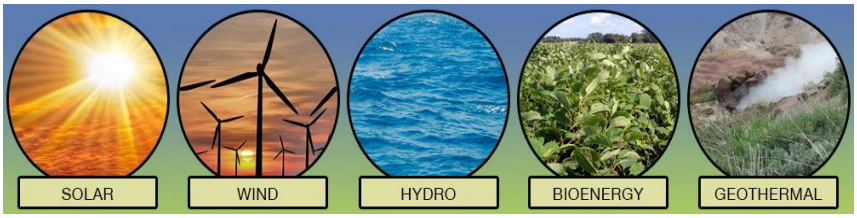
Energy & Environmental Science

Solar Thermal energy

Solar energy devices & saving potential



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Director, EnSave Academy

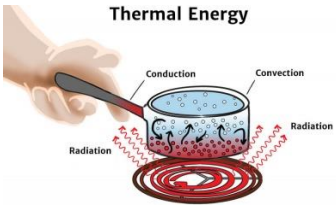
Unit – 2 [4 Hours]: Solar Energy

- ✓ Basics of Solar Energy
- ✓ Solar Thermal Energy
- ✓ Solar Photovoltaic:
  - Advantages and Disadvantages,
  - Environmental impacts and safety

In this chapter you will be able to

1. Describe the **process of harnessing solar energy** in the form of heat
2. Explain the **construction and operation of various types of solar Collectors**
3. Discuss **various useful thermal applications** of solar energy and its advantages.

Thermal Energy Basics



Temperature

1. **Temperature** is the degree of hotness or coldness measured on a definite scale and is denoted in Fahrenheit (^{O}F) or Celsius (^{o}C) .
2. In **Fahrenheit scale** (British system), the freezing point of water is 32 ^{O}F and the boiling point of water is 212^{o}F at atmospheric pressure.
3. **The Kelvin scale** is the temperature standard and fixes its origin, or **null point, at absolute zero (^{0}K = –273.15°C)**

Conversion of the degree Celsius into Fahrenheit = (^{O}C x 1.8) + 32

Conversion of the Fahrenheit into degree Celsius , ^{O}C = (^{O}F - 32) / 1.8

Degrees Celsius (C) to degrees Kelvin (K) = (^{O}C) + 273 = (K)

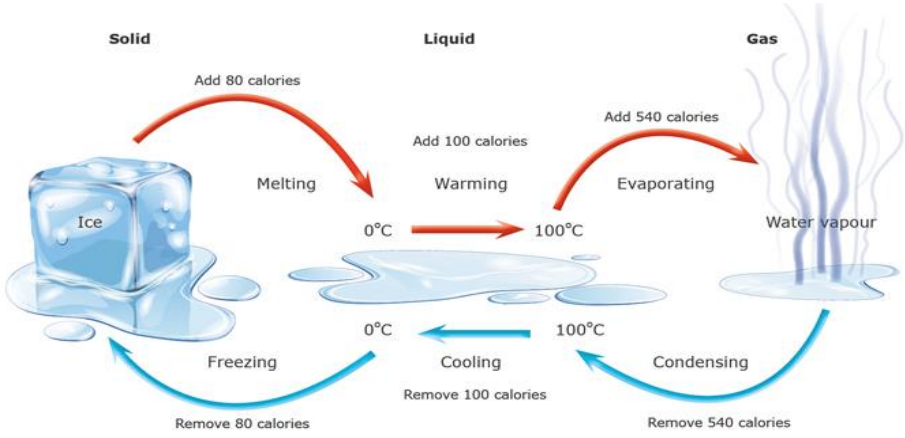
$$^{o}C = (^{o}F - 32) \times 5/9$$

Thermal Energy Basics

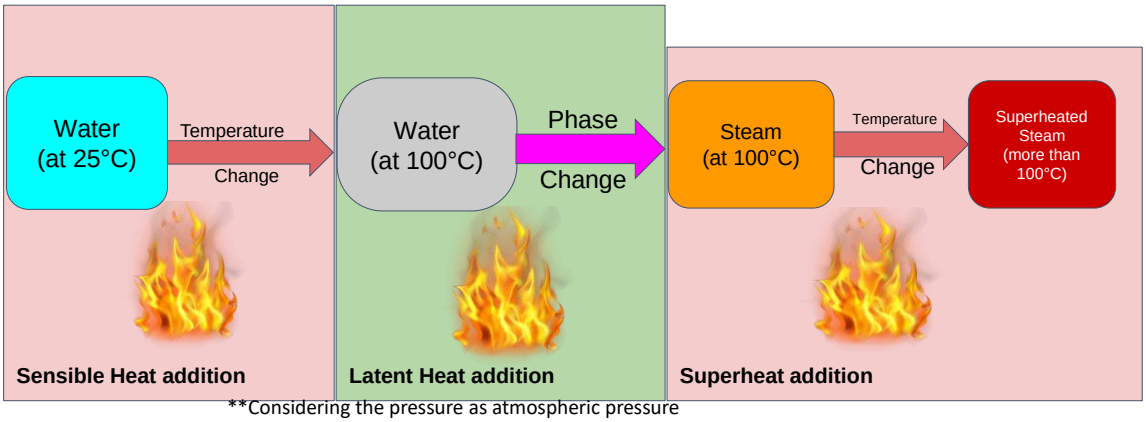
- **Calorie** is unit of heat: 1 kilocalorie can raise 1 kg of water by 1°C
- **Specific heat** is amount of heat required to raise 1 kg of water by 1°C
- **Heat quantity** =mass x specific heat x rise in temperature **M cp Delta T**

Specific Heat of Some Common Substances	
Substance	Specific heat (J/kg°C)
Copper	390
Aluminium	910
Water	4200
Alcohol	2400
Iron	470

Properties of Steam: Sensible and Latent Heat



Properties of Steam: Sensible and Latent Heat



**Considering the pressure as atmospheric pressure

Heat is transferred from one body to another body at a lower temperature by virtue of temperature difference It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.
1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.
Calorie = 4.187 J

Sensible Heat The amount of heat which when added to any substance causes a change in temperature. Sensible heat = mass x specific heat x change in temperature

Latent heat It is the change in heat content of a substance, when its physical state is changed without a change in temperature. The latent heat of fusion of a substance is the quantity of heat required to convert 1 kg solid into liquid state without change of temperature. **Q_L (ice) = 335 KJ/kg.** $Q_L = m \times h_{if}$

Super Heat
Super heating is the heating of vapour, particularly saturated steam to a temperature **much higher than the boiling point** (saturation temperature) at the existing pressure.

