Renewable Energy Sources
(18EE653)
IAT-1
Solution

1(a)Define Energy and energy resources. Discuss different ways of their classification with examples in each category.

- **Energy**

Energy is the capacity to do work and is required for life processes.

- An energy resource is something that can produce heat, power life, move objects, or produce electricity. Matter that stores energy is called a fuel.

Classification of Energy Resources

- Based on Usability of energy
  - Primary resources
  - Secondary resources
- Based on traditional use
  - Conventional energy
  - Non-Conventional energy
- Based on availability
  - Non-renewable Energy Sources
  - Renewable Energy Sources
- Based on commercial applications
  - Commercial energy source
  - Non-commercial energy source
- Based on origin
  - Fossil fuel energy, Nuclear energy, Hydro energy, Solar energy, Wind energy, etc.
-

Classification of Energy Resources

1. Primary Energy Resources
   - Derived directly from natural reserve
   - Chemical fuels, solar, wind, geothermal, nuclear and hydro power etc.
   - Use either raw energy form or by converting them to usable form
2. Secondary Energy Resources
   - Energy generated from primary energy sources
   - Electrical Energy, Steam power, hydrogen energy etc.
3. Secondary energy storage is,
   - Cost effective
   - Highly efficient with improved performance Environmentally
   - acceptable and system acceptability index approaching to unity is achievable during conversion, transportation, distribution and end use

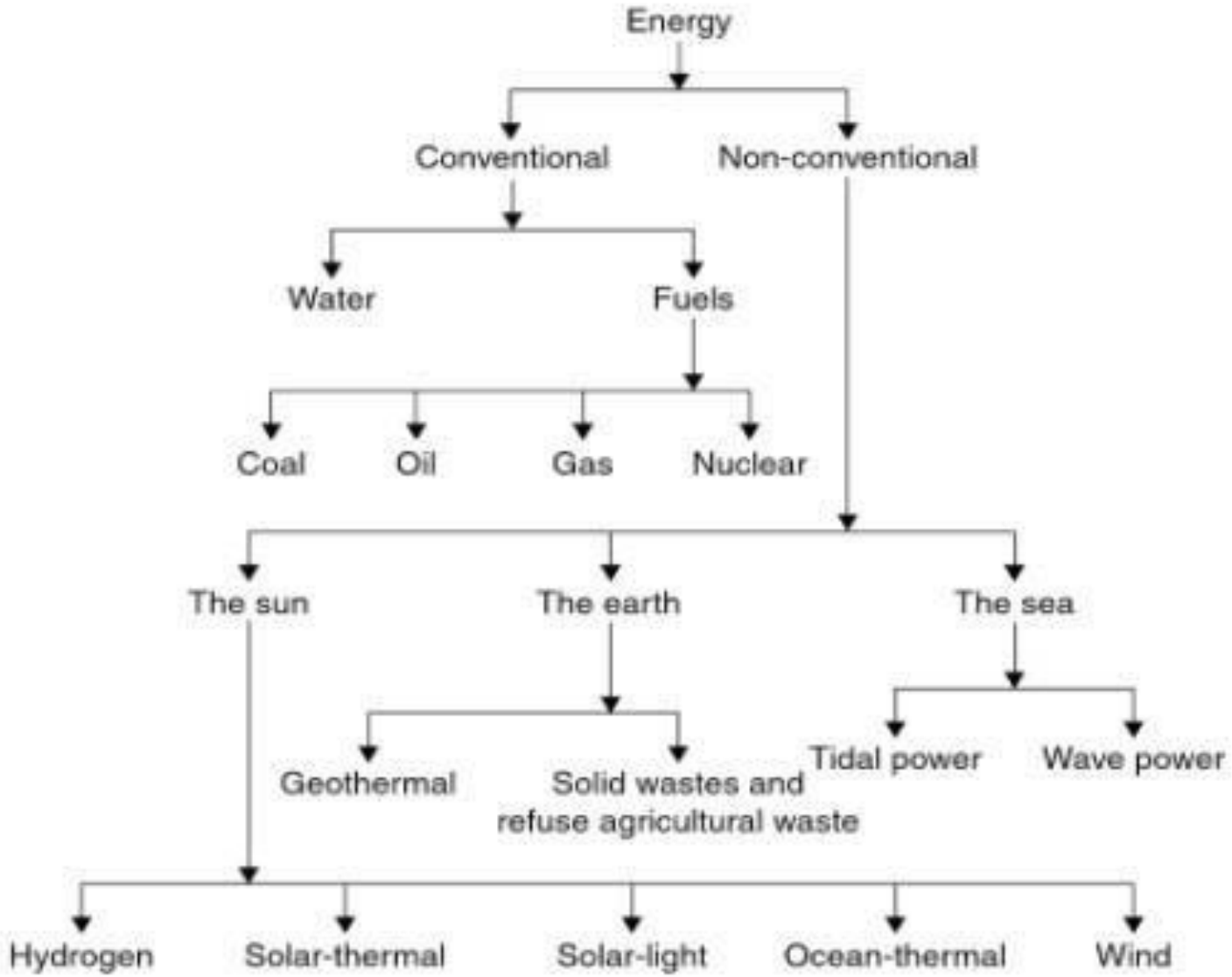
Cont d...

Primary energy resources may be further sub-classified as follows:

1. Conventional energy resources
   - The energy stored stored within the earth and the sea.
   - Includes fossil fuels (coal, oil, and gas) and nuclear energy (Uranium and Thorium)
   - Formed over hundreds of millions of years ago.
   - Continuous usage leads to fossil fuels will be no more for future generations.
   - Finite energy sources
2. Non-Conventional energy resources
   - Infinite energy resources
   - Limited technical knowledge
   - Required full exploitation and improved technical knowledge
   - Cost factor and overall performance

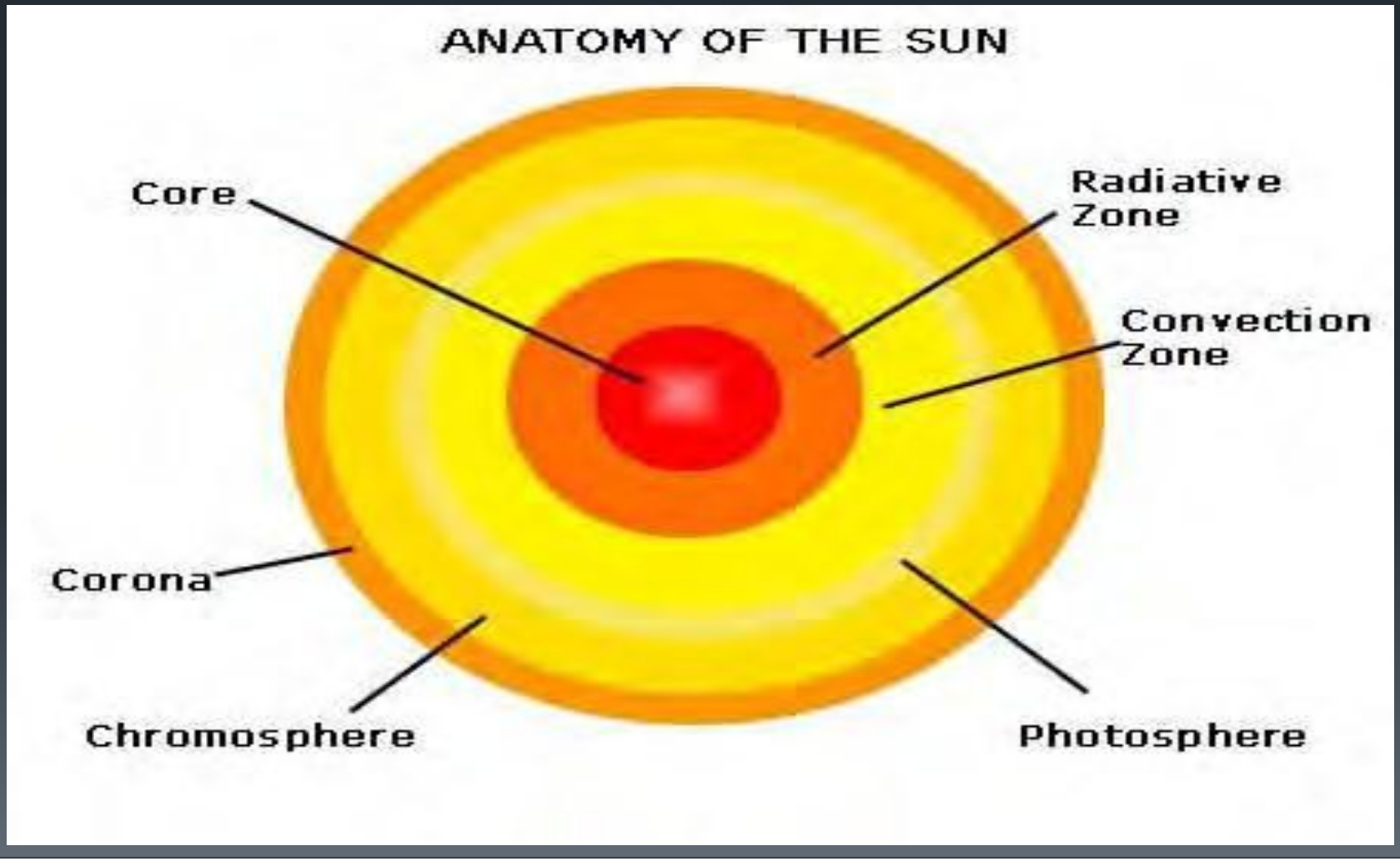
Cont

Classification of Energy Resources



1(b) Write short notes on the layers of the sun.

