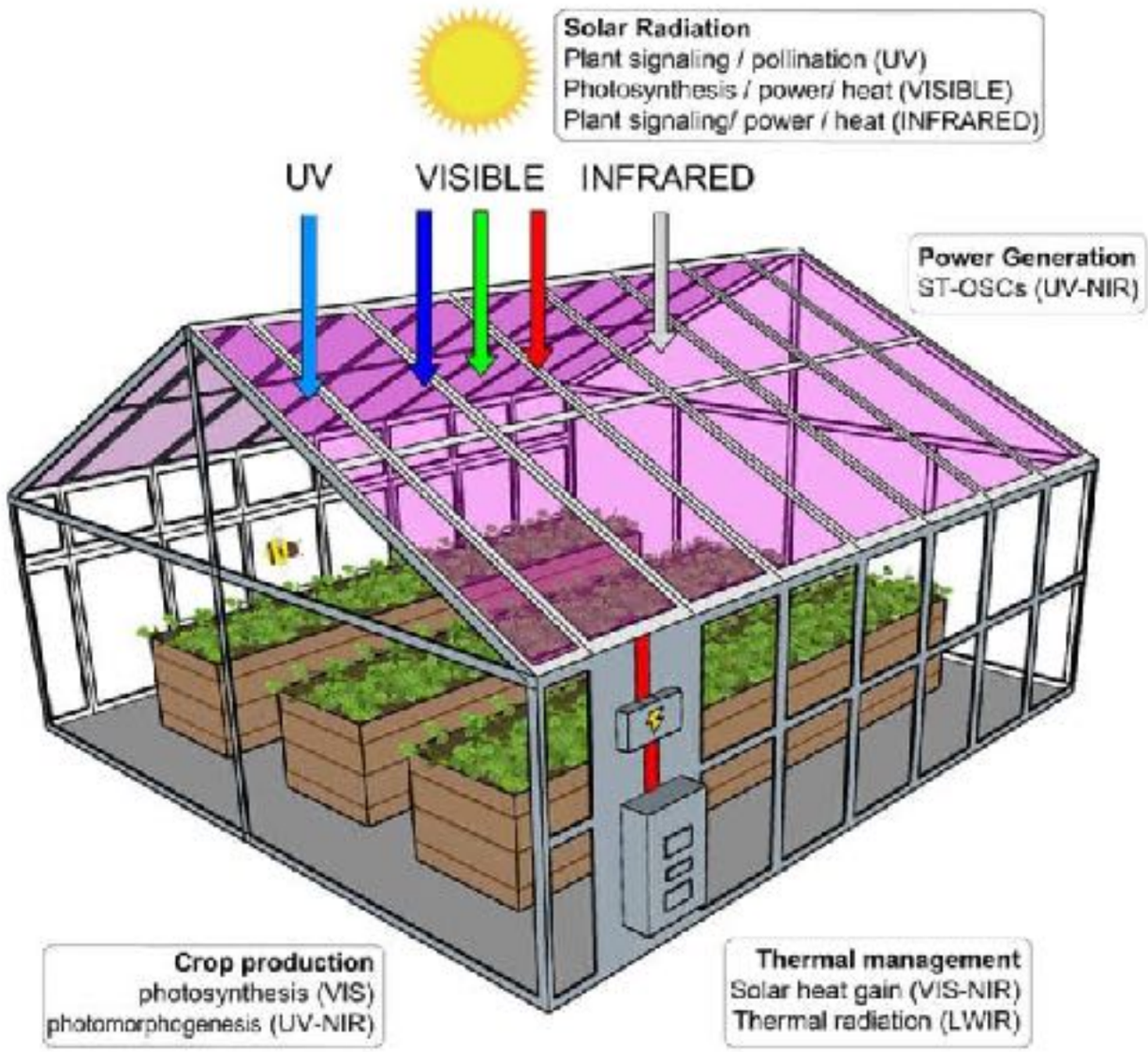
Advantages: Low cost, long-term heat storage, simple technology

SOLAR GREENHOUSE

A greenhouse that uses solar energy to maintain a controlled environment for plant growth.

Working Principle:

1. Transparent walls/roofs allow sunlight in, warming the air and soil.
2. The structure traps heat (greenhouse effect), supporting plant growth even in colder climates.
3. Some solar greenhouses use **passive solar heating** (thermal mass like water barrels or stones) or **active solar systems** (solar panels for fans, heaters).



Advantages:

- Reduces energy costs
- Energy Efficiency
- Environmentally friendly
- Carbon Footprint Reduction
- Enhanced Crop Quality

Applications: Agriculture, horticulture, especially in off-grid or remote areas.