1. Concept of New and Renewable Energy

- ❑ Renewable energy is energy obtained from sources that are essentially inexhaustible .
  - ➢ **Examples: solar, wind ,geothermal , tidal ,bio-energy & hydropower**.
- ❑ Important feature of renewable energy is that it can be used without the release of harmful pollutants

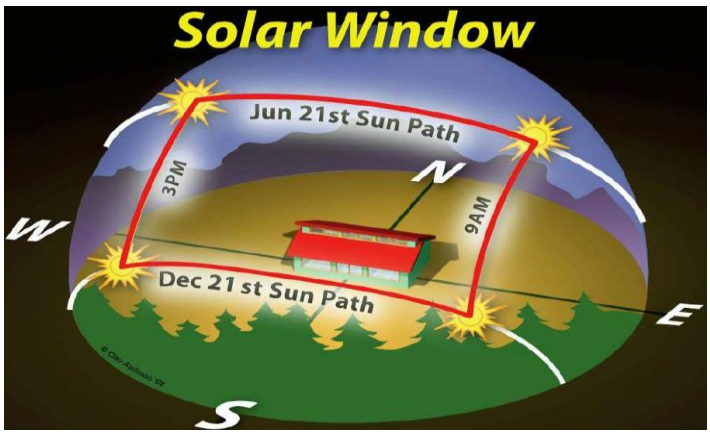
Solar Window is the period, typically 9 AM - 3 PM, when maximum sunlight is available

2. Fundamentals of Solar Energy

- ❑ **Solar radiation** is radiant energy emitted by the sun comprising of ultra-violet, visible and infra-red radiation.
- ❑ **Solar constant** is the rate at which solar energy, at all wavelengths, is received per unit area at the top level of Earth's atmosphere . The solar constant varies 0.3% over the 11-year solar cycle but averages about **1,368 W/m2**.
- ❑ **Solar Insolation** is the amount of solar energy that strikes a square meter of the earth's surface in a single day.
- ❑ The average incoming radiation is known as solar insolation and is one-fourth the solar constant, or **342 W/m2.**

- The insolation values is expressed in kWh/m^2/day.
- India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year.
-
- This energy is sufficient to set up 20 MW solar power plant per square kilometre land area.

❑ **Solar Window** is the period, typically 9 AM - 3 PM, when maximum sunlight is available



Solar Thermal Systems

Solar Energy In Rural India

Rural Needs are Simple
- **Light for studying**
- **Water for drinking**
- **Fuel for cooking**
- **Television and telephone**

- Current sources available for cooking are firewood, crop residues and animal dung in rural
- Promoted by the Government of India
  - **Parabolic Dish Solar Cookers**
  - **Solar Box Cooker**
  - Community Solar Cooker
  - Solar Steam Cooking System

700 Million Rural People

80% of total energy for these needs

Making India's rural population and India more energy independent

Solar Thermal Energy Systems

- Solar thermal systems uses the sun's heat and convert it into heat energy while solar photovoltaic systems uses sun's heat to produce electricity.
- **Solar collectors are the main component of most of solar energy** systems. The collector absorbs the sun's energy and converts it into **heat energy.**

This energy is then transferred to a fluid or air which is used

- ✓ **heat water,**
- ✓ **generate electricity,**
- ✓ **dry materials,**
- ✓ **distill water or**
- ✓ **cook food.**

When used for heating purpose, solar thermal system can partially or fully **replace the conventional fuels such as coal, oil and electricity**

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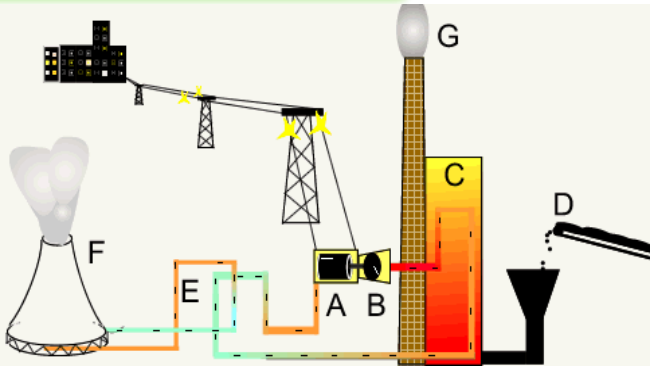
Thermal Power Plant



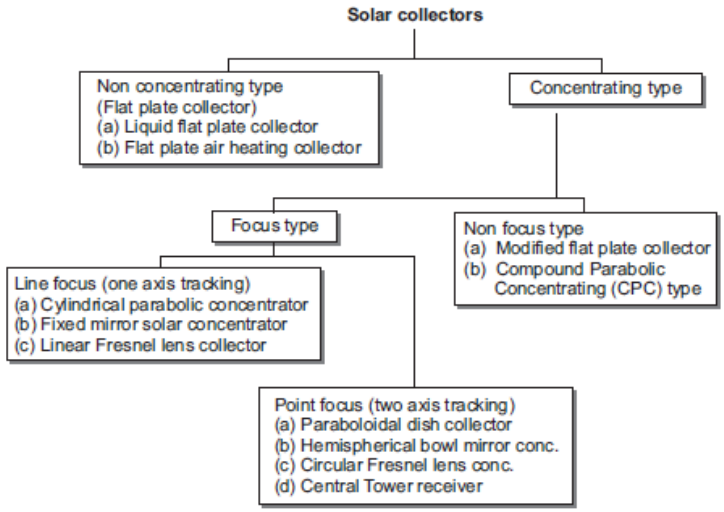
SOLAR THERMAL TECHNOLOGIES

Technologies can be used for both, supplying thermal energy as well as for generating electricity.