Layers of the Sun



Core

- Innermost layer
- Highly dense 160g/cm^3
- 40% suns mass in 10% volume
- Gaseous state
- 1,50,00000 degree celcius
- Fusion reactions produce gamma rays and neutrinos
- Each high energy gamma ray that leaves the solar envelope will become thousand low energy photons
- Neutrinos are non reactive

Solar envelope

- Radiative envelope surrounded by convective envelope
- Temp is 4 million Kelvin
- Less dense than core
- 60% mass in 90% volume
- Puts pressure on core and maintains core temperature
- Cooler and More Opaque than core
- Energy movement in huge cells in convection zone only

Photosphere

- Zone from which sunlight is seen and emitted
- Thin layer of low pressure gases
- 6000 degree celcius

Chromosphere

- A red circle can sometimes be seen outside the sun during eclipse which is called chromosphere
- Hydrogen abundant so red in colour
- 7000 K, hotter than photosphere

Corona or Crown

- The outermost layer of the sun
- Thin and faint so difficult to observe from the earth
- Visible during total solar eclipse
- Outer layer is very dim
- It is the hottest 10^6Klayer though Spreads over several million kilometers into space, lots of room for molecules to move
- Causes Solar winds

2(a) Define (i) Hour angle (ii) latitude angle (iii) Day Length Equation

Hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains sun

Latitude angle - Angle between line drawn on a point from earth's surface to the center of earth and the earth's equitorial plane

Day Length Equation

The daylight hour = 2TH = sunrise time + sunset time

$=2^* (1/15)\cos^{-1} (-\tan\phi * \tan\delta)$

2 (b)

- Calculate zenith angle, of the sun at Lucknow (26.75° N) at 9:30 am on February 16,2012

- $\delta = 23.45 \sin [360\ (284+n)/365]$

  $n = 31+16 = 47$

  $\delta = -12.95° = -13°$

- Hour angle ω

  $\omega = (1/4)\ t_m$

  $t_m = 12.00 - 9.30 = (12*60) - (9*60) + 30 = 720 - 570 = 150$ min

  $\omega = \frac{150}{4} = -37.5$

- $\phi = 26.75$
- $cos(\theta_z) = cos(\delta)cos(\omega)cos(\phi) + sin(\delta)sin(\phi)$
- $\theta_z = 53.914$

3(a) Discuss about the causes of energy scarcity.

Causes of Energy Scarcity

1. Increasing Population
2. Increase Energy Usage or Consumption
3. Uneven Distribution of Energy Resources
4. Lacks of Technical Knowhow
5. Poor Infrastructure at power generating stations
6. Unexplored Renewable Energy Options
7. Delay in Commissioning of Power Plants
8. Wastage of Energy
9. Poor Distribution System
10. Major Accidents and Natural Calamities
11. Wars and Attacks
12. Miscellaneous Factors-strikes, military coup, political events, severe hot summers or cold winters.

Population and Energy Consumption (Energy Council)

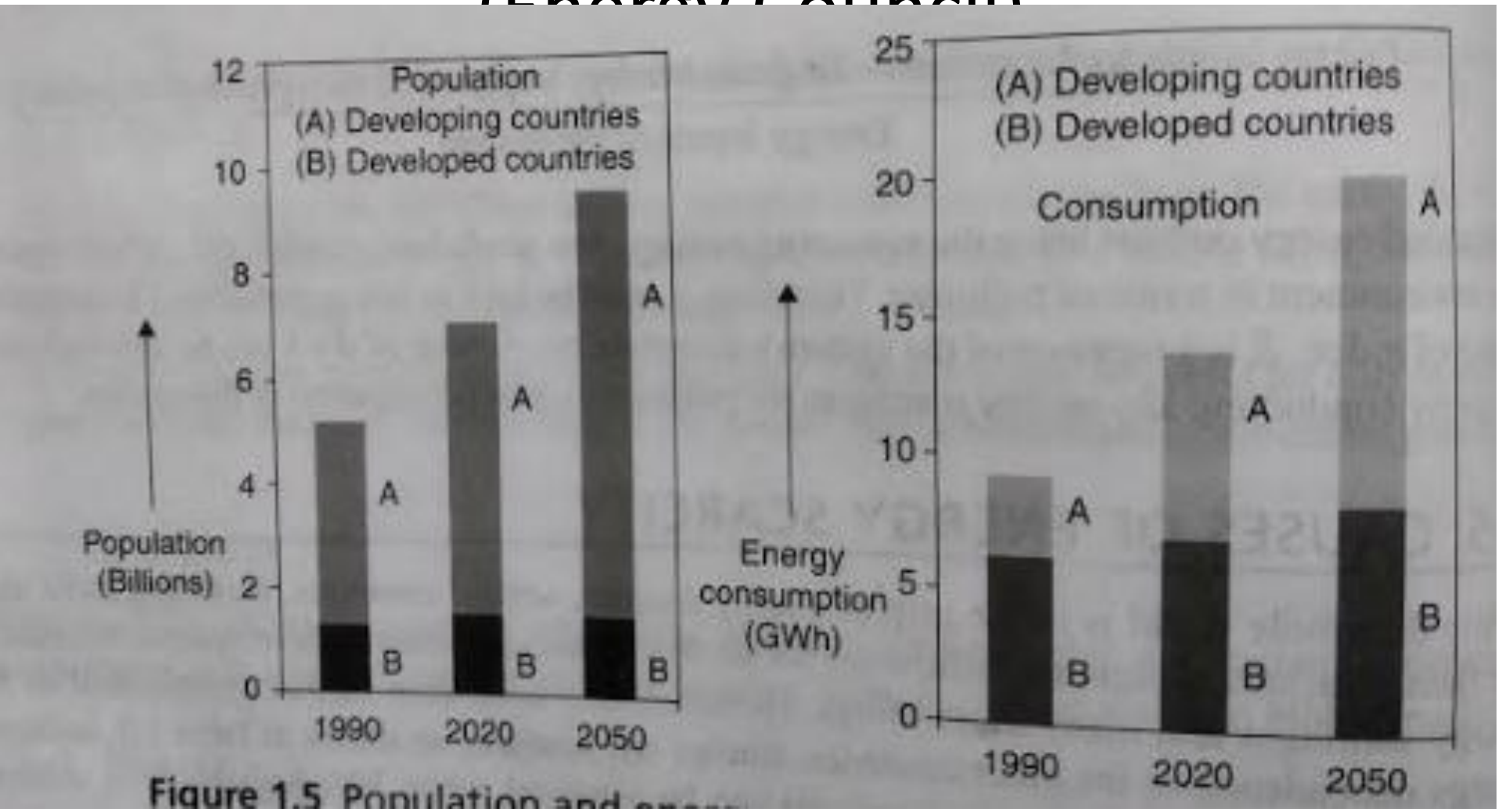


Figure 1.5 Population and ener...

3(b)List the Solar thermal energy applications.

Solar Thermal Energy Applications

- Technologies for conversion of solar energy into usable form includes

➢ Passive system

-- collects energy through the orientation, materials and construction of collector

--suited for

--- design of buildings

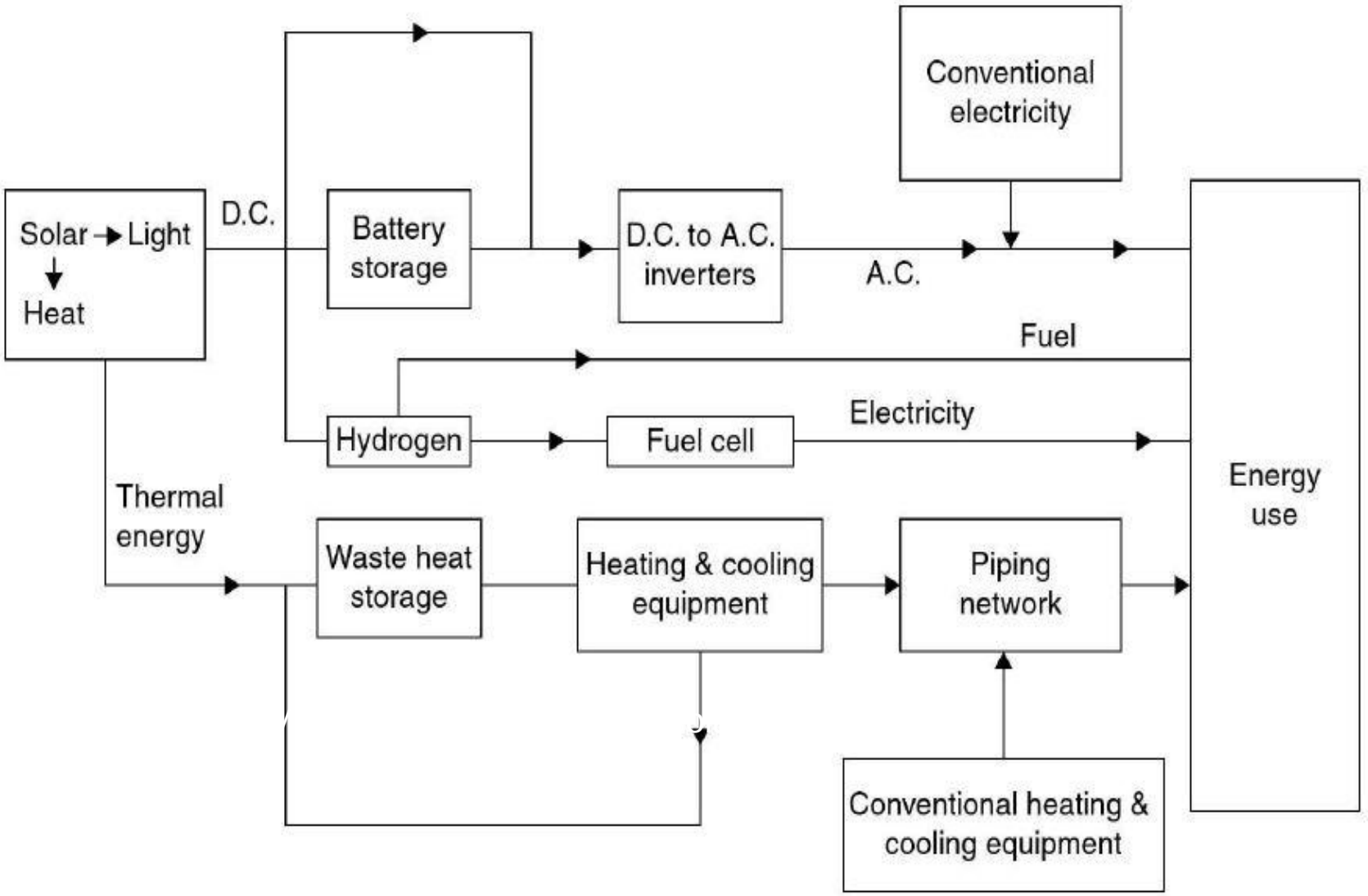
--- thermo siphoning solar hot water systems(refers to a method of passive heat exchange based on natural convection, which circulates a fluid without the necessity of a mechanical pump)

➢ Active System

-- Use pumps to circulate water or any other absorbing fluid through solar collectors