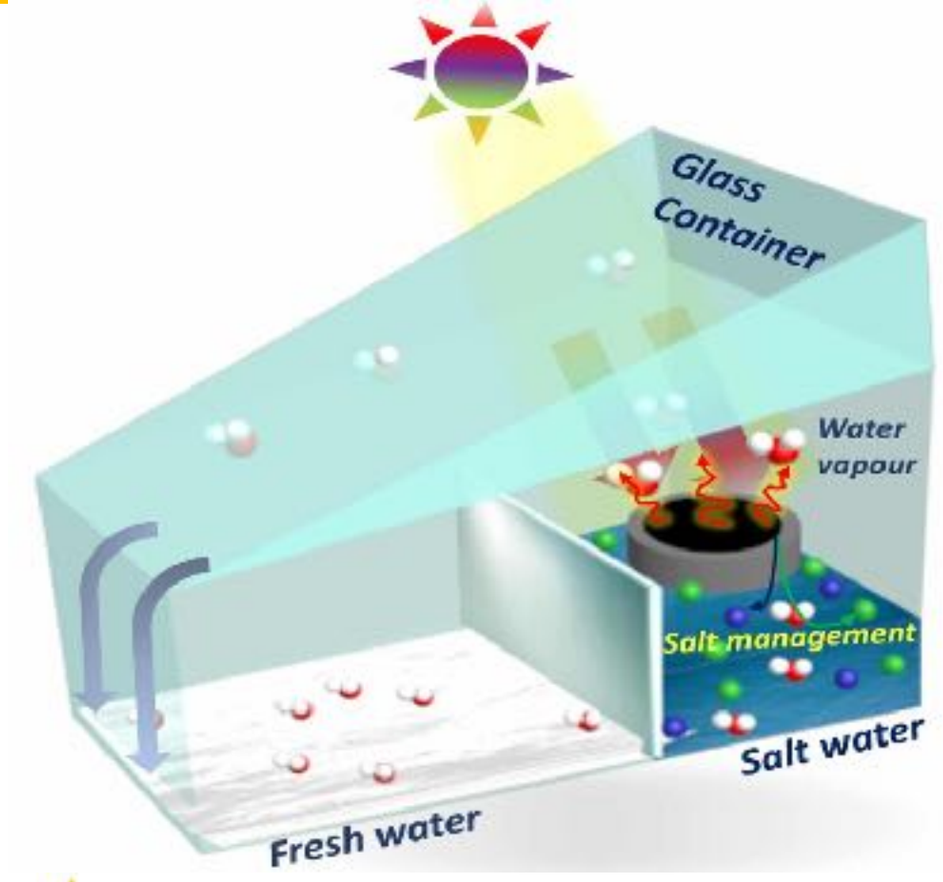
SOLAR SEAWATER DESALINATION

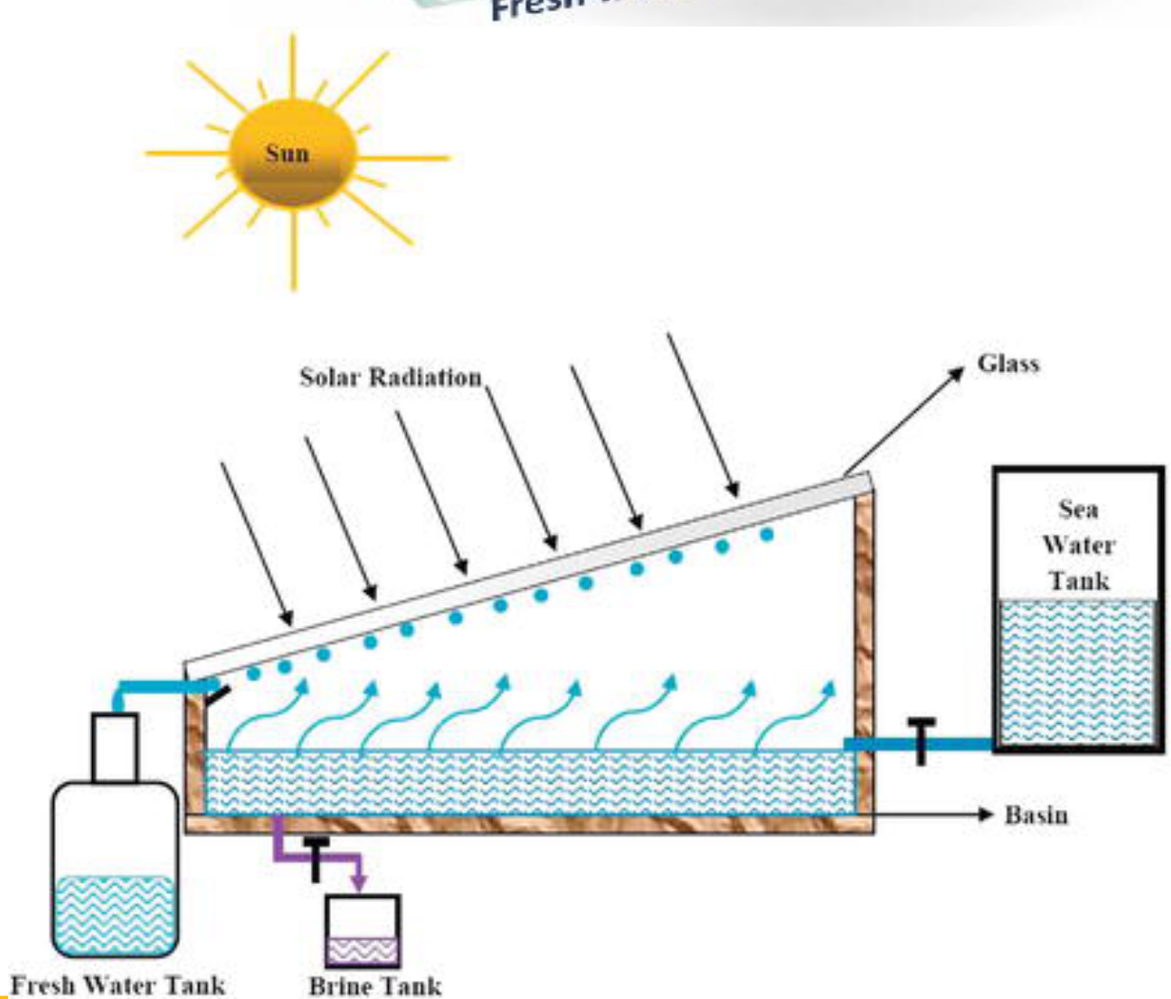
The process of removing salt and impurities from seawater using solar energy.

Types:

Solar Still (Direct Method):

- Enclosed shallow basin filled with seawater.
- Sun heats the water → evaporation → condensation on glass → collected as freshwater.
- Simple, low-cost, but limited output.





SOLAR SEAWATER DESALINATION

Indirect Solar Desalination:

- Uses solar collectors to heat water.
- Works with methods like Multi-Effect Distillation or Reverse Osmosis driven by solar PV or thermal systems.