1. **Solar water and space heating**
2. **Solar process heating for industrial applications**
3. **Solar drying**
4. **Solar refrigeration and air conditioning**
5. **Solar cooking**
6. **Solar passive architecture**
7. **Solar water desalination and water purification,**
8. **Solar thermal power generation**

SOLAR COLLECTORS

- Solar power has low density per unit area . Hence it is to be collected by covering **large ground area** by solar thermal collectors.
- It **absorbs solar energy as heat** and then transfers it to heat transport fluid efficiently.
- The heat transport fluid **delivers this heat to thermal storage tank** / boiler / heat exchanger, etc., to be utilized in the subsequent stages of the system.



Types of solar collectors

SOLAR COLLECTORS

Performance Indices

Collector efficiency is defined as the **ratio of** the energy actually absorbed and transferred to heat transporting fluid by the collector (useful energy) to the energy incident on the collector.

Concentration ratio (CR) is defined as the **ratio of** the area of aperture of the system to the area of the receiver. The aperture of the system is the projected area of the collector facing (normal) the beam.

Temperature range is the range of temperature to which the heat transport fluid is heated up by the collector.

Solar Thermal Energy Devices

Applications of solar thermal energy are

1. **Solar Water Heating System**
2. **Solar Thermal Power Systems**

Solar Water Heating System

i. **Solar Flat Plate Collector**

ii. **Evacuated Tube Collector**

Solar Electrical Energy system

i. **Power Towers**

ii. **Parabolic Trough Collector**

iii. **Solar Photovoltaic Technology**

Solar Thermal Technologies

(based on output temperature)

Low (<100^{0}C)

1. Flat Plate
2. Solar Chimney
3. Solar Pond


Medium (100^{0}C - 400^{0}C)

1. Parabolic Trough
2. Linear Fresnel

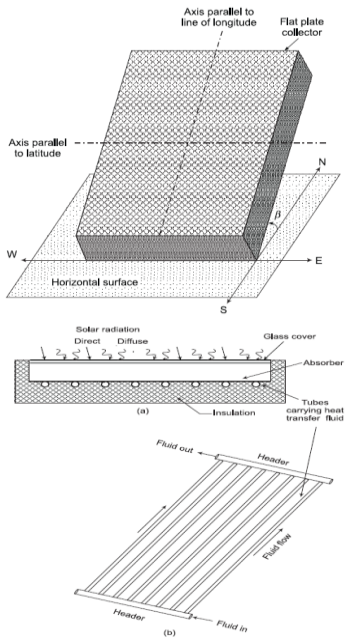
High (> 400^{0}C)

1. Dish with
   a. Power Cycle
   b. Sterling Engine
2. Solar Tower Heliostat


SOLAR COLLECTORS

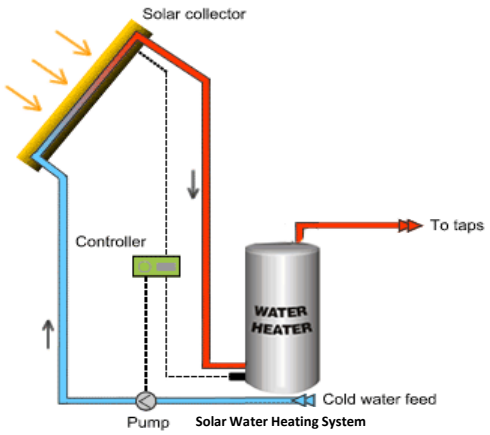
Liquid Flat Plate Collector

- A flat plate collector is placed at a location in a position such that **its length aligns with** line of **longitude and suitably tilted towards south** to have maximum collection.
- **water is used as heat transport medium** from collector to next stage of the system.
- As **solar radiation strikes on specially treated metallic absorber plate**, it is absorbed and raises its temperature.
- The heat is transferred to heat transfer liquid circulating in the tube (or channels), beneath the absorber plate and in intimate contact with it.
- The **glass-cover permits the entry of solar radiation** as it is transparent for incoming **short wavelengths** but is largely opaque to the longer infrared radiation reflected from the absorber. **As a result, heat remains trapped in the airspace between the absorber plate and glass cover** in a manner **similar to green house**.
- **The glass cover** also **prevents heat loss due to convectio**n by keeping the air stagnant.



Solar Water Heating System

- A solar water heating system (Figure 11.1) consists of a flat plate or evacuated tube solar collector, a storage tank and connecting pipes.
- The system is generally installed on the roof or on open ground, with the collector facing the sun and connected to a continuous water supply.
- The collectors are generally mounted on a north-facing roof (in southern hemisphere).
- Water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small



Solar Water Heating System

Solar Flat Plate Collector

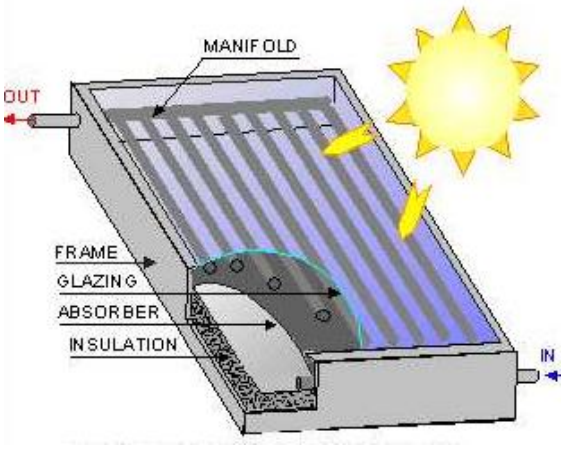


Figure 11.2 Solar Flat Plate Collector

- ✓ The most common collector is called a flat-plate collector.
- ✓ Heat the circulating fluid to a temperature of about **40-60°C.**
- ✓ Usually comprises of **copper tubes** welded to copper sheets (both coated with a highly absorbing **black coatings**) with toughened **glass sheet** on top for cover and insulating material at the bottom. The entire assembly is placed in a flat box.