--can be open loop(water is directly heated by collector) or closed loop(antifreeze or glycol mixture is heated before transferring it to water via heat exchanger)

Multi-purpose utilization of solar energy



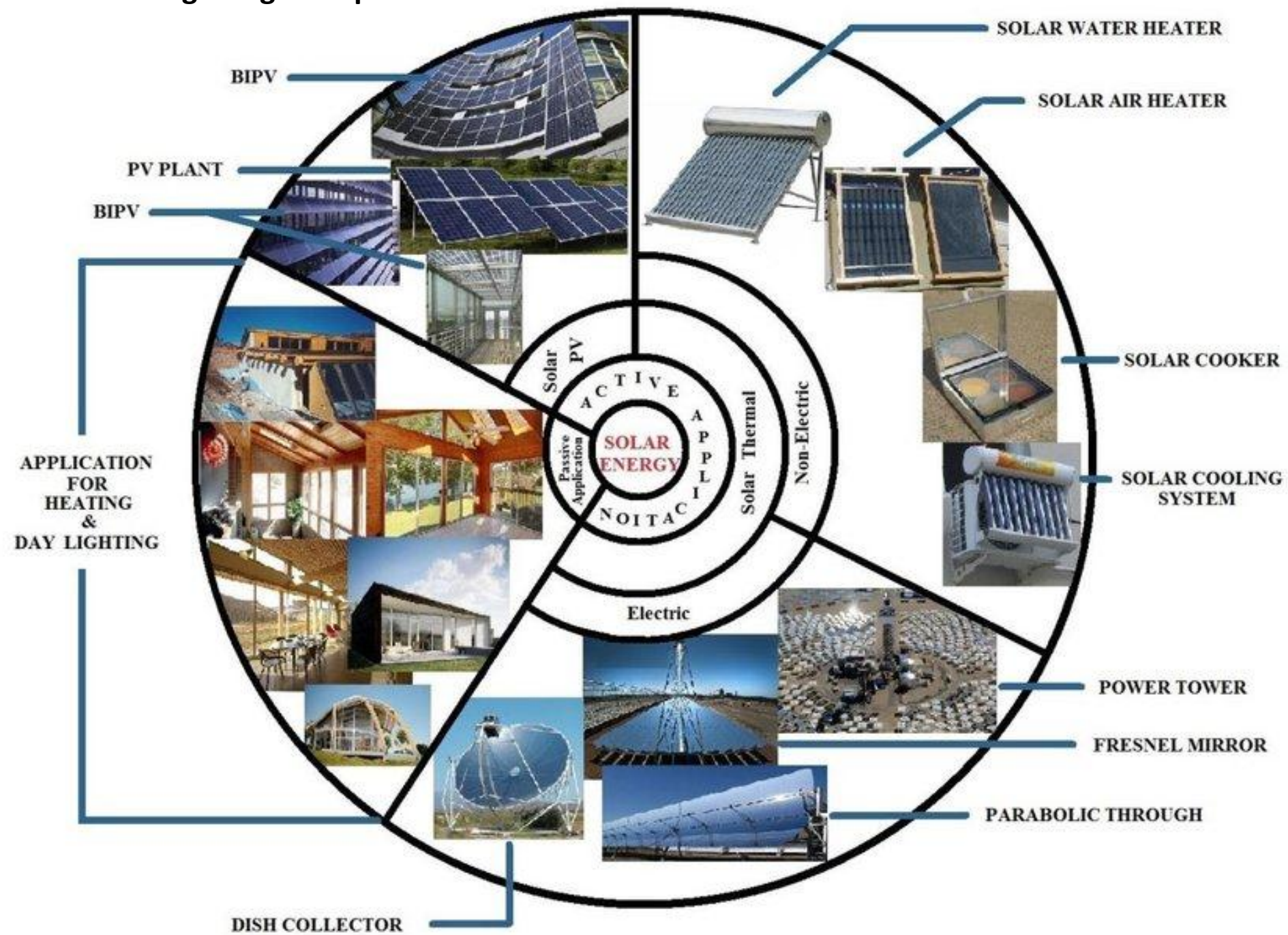
Direct Thermal Applications

- Solar energy can be collected to create high temperature steam as well as low temperature heat
- Low ,Medium, and high temperature collectors
- Low and medium temperature collectors are flat plates
- Low temperature collectors are used to heat swimming pools whereas Medium temperature collectors are used to heat water or air for domestic and commercial purposes
- High temperature systems use mirrors or reflective surfaces to concentrate sunlight and are used for electric power generation

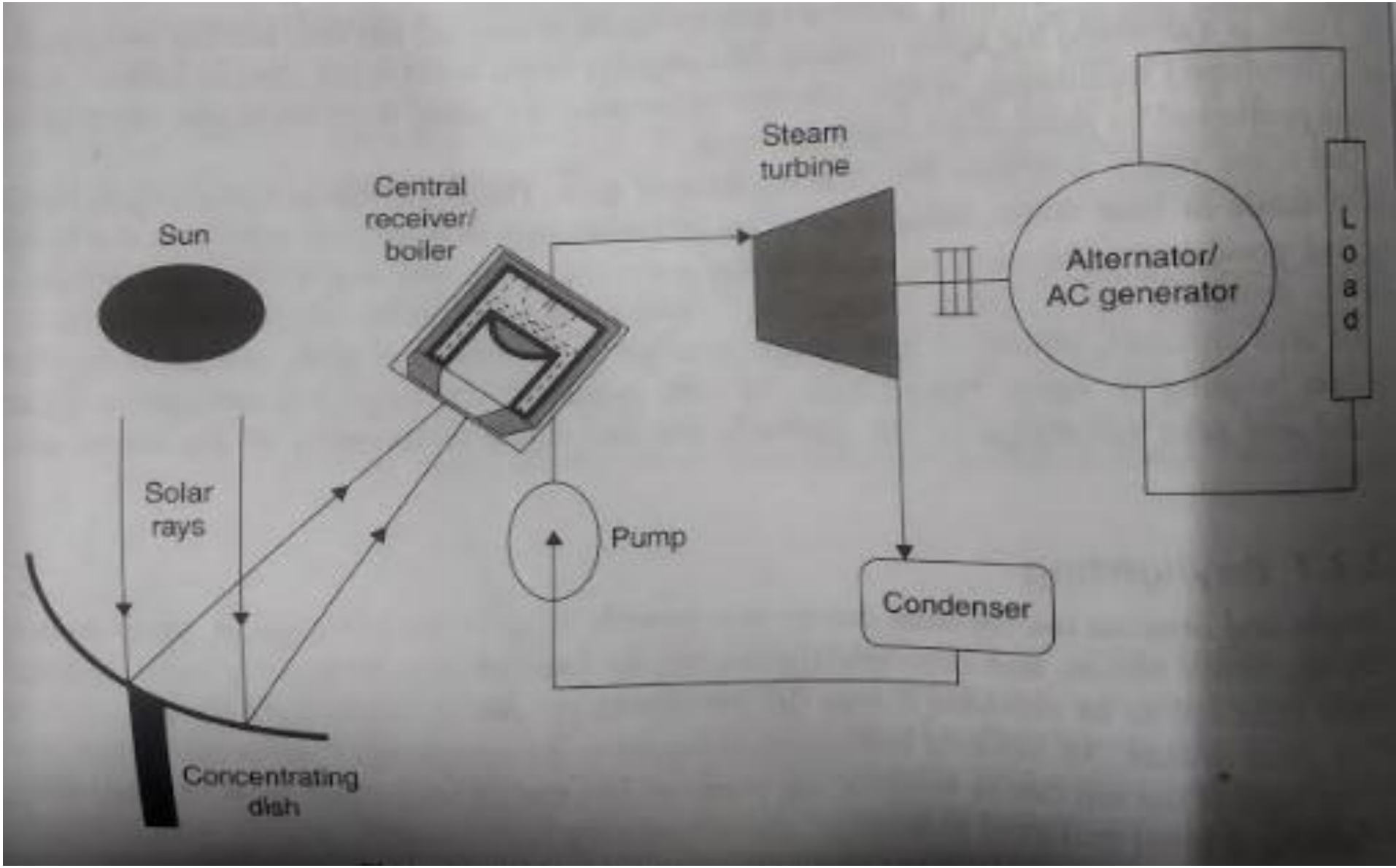
Low Temperature Solar Thermal Systems

- Space Heating for Homes ,offices and green houses
- Domestic and Industrial hot water
- Pool heating
- Desalination (removal of salts and minerals from a target substance)
- Solar Cooking
- Crop Drying