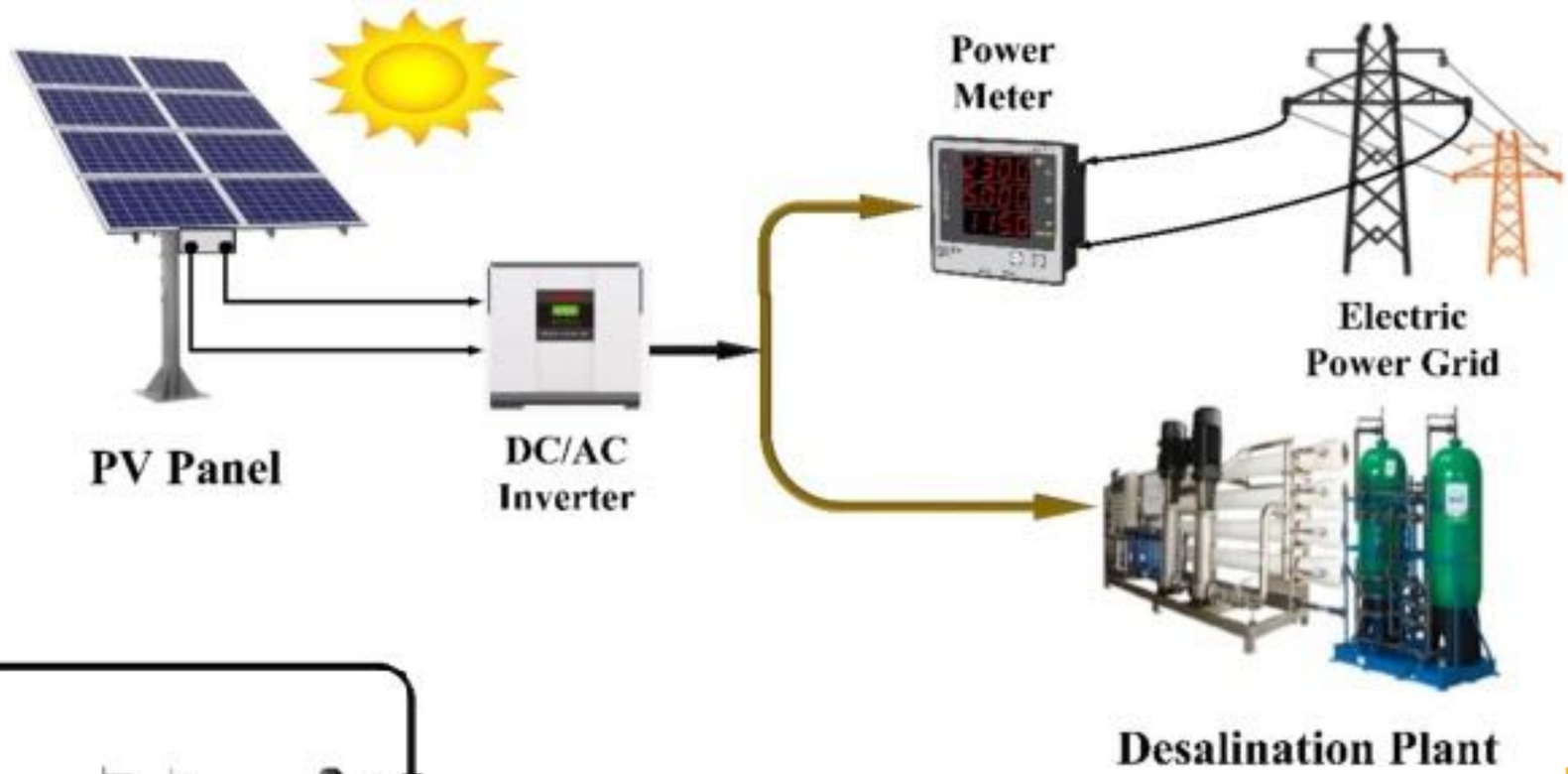


Diagram for a PV-powered, on-grid desalination plant

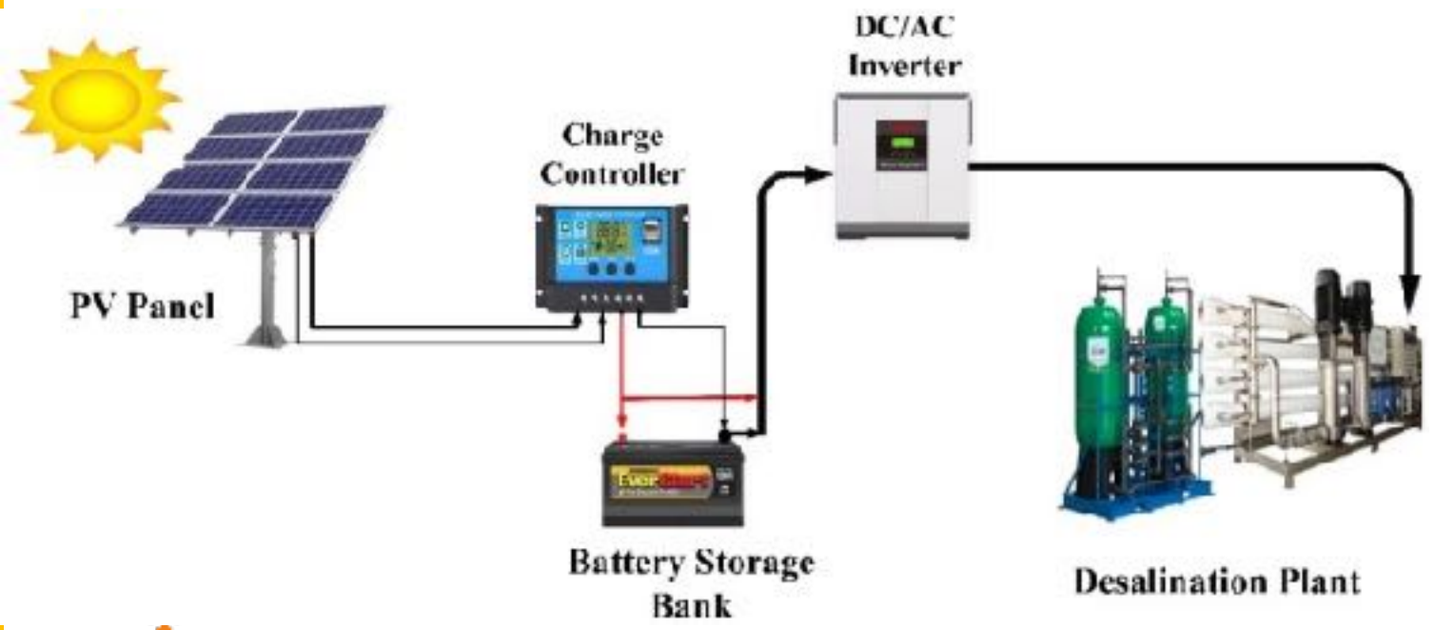
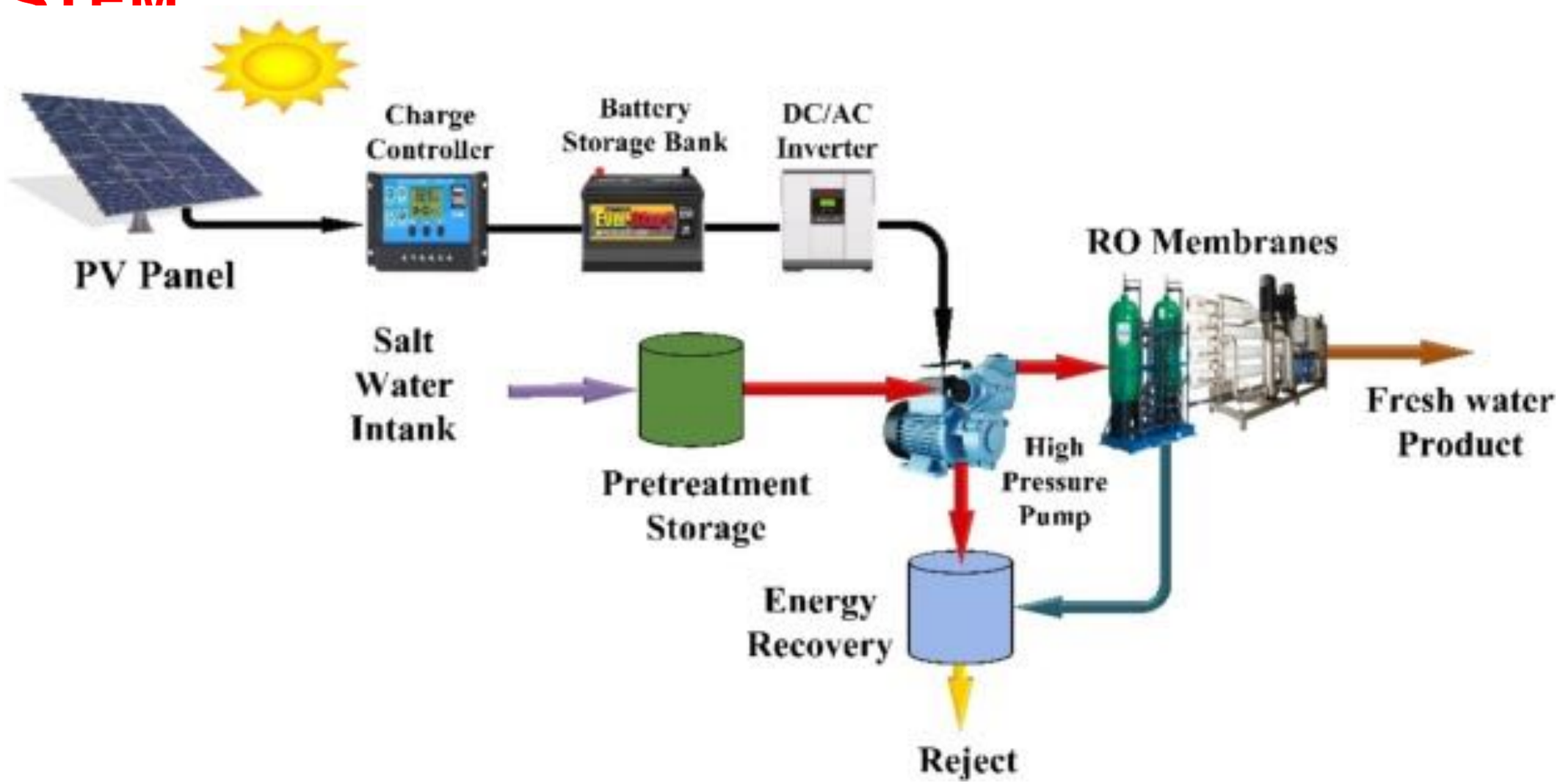


Diagram for a PV-powered desalination plant that is off-grid

PV-RO DESALINATION SYSTEM



The systems for reverse osmosis contain five main pieces of equipment

1. Supply system,
2. Pretreatment filters,
3. High-pressure pumps,
4. An RO membrane, and a post-treatment system.

THANK YOU