Case Study

- **SOLAR THERANL**
- This training is imparted in a real life scenario using the 3x 300 LPD system installed on the rooftop .
- practical training trials carried out are:
- Solar Water heating Technologies available
- Solar irradiance variation
- Hourly Variation of temperature
- Performance assessment
- Case studies for industrial & commercial application

100% hot water generation for Gust house is from solar energy

Evacuated Tube Collector

Evacuated Tube Collector

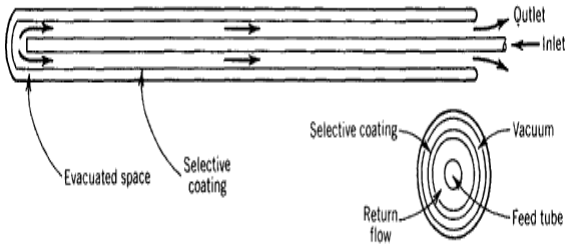
- ❑ Used for higher temperatures.
- ❑ Evacuated tube collector is less dependent upon ambient temperature unlike flat plate collector and its efficiency **does not drop with ambient temperature**.
- ❑ **Evacuated glass tubes** are used instead of copper in which case a separate cover sheet and insulating box are not required.
- ❑ Can reach high temperatures upto **150°C.**

Evacuated Tube Collector

Evacuated tube collector comprises of two concentric glass tubes fused in the ends as shown in Figure.

The air is evacuated from the gap between the tubes. The evacuated double-walled glass tube provides thermal insulation similar to that of thermally insulated "Thermos" bottle.

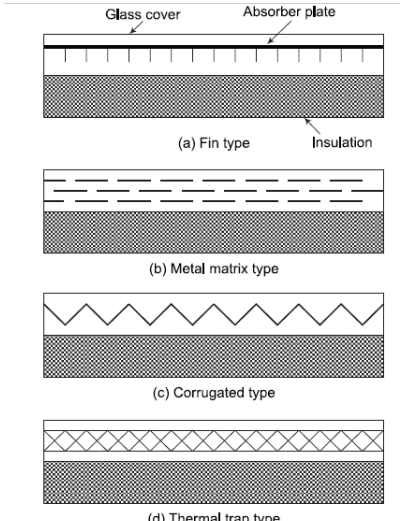
The outer glass tube is clear, and the surface of the inner glass tube is coated with a special heat material that absorbs the sun's energy.



SOLAR COLLECTORS

Flat Plate Air Heating Collector (Solar Air Heater,Solar Air Collector)

- A **solar air-heating collector** is **similar to a liquid** flat plate collector with change in configuration of absorber and tube (riser).
- The value of heat transfer coefficient between the absorber plate and the air is low. For this reason the surfaces are sometimes roughened or longitudinal fins are provided in the airflow passage. **Corrugated, V-shape, matrix, etc., are some of the other variations of absorber plate.**
- The principal applications of theses collectors are **drying for agricultural and industrial purposes, and space heating.**

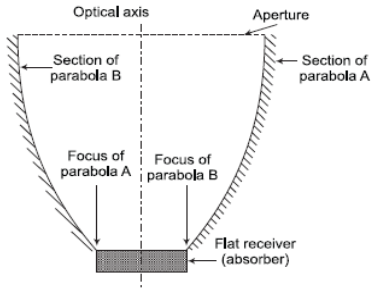


Various types of flat plate air heating collector

SOLAR COLLECTORS

Compound Parabolic Concentrator (CPC)

- Compound parabolic concentrator consists of **two parabolic mirror segments**, attached to a flat receiver.
- The segments are oriented such that focus of one is located at the bottom end point of the other in contact with receiver.
- It has a large acceptance angle and need to be adjusted intermittently.
- Rays in the central region of the aperture reach the absorber directly whereas those near the edges undergo one or more reflections before reaching the absorber.
- The concentration ratio achieved from this collector is in the range of **3-7**.

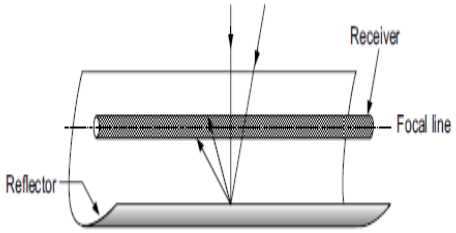


Compound parabolic concentrator

SOLAR COLLECTORS

Cylindrical Parabolic Concentrator

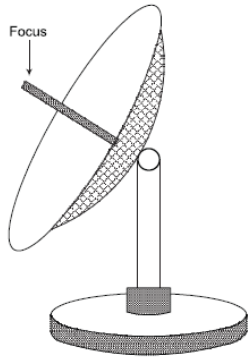
- It consists of a cylindrical parabolic trough reflector and a metal tube receiver at its focal line. The receiver tube is blackened at the outside surface to increase absorption.
- It is rotated about one axis to track the sun. The heat transfer fluid flows through the receiver tube, carrying the thermal energy to the next stage of the system.
- This type of collector may be oriented in any one of the three directions: East-West, North-South or polar.
- The concentration ratio in the range of 5–30 may be achieved from these collectors.



Cylindrical parabolic concentrator

SOLAR COLLECTORS

Paraboloidal Dish Collector (Scheffler Solar Concentrator)



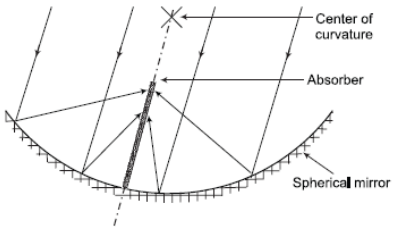
Paraboloidal dish collector (Scheffler solar concentrator)

- When a parabola is rotated about its optical axis a paraboloidal shape is produced.
- **Beam radiation** is focused at a point in the paraboloid. This requires two-axis tracking.
- It can have concentration ratio ranging from 10**°C** to few thousands and can yield temperature up to **3000 °C.**
- Paraboloidal dish collectors of **6-7m** in diameter are commercially manufactured.