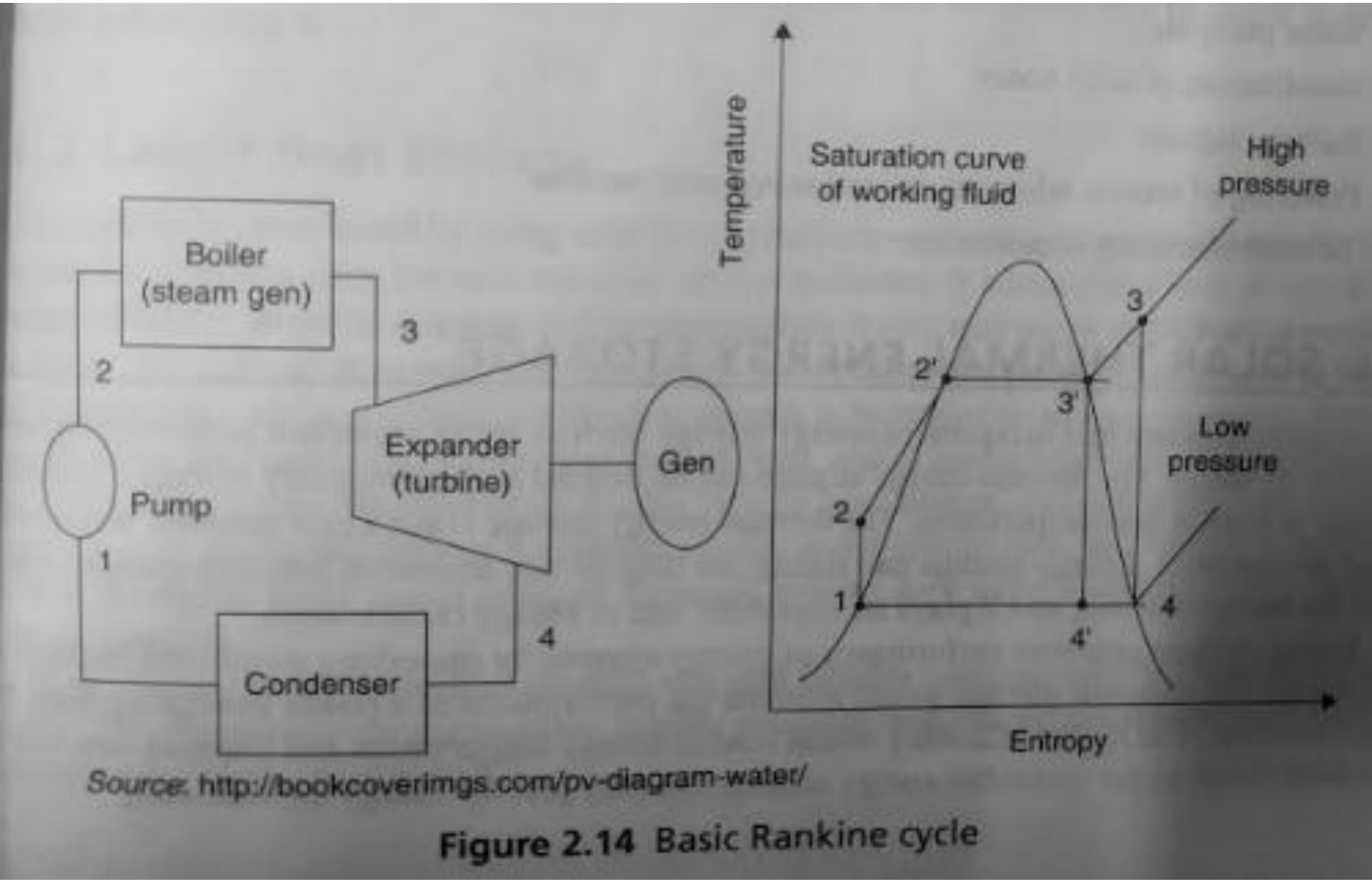
BIPV-Building-integrated photovoltaics



Solar Electric Conversion and Applications



Basic Rankine Cycle



Source: http://bookcoverimgs.com/pv-diagram-water/

Figure 2.14 Basic Rankine cycle

4(a)List the difference between renewable and non-renewable energy sources.

Basis For Comparison	Conventional Sources of Energy	Non-Conventional Sources of Energy
Meaning	Conventional sources of energy are the sources that are commonly in use since long time.	Non-conventional sources of energy refers to the sources that are identified few decades ago.
Exhaustible	They can be exhausted due to over consumption.	They cannot be exhausted.
Pollution	They pollute environment, on a large scale and adds to global warming.	They are environment friendly sources, which does not causes pollution.
Use	They are primarily used for industrial and commercial purposes.	They are mainly used for domestic purposes.
Expense	Costly.	Comparatively less expensive.

4(b) Explain briefly the Indian energy scenario.

Renewable Energy In India

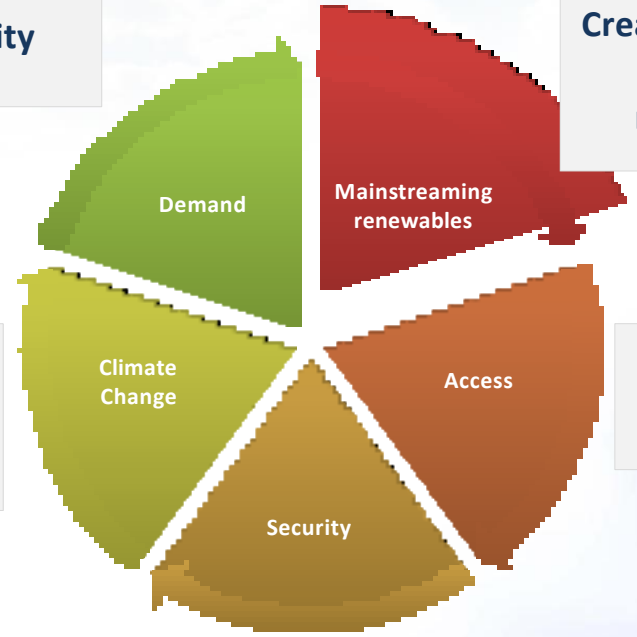
Renewable Energy Systems

Renewable Energy In India

India's Energy Challenge

Growing electricity demand

Creating pan-India market for renewables



India's INDCs under Climate Change seeks 40% of electric installed capacity by non-fossil fuel by 2030

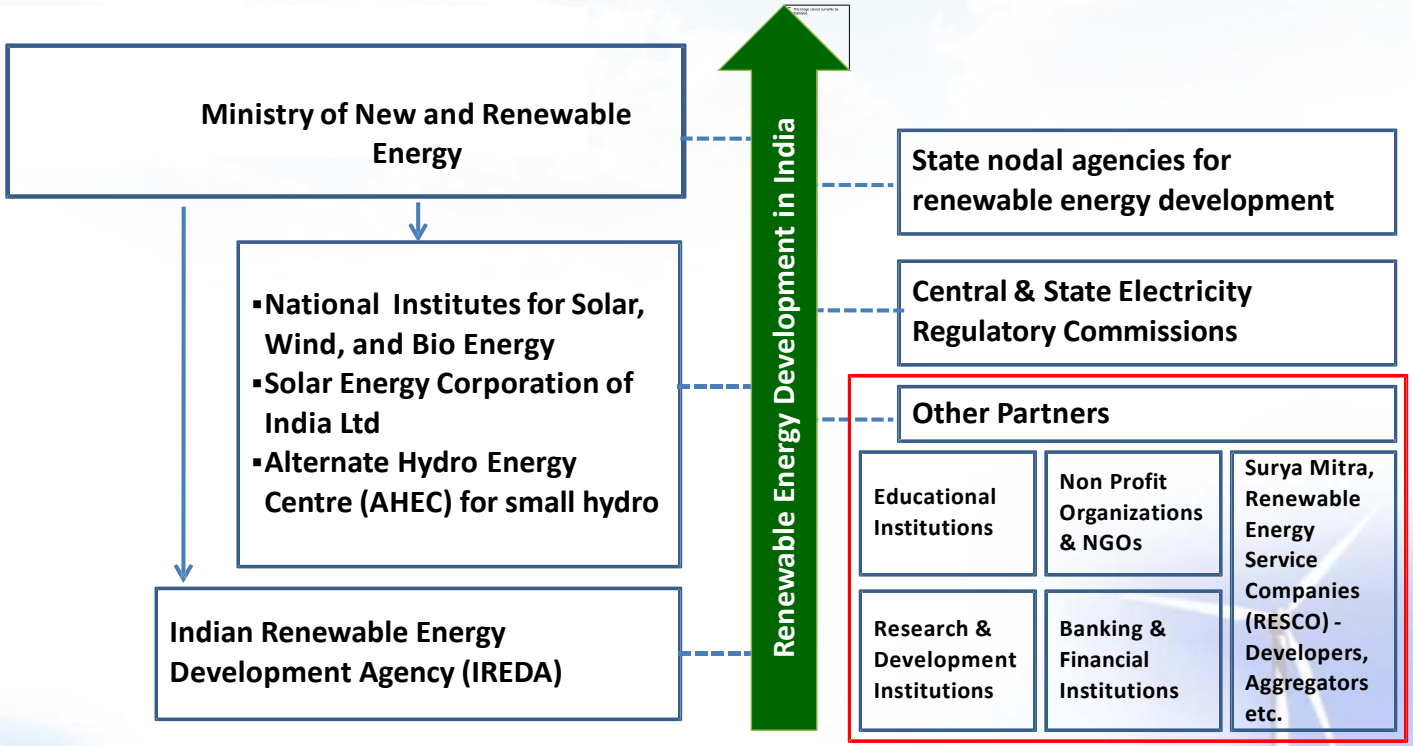
India is yet to achieve universal electricity Access

India is dependent on oil imports for 80% of its demand

Renewabl
Energy Syst

Renewable
Energy In Ind

Institutional Structure

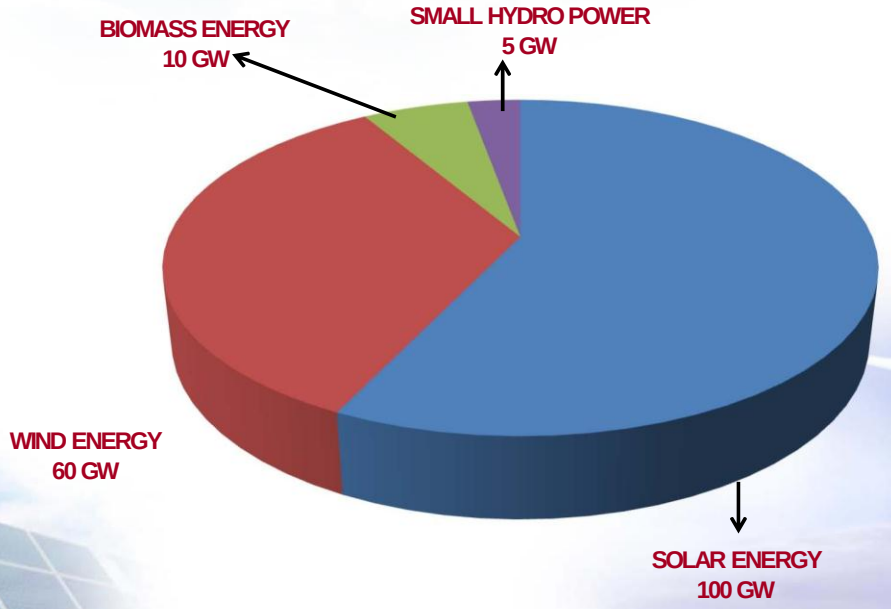


Renewable Energy Systems

Renewable Energy In India

Mission 175 GW by 2022

- India made a commitment in Paris Climate Agreement
  - to reduce emission intensity of the economy and
  - for having at least 40 % electric power installed capacity from clean energy sources by the year 2030



National Solar Mission (NSM)

- National Solar Mission (NSM) was launched on 11th January, 2010.
- Mission targets :
  - (i) 20GW grid connected solar power by 2022;
  - (ii) 2GW off-grid solar applications including 20 million solar lights by 2022;
  - (iii) 20 million sq. m. solar thermal collector area;
  - (iv) to create favourable conditions for developing solar manufacturing capability in the country; and
  - (v) support R&D and capacity building activities to achieve grid parity by 2022.
- In June 2015 the targets were scaled up to 100 GW by 2022
- Broadly consists of 40 GW Grid connected Rooftop and 60 GW large and medium size land based solar power projects.