SOLAR COLLECTORS

Hemispherical Bowl Mirror Concentrator

- It consists of hemispherical fixed mirror, a tracking absorber and supporting structure.
- All rays entering the hemisphere **after reflection cross the paraxial line at some point** between the focus and the mirror surface.
- Therefore, a linear absorber pivoted about the center of curvature of the hemisphere intercepts all reflected rays. **The absorber is to be moved so that its axis is always aligned with solar rays passing through the center of the sphere.**
- This requires **two-axis tracking**. The absorber is either driven around a polar axis at a constant angular speed of 15 degrees hour or adjusted periodically during the day. This type of concentrator gives lesser concentration, owing to spherical aberration, than that obtained in paraboloidal concentrator.

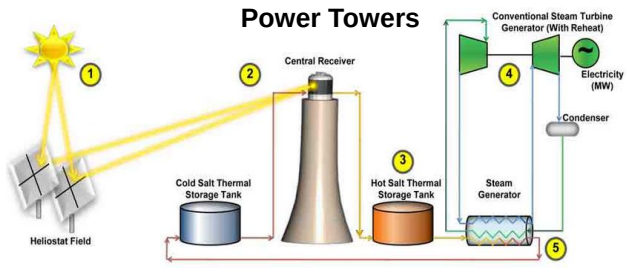


Hemispherical bowl mirror concentrator

1.4 Solar Electrical Energy Generation Technology

Solar Electrical Energy

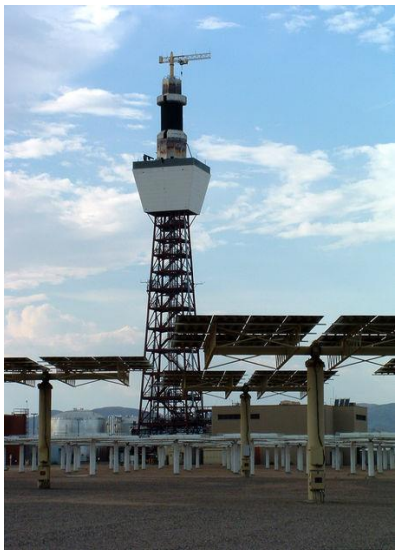
- ❑ Power Towers
- ❑ Parabolic Trough Collector
- ❑ Solar Photovoltaic Technology



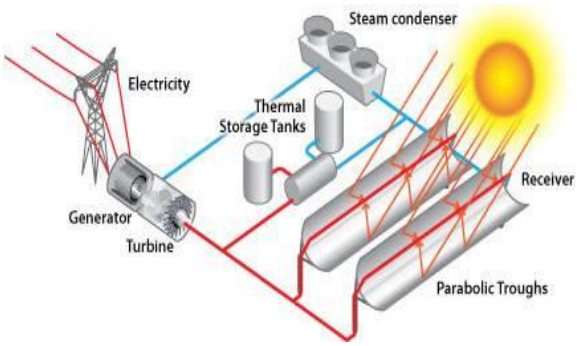
1. **Sunlight is concentrated** and directed from a large field of heliostats (mirrors) to a receiver on a tall tower.
2. Molten salt from the cold salt tank is pumped through the central receiver where it is **heated to 566°C).**
3. The heated salt from the receiver is stored in the **hot salt thermal storage tank**.
4. **Molten salt is pumped** from the hot salt tank through a steam generator that creates steam, which **drives a steam turbine, generating electricity**.
5. Cold salt at **288°C** flows back to the cold salt thermal storage tank and is re-used.

Solar Tower Technology

- **Power Tower (also known as 'central tower') use an array of flat, moveable mirrors (called Heliostats) to focus the sun's rays upon a collector tower (the receiver).**
- **A heat transfer medium (molten salt or saturated steam) is heated up to about 600 deg C.**
- **Molten salt is composed of a mixture of 60% sodium nitrate and 40% potassium nitrate for the desired temperature range.**
- **Operating Temperature – 565 Deg C**
- **Peak Efficiency - 23%**



Parabolic Trough Collector

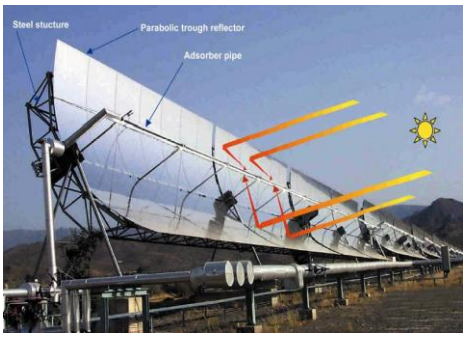


- Uses a series of specially designed parabolic curved, trough shaped reflectors that focus the sun's energy onto a receiver tube running at the focus of the reflector
- Because of parabolic shape, troughs can focus the sun at 30-60 times its normal intensity on the receiver pipe
- Heat transfer fluid (water) in the receiver is heated to a temperature of about 400^{o}C.

- Large arrays of these collectors are coupled to provide high temperature water for driving a steam turbine. power stations can produce many MW of electricity, but are confined to areas where there is sufficient solar insolation.

Parabolic Trough Technology

- **Most established of CSP technologies**
- **Consists of rows of parabolic mirrors, aligned on a north-south horizontal axis**
- **As the liquid runs through a tube in the trough, it heats up.**
- **Common fluids are synthetic oil, molten salt and water-steam.**
- **Hot liquid is passed through a series of heat exchangers to generate steam**
- **Conventional turbine is used to generate power.**
- **Operating Temperature- around 380 deg C**
- **Peak Efficiency-20%**

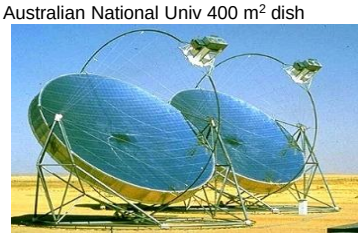


Paraboloid Dish Technology

Key Technology Indices	
Max Temperature	**300 C (d)** **800 C (p)**
Overall Efficiency	**15% (d)** **21% (p)**
Maximum Thermal Storage [Hrs]	**3 Hrs (d)**
Status of Technology	•**High Temp-High Efficiency** •**Demo Plant**
d: Demonstrated p: Predicted	

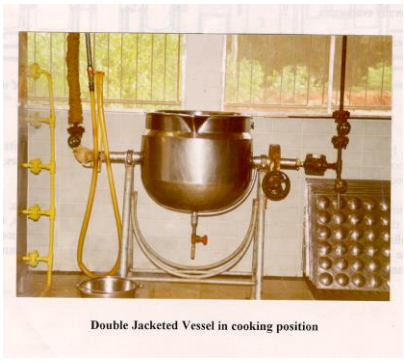
HiTek's 14 m^2 dish prototype

Australian National Univ 400 m^2 dish



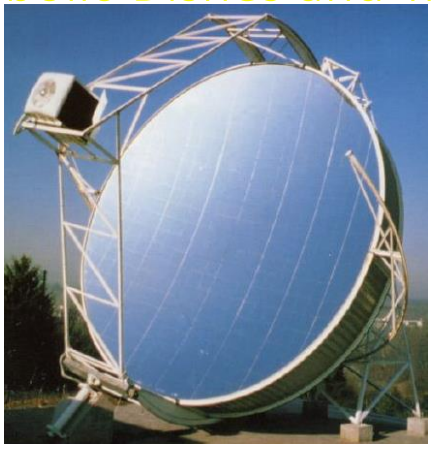
Bergermann Solar dish

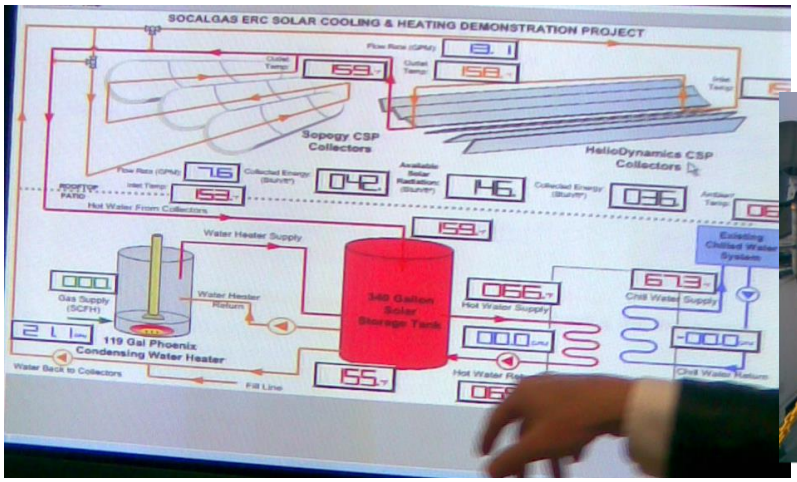
Solar Bowl Concentrator for Steam Cooking at CSR, Auroville



Double Jacketed Vessel in cooking position

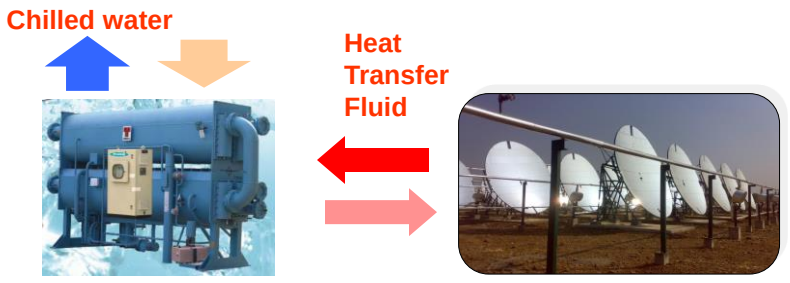
Parabolic Dishes and Troughs





Solar Air condioning

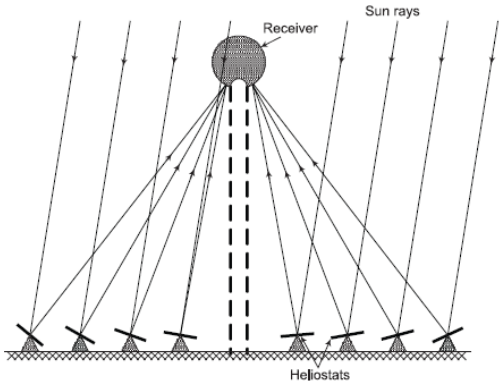
- Produce chilled water directly from solar THERMAL energy
- Solar cooling technologies use solar thermal energy collected through solar collectors to power thermally driven cooling machines.



SOLAR COLLECTORS

Central Tower Receiver

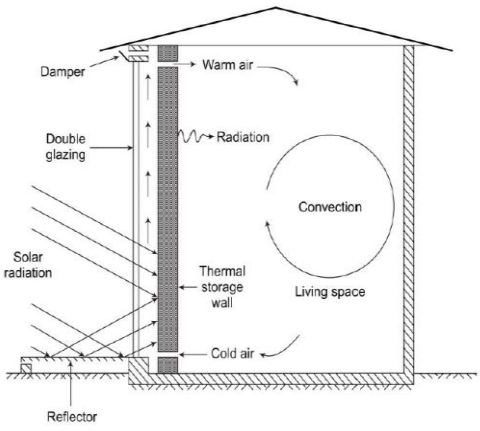
- In **central tower receiver collector**, the receiver is located **at the top of a tower**.
- **Beam radiation** is reflected on it from a large number of independently controlled; almost flat mirrors, known as **heliostats**, spread over a large area on the ground, **surrounding the tower**.
- Thousands of such heliostats track the sun to direct the beam radiation on the receiver from all sides.
- Concentration ratio of as high value as 3000 can be obtained.
- The absorbed energy can be extracted from the receiver and delivered at a temperature and pressure suitable for **driving turbines for power generation.**