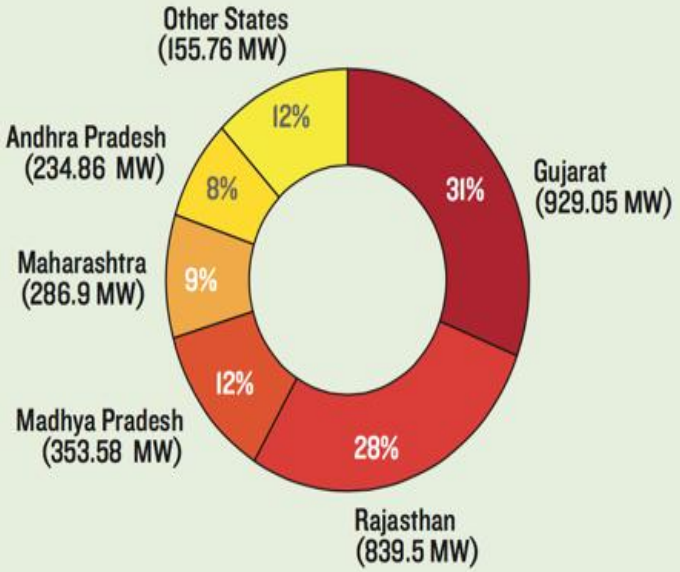
Leading States

Renewable

SOLAR PV INSTALLED CAPACITY LEADERS

*(as of December 2014)**

Gujarat	929.05 MW
Rajasthan	839.50 MW
Madhya Pradesh	353.58 MW
Maharashtra	286.90 MW
Andhra Pradesh	234.86 MW

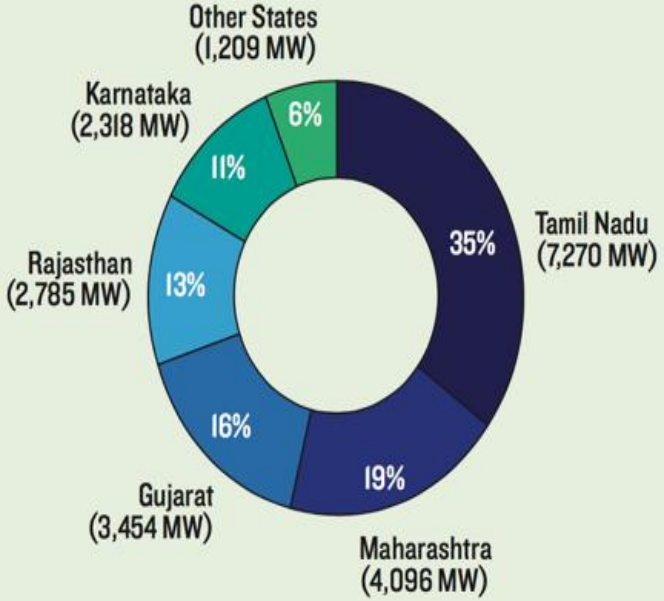


* Government of India, Ministry of New and Renewable Energy, "State Wide Installed Capacity of Solar Projects Under Various Schemes as on 15/12/2014," mnre.gov.in/file-manager/UserFiles/State-wise-Installed-Capacity-of-Solar-PV-Projects-under-various-Scheme.pdf, (accessed January 28, 2015).

WIND INSTALLED CAPACITY LEADERS

*(as of January 2014)***

Tamil Nadu	7,270 MW
Maharashtra	4,096 MW
Gujarat	3,454 MW
Rajasthan	2,785 MW
Karnataka	2,318 MW



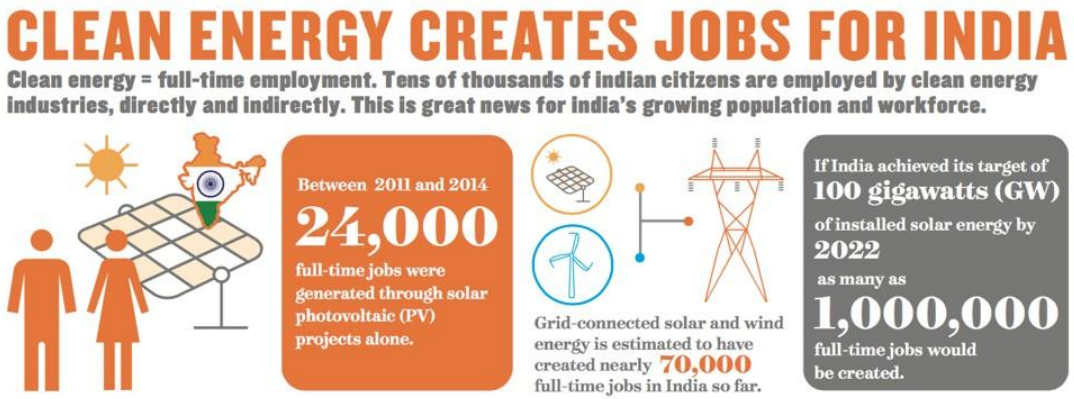
** Government of India, Ministry of New and Renewable Energy, "Annual Report 2013-2014," mnre.gov.in/file-manager/annual-report/2013-2014/EN/index.html, (accessed January 28, 2015).

Solar Energy Target: 100 GW by 2022

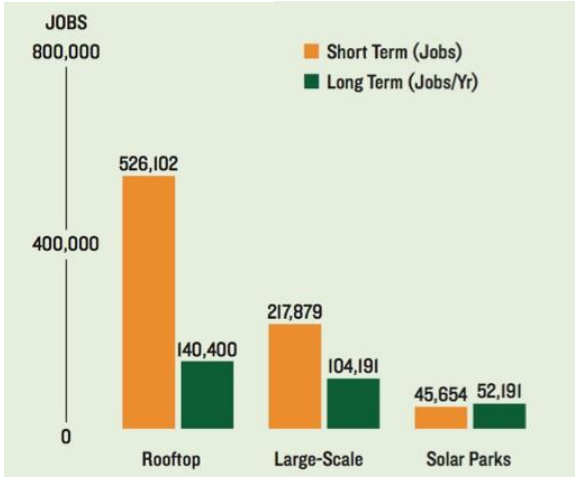
Off Grid Solar	Rooftop Projects	Large Scale Projects	
Off-Grid Applications 2,000 MW	Residential / Commercial 40,000 MW	Solar Parks 20,000 MW	Utility Scale 40,000 MW




Solar Job Creation: Over 1 Million Jobs by 2022



40 GW Rooftop,
40 GW Large-scale Projects,
20 GW Solar Parks



Source: CEEW – NRDC, Clean Energy Powers Local Job Growth in India

Renewable Energy In India

Renewable Energy Systems

Renewable Energy In India

- India is one of the countries with the largest production of energy from renewable sources.
- In the electricity sector, renewable energy account for 34.6% of the total installed power capacity.
- Large hydro installed capacity was 45.399 GW as of 30 June 2019, contributing to 13% of the total power capacity.
- The remaining renewable energy sources accounted for 22% of the total installed power capacity (80467 GW) as of 30 June 2019.
- Wind power capacity was 36,625 MW as of 31 March 2019, making India the fourth-largest wind power producer in the world.

Contd…

- The country has a strong manufacturing base in wind power with 20 manufactures of 53 different wind turbine models of international quality up to 3 MW in size with exports to Europe, the United States and other countries.
- Wind or Solar PV paired with four-hour battery storage systems is already cost competitive, without subsidy, as a source of dispatchable generation compared with new coal and new gas plants in India.
- The government target of installing 20 GW of solar power by 2022 was achieved four years ahead of schedule in January 2018, through both solar parks as well as roof-top solar panels.
- India has set a new target of achieving 100 GW of solar power by 2022.

- Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). India was the first country in the world to set up a ministry of non-conventional energy resources, in the early 1980s.
- Solar Energy Corporation of India is responsible for the development of solar energy industry in India.
- Hydroelectricity is administered separately by the Ministry of Power and not included in MNRE targets.
- In the 2027 forecasts, India aims to have a renewable energy installed capacity of 275 GW,
- In addition to 72 GW of hydro-energy, 15 GW of nuclear energy and nearly 100 GW from ”other zero

5(a)List the factors affecting Energy Resource Development.

Factors affecting Energy Resource Development

- Energy or Fuel Substitution or Scale of Shift
  - Substitute for fossil fuels at requisite scale is not available.
- Energy Density
  - The amount of energy contained in a unit of material object (energy resource) is termed as energy density.
  - Air-dry crop residue (mostly straw and agricultural waste) contain only 12–15 MJ/kg.
  - The energy density of good quality coal is twice as high (i.e., 25–30 MJ/ kg) as that of crude oil (i.e., 42–45 MJ/kg).
  - In order to obtain an equivalent output, replacement of a unit of fossil fuels with approximately 2 kg of phytomass will be needed to substitute solid biofuel.
  - The ratio would be about 1.5 times when substituting plant-derived ethanol for petrol.
  - These realities would be reflected in the reserve capacity, cost, and operation of the required infrastructure.

Cont d...

- Power Density
  - Power density refers to the rate of energy production per unit of earth's area.
  - Expressed in watts per square meters (w/m^2).
  - Owing to lengthy period of formation (from biomass to coal and then from coal to hydrocarbons), fossil fuel deposits are an extraordinarily concentrated source of high quality energy.
  - They are commonly produced with power densities of 10^2 or 10^3 w/m^2.
  - small land areas are required to supply enormous energy
  - Biomass Energy production has densities below 1 w/m^2, while density of electricity produced by water and wind is below 10 w/m^2.
  - Photovoltaic electricity generation can deliver larger than 20 w/m^2.
  - The cost and performance are the constraints of mass utilization.

Cont d...

- Intermittency
  - Growing demand for fuels, energy, and electricity fluctuates daily and seasonally in modern civilization.
  - Further, the base load, which is defined as the minimum energy required meeting the demand of the day, has been increasing.
  - Easily storable high-energy density fossil fuels and thermal electricity generating stations that are capable of operating with high load factors meet these needs.
  - On the other hand, wind and direct solar radiation are intermittent and far from practicable. They can never deliver such high load factors.
  - Photovoltaic electric generation is still so negligible to offer any meaningful averages.
  - The annual load factors of wind generation in countries with relatively large capacities are 20%-25%.
  - Unfortunately, we still lack the means for storing wind or solar-generated electricity on a large scale.