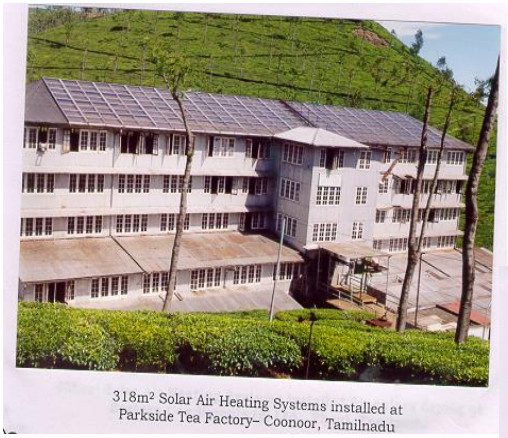
Central tower receiver

SOLAR PASSIVE SPACE HEATING AND COOLING SYSTEMS

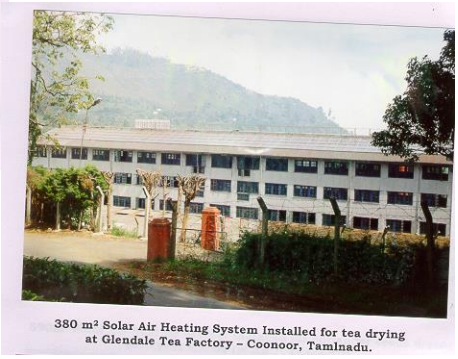
- The **south facing thick wall,** called 'Trombe Wall'. In order to increase the absorption, the outer surface is painted black.
- The entire south wall is covered by one or two sheets of glass or plastic sheet with some **air gap** (usually 10–15 cm) between the wall and inner glazing.
- Solar radiation after penetration through the glazing is absorbed by the thermal storage wall. The air in the air gap between the glazing and the wall thus gets heated, rises up and enters the room through the upper vent while cool air from the room replaces it from the bottom vent.
- The circulation of air continues till the wall goes on heating the air.
- **Thus the thermal wall collects stores and transfers the heat to the room**.
- **Heating can be adjusted by controlling the airflow** through the inlet and outlet vents by shutters.
- Opening the damper at the top of the glazing allows the excess heat to escape outside, when heating is not required.



Solar space heating



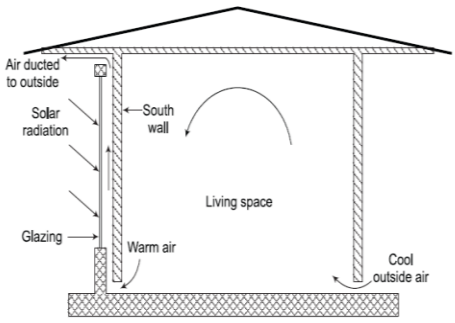
318m² Solar Air Heating Systems installed at Parkside Tea Factory– Coonoor, Tamilnadu



380 m² Solar Air Heating System Installed for tea drying at Glendale Tea Factory – Coonoor, Tamlnadu.

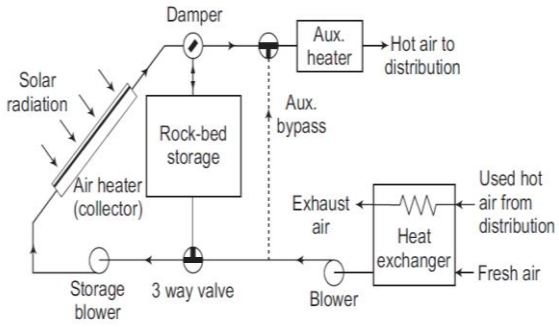
SOLAR PASSIVE SPACE HEATING AND COOLING SYSTEMS

- This **scheme utilizes solar 'chimney effect' a**nd is effective where outside temperatures are moderate.
- Solar radiation is allowed to heat up the air between the glazing and interior south wall.
- The heated air rises up and ducted outside and the warm air from the room is drawn into this space due to natural draught thus produced.
- As a result, cool outside air enters the room from the bottom air vent on the other side of the room.



Solar passive cooling through ventilation

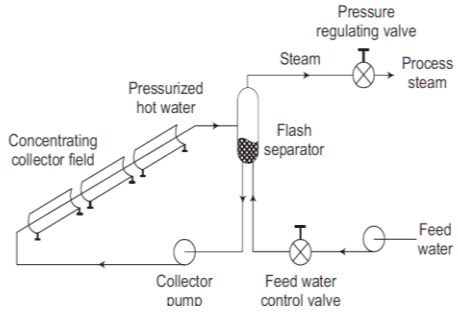
SOLAR INDUSTRIAL HEATING SYSTEMS



Hot air industrial process heat system

- Solar active heating systems are used for several industrial process **heat requirements**
- **Thermal energy is transported from collector through hot air and utilized for process heat**. The **excess heat is stored in rock bed thermal storage** to be used later when solar radiation is not available.
- Auxiliary heating augments the supply when the heat supplied by collector or storage is not sufficient.
- The used air is passed through a heat exchanger to recover the heat from the exhaust air to raise the initial temperature of fresh air entering the collector.

SOLAR INDUSTRIAL HEATING SYSTEMS

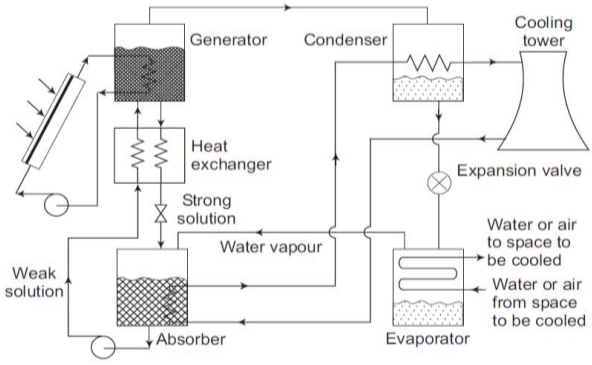


Solar process steam system

- Pressurized water is circulated through concentrating collector to prevent boiling. The high-pressure heated water is throttled and flash separated in a flash separator. To maintain the necessary liquid level in the flash tank, boiler feed water is injected into the pump suction.
- The **saturated steam obtained from the flash separator** is recirculated through the collector field and distributed for use. A pressure regulator valve regulates the pressure

SOLAR REFRIGERATION AND AIR CONDITIONING SYSTEMS

A solar energy operated Lithium Bromide-Water Absorption Cooling System



- A flat plate collector is used to supply heat to the generator and water vapours are raised at a temperature lower than 100 °C at low pressure.
- These vapours are condensed in condenser by cooling water supplied from cooling tower.
- The condensed water is evaporated by passing it through the expansion valve and maintaining lower pressure in the evaporator.
- Cooling effect is produced here and heat is absorbed from the space to be cooled through heat transport fluid.
- The water vapours from evaporator go to the absorber where they are absorbed in lithium bromide solution.