Cont d...

- Geographical Energy Distribution
  - There are uneven distributions of fossil fuels and the non-fossil fuels (solar, wind, etc.).
  - Cloudiness in the equatorial zone reduces direct solar radiation.
  - Whole stretches of continent has insufficient wind.
  - There are very few sites with the best potential for geothermal, tidal, or ocean energy conversions.

5(b)Find the solar altitude angle at 2 hour after local solar noon on 1st June 2012 for a city, which is located at 26.75°N latitude.

- Declination angle $\delta = 23.45 \sin [360 (284+n) / 365]$
- $n = 31+29+31+30+31+1 = 153$
- $\delta = 22.17°$
- The hour angle $\omega = (1/4)\, t_m = (1/4)\, 120 = 30°$
- Solar Altitude Angle α
- Zenith angle $\Theta_z = 90° - \alpha$
- $\cos \Theta_z = \cos (90° - \alpha) = \sin \alpha$
- $\sin \alpha = \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta$
- $= \cos 26.75° \cos 22.17° \cos 30° + \sin 26.75° \sin 22.17°$
- $\sin \alpha = 0.88265$
- $\alpha = 62.4°$ (approx)

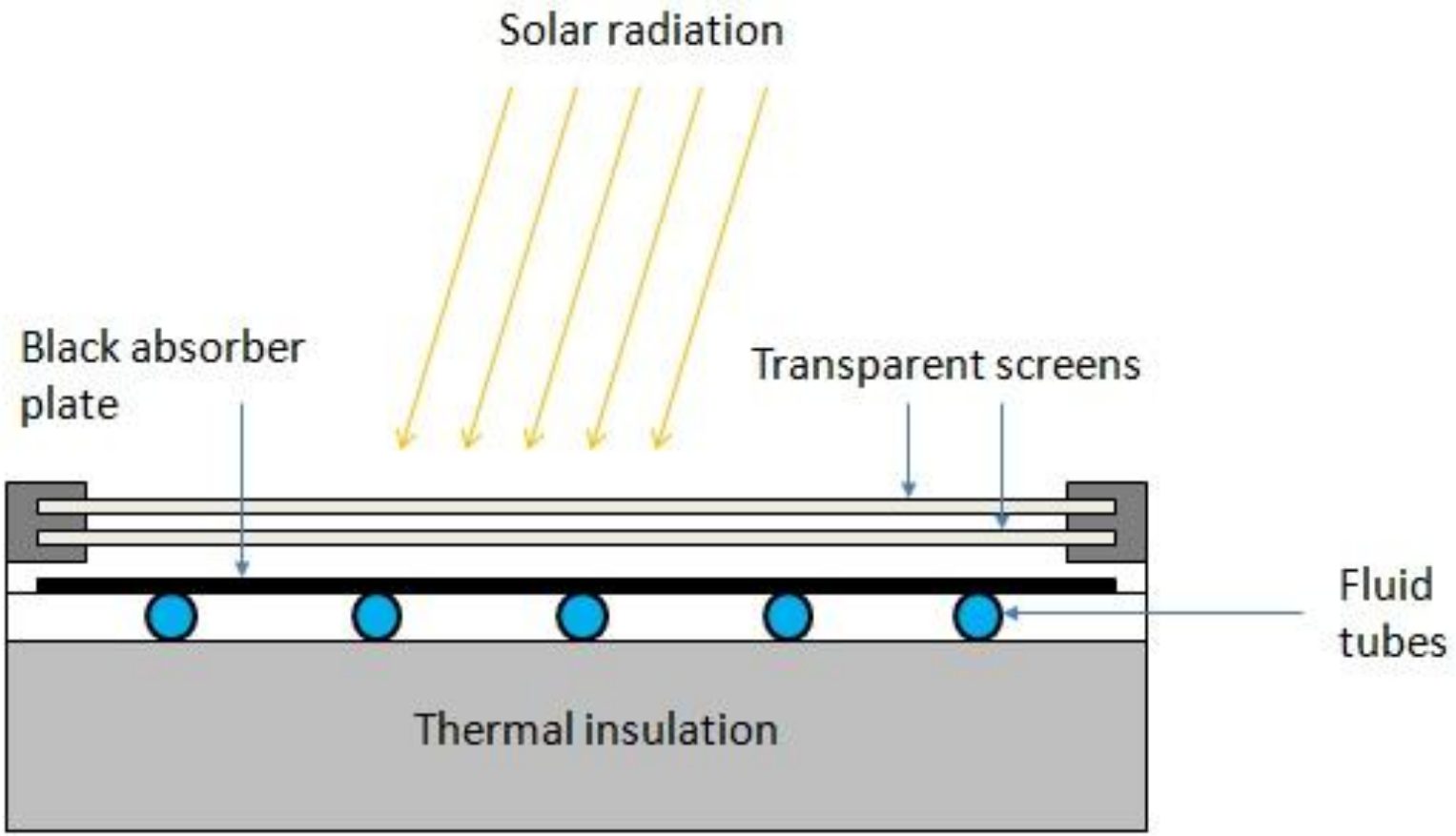
6. Explain in brief the types of solar collectors with the help of relevant diagram.

Types of Solar Collectors

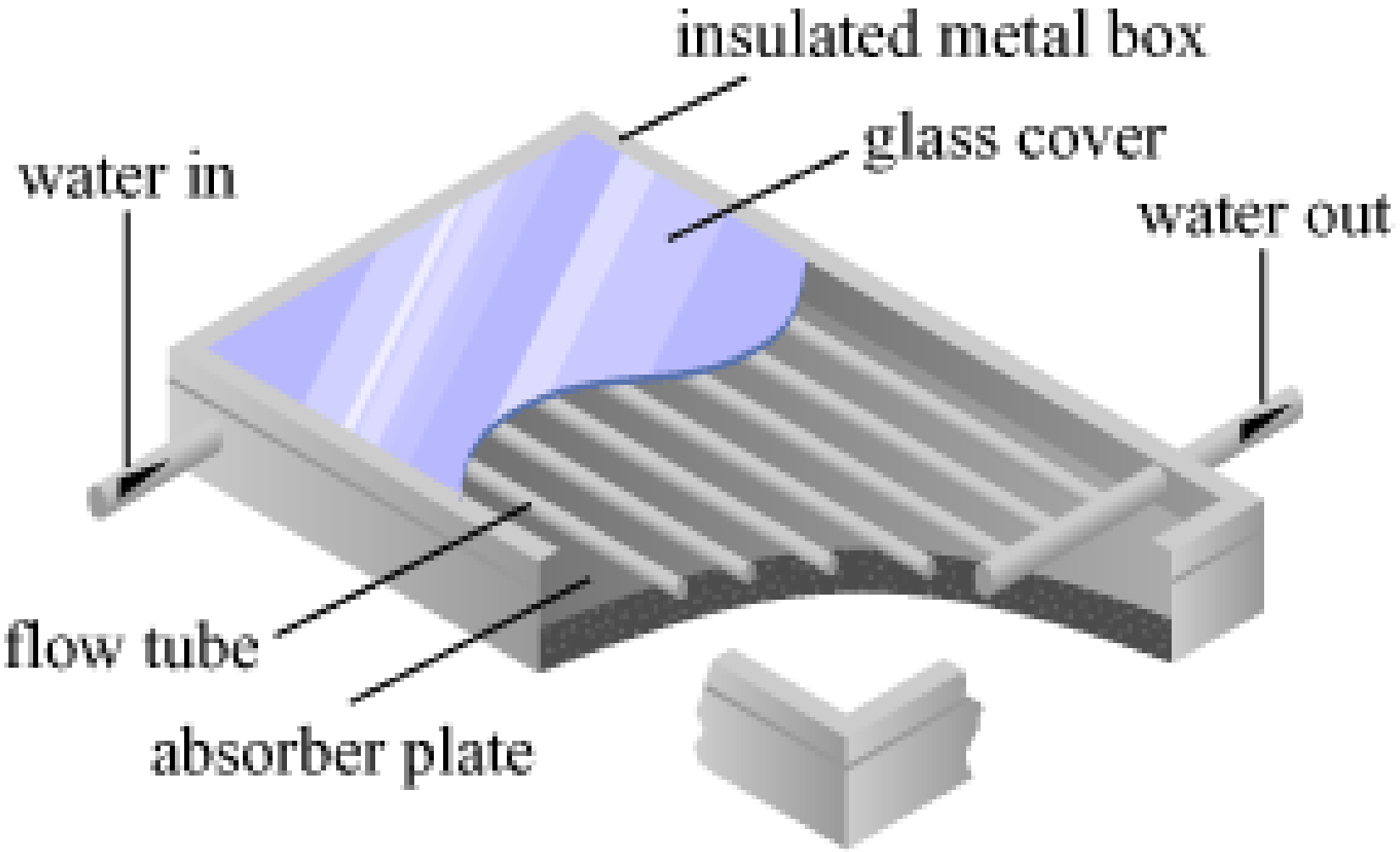
- Flat Plate Collectors
  - Flat air plate collectors
  - Flat plate liquid collectors
- Concentrating Collectors
  - Stationary concentrating collectors
  - Tracking concentrating collectors

Flat Plate Collectors

- Referred to as the non concentrating type
- Same area for intercepting and absorbing solar radiation