1.Solar Water Heaters

Collector : converts solar radiation into thermal energy

- **Hot water at 60-80C for hotels**
- **hospitals,**
- **dairies,**
- **swimming pools, industry**
- **domestic use etc.**

SOLAR COOKERS

- Thermal energy requirements for cooking purpose forms a major share of total energy consumed, especially in rural areas.
- Variety of fuels like **coal, kerosene, cooking gas, firewood, dung cakes and agricultural wastes are being used to meet the requirement.**
- Fossil fuel is a fast depleting resource and need to be conserved, firewood for cooking causes deforestation and cow dung, agricultural waste, etc., may be better used as a good fertilizer.

Harnessing solar energy for cooking purpose is an attractive and relevant option.

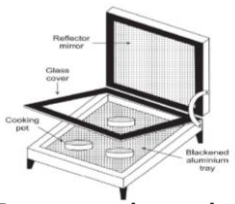
A variety of solar cookers have been developed, which can be clubbed in four types of basic designs:

(i) box type solar cooker,
(ii) dish type solar cooker,
(iii) community solar cooker, and
(iv) advance solar cooker.

SOLAR COOKERS

Box Type Solar Cooker

- This cooker is simple in construction and operation.
- An insulated box of blackened aluminum contains the utensils with food material.
- The box receives direct radiation and also reflected radiation from a reflector mirror fixed on inner side of the box cover hinged to one side of the box.
- The angle of reflector can be adjusted as required. A glass cover consisting of two layers of clear window glass



Box type solar cooker

Paraboloidal Dish Type (Direct Type) Solar Cooker

- The vessel directly receives the concentrated solar radiation. The reflector is periodically adjusted to track the sun.
- A fairly high temperature of about 450 °C can be obtained and a variety of food requiring boiling, baking and frying can be cooked for 10–15 persons.
- It can save on fuel up to 10 LPG cylinders annually on full use. Cooking time is approximately 20–30 minutes.


Paraboloidal dish type solar cooker

- **Community Solar Cooker-** Community solar cooker has been developed for indoor cooking. It has a large automatically tracked paraboloidal reflector standing outside the kitchen. The reflector reflects the sunrays into the kitchen through an opening in its north wall.
- It can cook all types of food for about **40–50 people and can save up to 30 LPG cylinders** in a year with optimum use.

BENEFITS:

- Approximate cost of 100 LPD solar water heating system is Rs.30,000/-.
- 100 LPD solar water heating system cater to 5 to 6 persons for bathing.
- Saves about 1,500 units of electricity per annum.
- Pay back period is 4 to 5 years.
- Life period is 15 years and above.

100 LPD SWHS prevents **1.5 tons of C O2 emission / annum**

Solar Water Heaters

Soft Loan Scheme

Participating Financial Institutions

IREDA
Canara Bank
Union Bank of India
Punjab & Sind Bank
Andhra Bank
Bank of Maharashtra
Syndicate Bank
Punjab National Bank

Himurja
Office Building, Shimla

A retrofitted building

- Air heating panels
- Double glazed windows
- Solar chimney
- Solarium on South for heat gain
- Integration of windows and light shelves for day lighting
- Solar water heating system
- Solar photovoltaic system

OBJECTIVE TYPE QUESTIONS

1. A solar thermal collector:
(a) collects the solar energy and reflects it back
(b) absorbs the solar radiation and dissipate it to the ambient
(c) collects and coverts the solar energy into electrical energy
(d) collects and coverts the solar energy into thermal energy and delivers it to heat transfer fluid,

2. The concentration type solar collectors:
(a) first absorb the radiation and then increase its concentration,
(b) increase the density of solar radiation before absorbing it
(c) dilute the density of solar radiation before absorbing it
(d) increase the intensity of solar radiation and then reflect it back

3. In evacuated tube collectors:
(a) both conductions as well as convection losses are suppressed,
(b) only conductions losses are suppressed
(c) only convections losses are suppressed
(d) only radiation losses are suppressed

4. Solar thermal water pump:
(a) uses solar thermal energy to evaporate water
(b) uses solar thermal energy to circulate hot water,
(c) uses electric powered pump to circulate water heated by solar energy
(d) uses solar thermal energy for production of power to drive the pump

5. A solar green house:
(a) uses solar energy to provide conducive conditions for growth of vegetation,
(b) provides enhanced radiation for photosynthesis process
(c) prevents fresh air to come into contact with plants
(d) uses solar thermal pump for irrigation

6. Solar constant is _____.
(a) 342 W/m2
(b) 1368 W/m2,
(c) 1342 W/m2
(d) 1380 W/m2

7. What is the Solar window period? _____.
(a) typically 6 AM - 6 PM
(b) typically 7 AM - 5 PM,
(c) typically 9 AM - 3 PM,
(d) typically 9 AM - 5 PM

REVIEW QUESTIONS

1. Define concentration ratio of a solar collector.
2. What are the main advantages of flat plate solar collector?
3. Discuss the principle of a solar collector. How collector coating can be used to improve the performance of a collector?
4. explain the working of solar water heating.
5. What is a greenhouse
6. Why evacuated tube collector is more efficient than flat plate collector?

Q & A

Thank You

Save energy and water for Sustainable Life

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