Flat Plate Collector

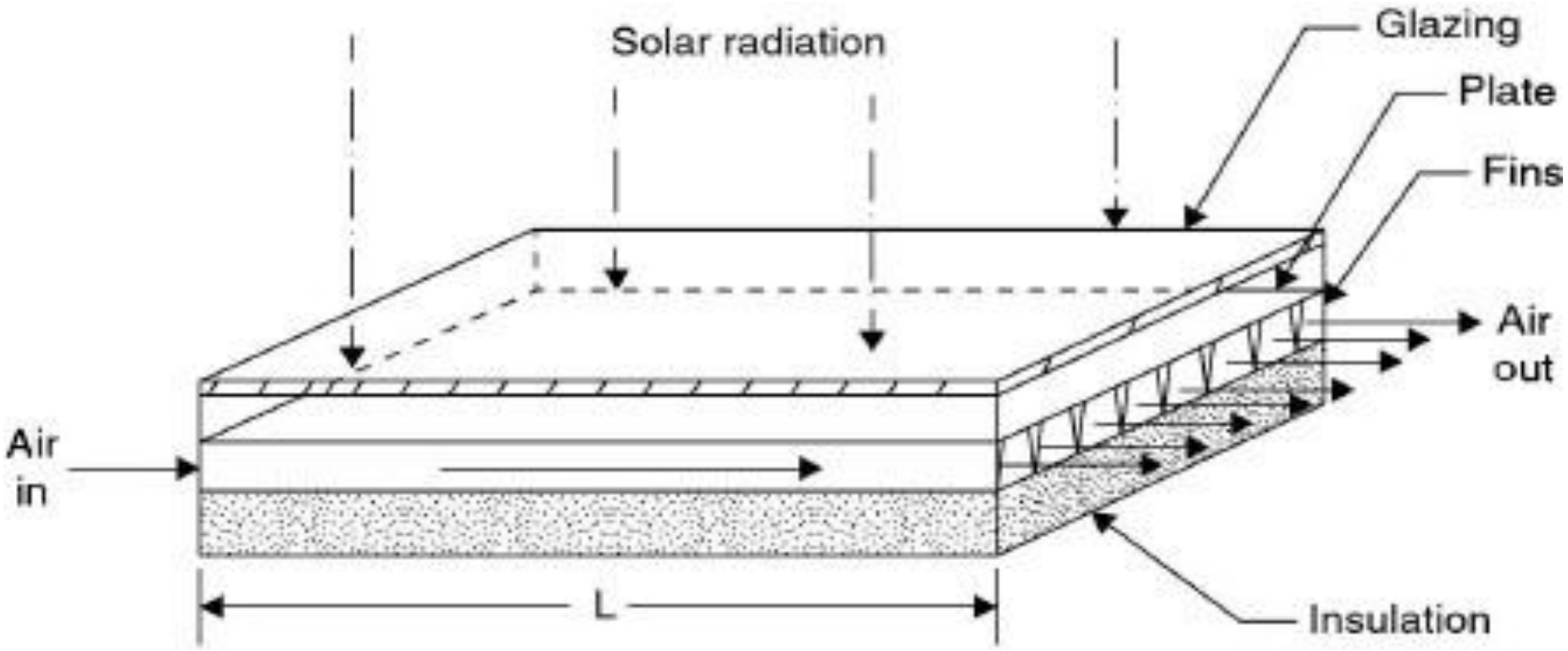


Flat Plate Collector

- Dark flat Plate Absorber of Solar energy
- ---consists of thin absorber sheet of thermally stable materials such as Al,Cu,steel,etc..
- Transparent Cover
- ---allows solar energy to pass through, but reduces heat losses
- ---reduces covection and radiation losses from
- absorber plate
- Heat Transport Fluid
- --air,water or antifreeze
- --To remove heat from absorber, fluid is usually circulated through tubing to transfer heat from absorber to an insulating tank
- Heat Insulation Backing
- Insulated casing of glass or polycarbonate cover

Flat Plate Air Collector

- Air is the transport medium
- Air flows past the absorber by natural covection or by blowers
- Less efficient than liquid type as air does not conduct heat as easily as liquid



Flat Plate Liquid Collector

- Liquid is the heat transfer medium
- Liquid gets heated as it passes through the tubes in or adjacent to the plates

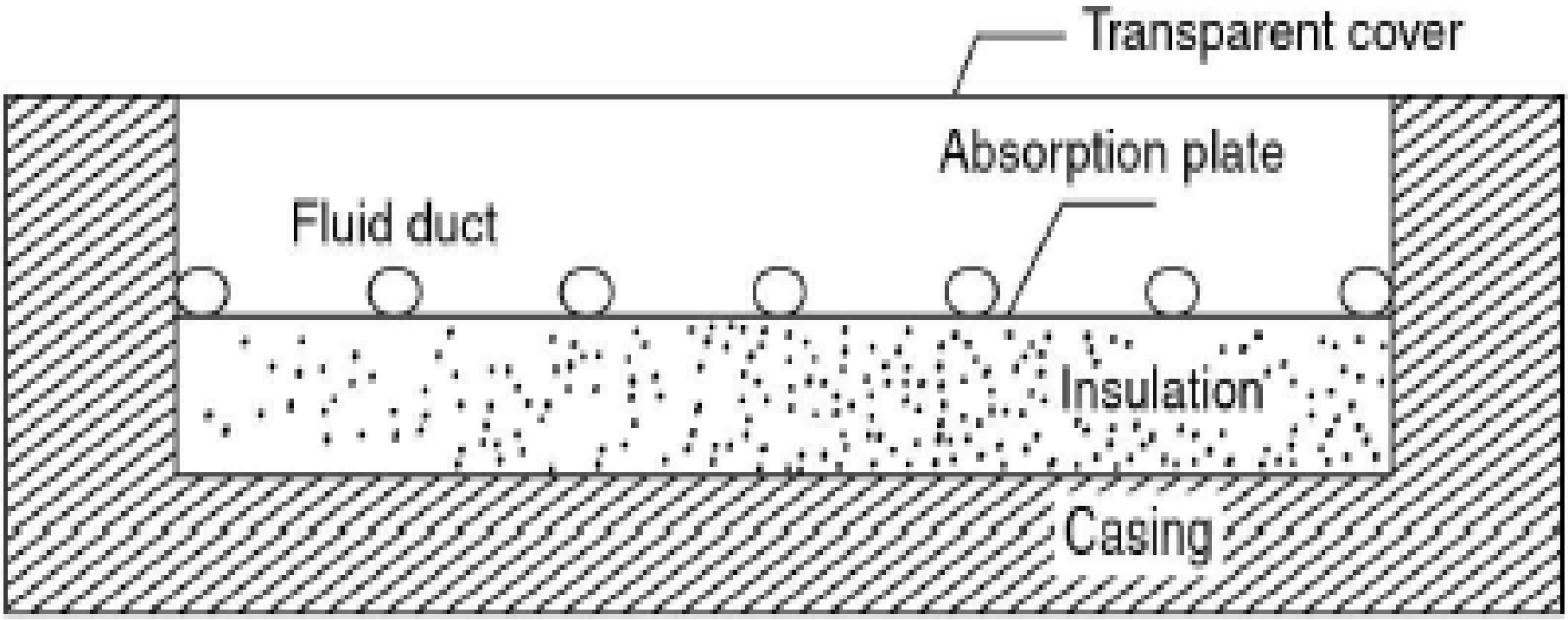
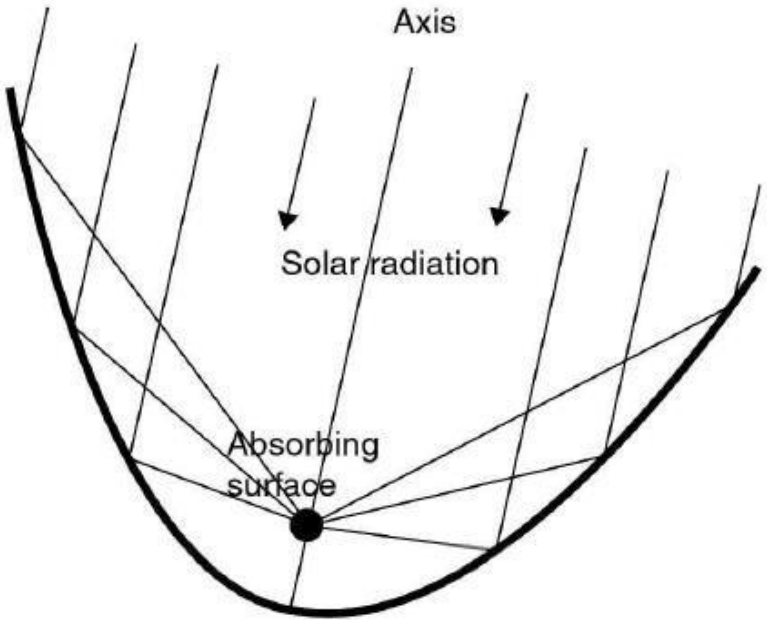


Figure 3.3 Flat plate liquid collectors

Concentrating collectors

- Uses reflectors to concentrate sunlight
- Reduces the size of absorber
- Reduce heat losses
- Increases efficiency at high temperature
- Used for high temperature applications such as steam production for electricity
- Best suited for climates that have abundance of clear sky days

Example:Parabolic reflector



Concentrating Collectors

- Stationary concentrating collectors
- Operated in stationary mode
- Uses compound parabolic reflector & flat reflectors for directing solar energy to an accompanying absorber or operate through a wide acceptance angle
- Wide acceptance angle eliminates the need for sun tracing
- Tracking Concentrating Collector
- Heliostats are tracking mirrors that reflect solar energy on to a fixed point

7. Explain in brief the configurations of Practical solar thermal collectors with the help of neat diagram.

Collector Configurations

- Flat Plate Collector
- ---Liquid Flat plate
- ---Air Flat plate
- Commonly used configurations are

1. Glazed flat Plate
2. Unglazed flat plate
3. Unglazed perforated flat plate
4. Back Pass flat plate
5. Batch Flat Plate
6. Solar Cooker
7. Evacuated Flat Plate
8. Concentrating

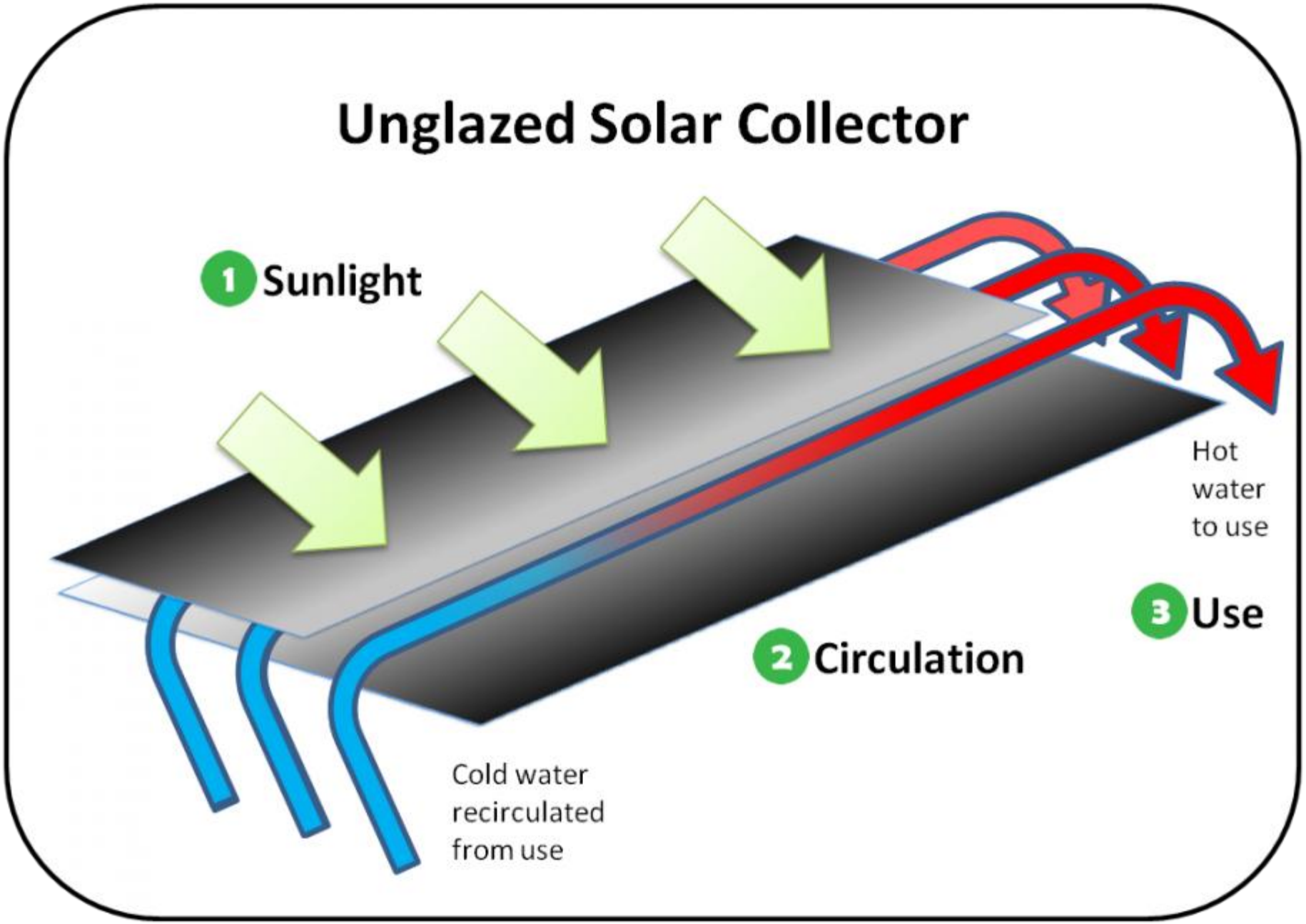
Glazed flat plate collector

- Commonly available as liquid or air based collectors
- Suited for moderate temperature
- 30-70 degree Celcius Used for
- ---Domestic and commercial building
- ---water heating
- ---Indoor swimming Pool

Unglazed Flat Plate Collector

- Suited for low temperature applications below 30 degree celcius
- Made of black plastic which can withstand ultraviolet rays
- Since no glazing is provided, it can absorb more heat
- But losses are also more
- They transfer heat so well to air so that they can even capture heat from air even at night
- Used for heating outdoor pools, fish farming, pre heating water for car washes, etc..

Unglazed Flat Plate Collector

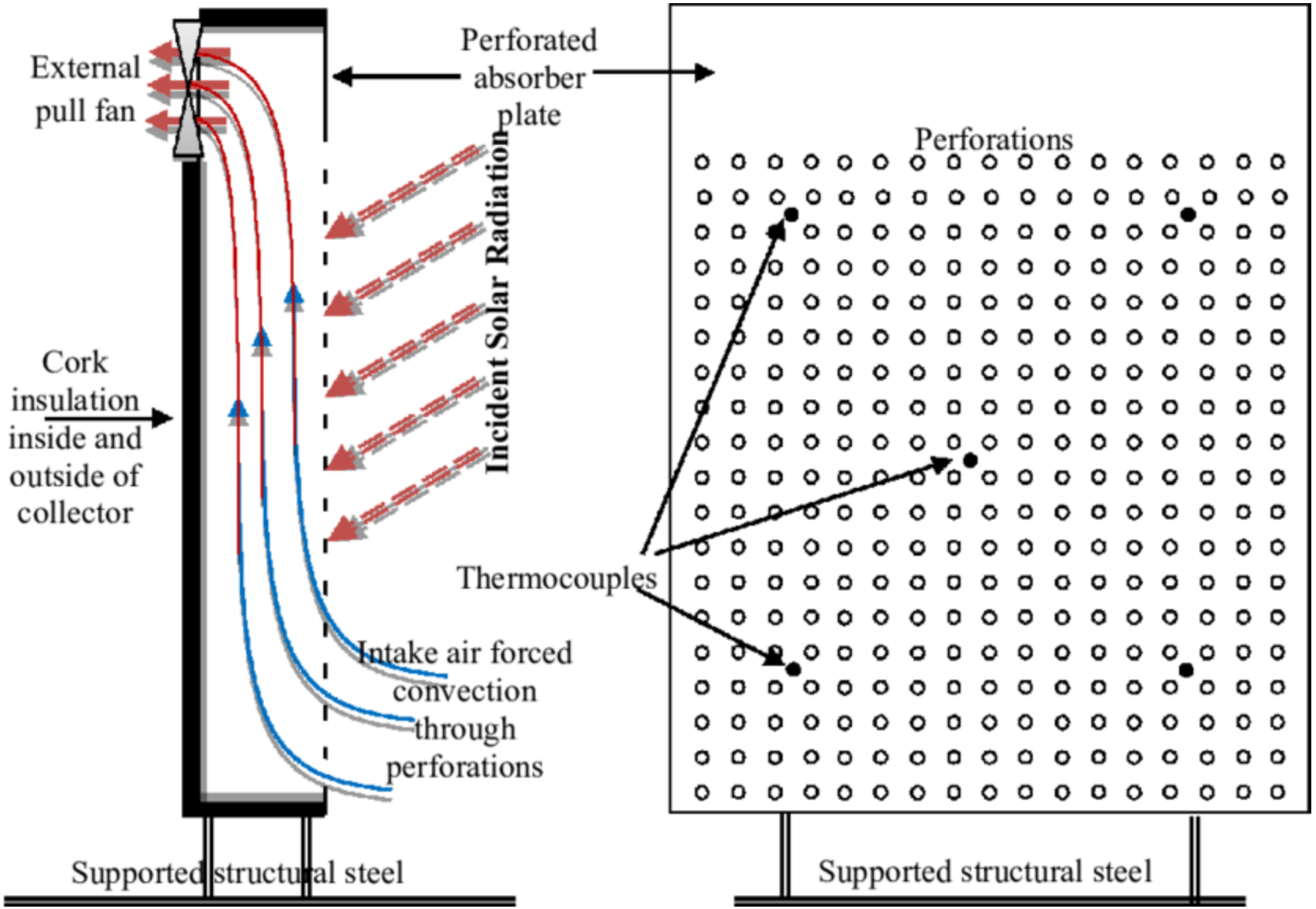


Solar Pool Heating

Unglazed Perforated Flat plate collector

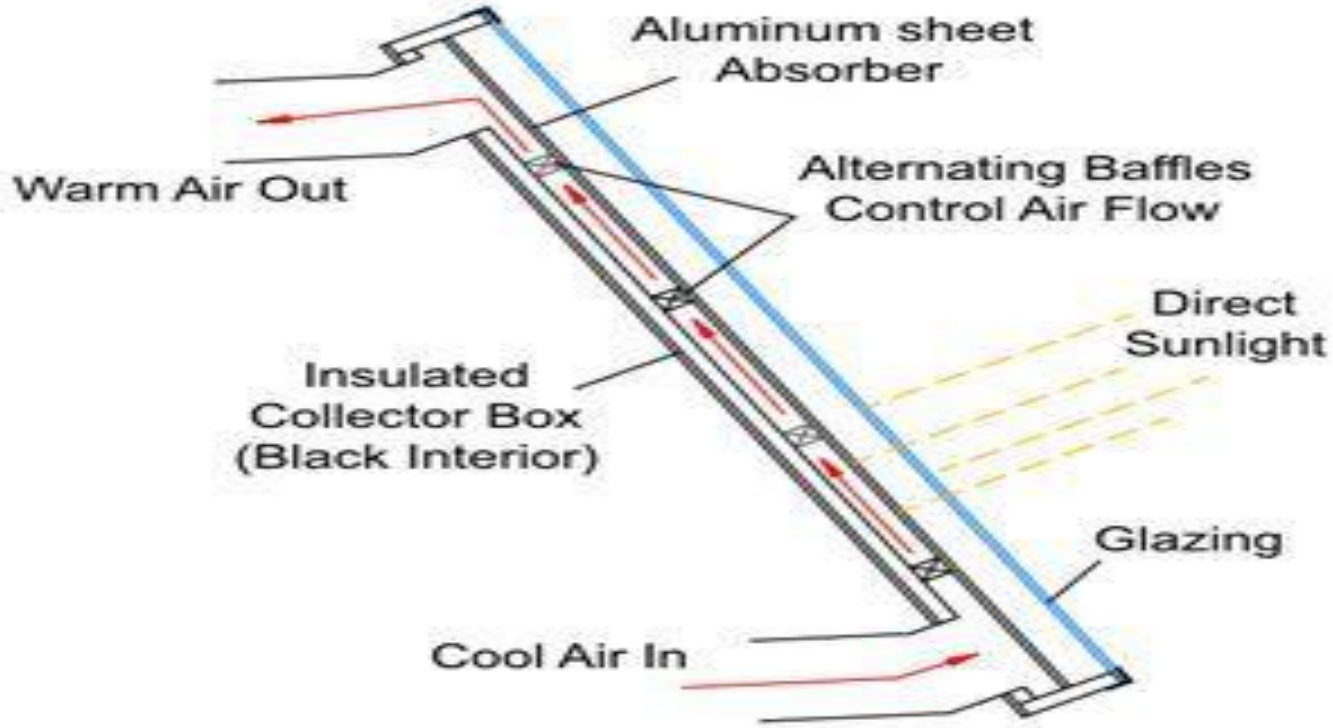
- Industrial grade siding or cladding having perforated small holes at a pitch of 2-5 cm
- Mainly used for heating of buildings
- Air is passed through the collector before it is drawn into the building to provide preheated fresh ventilation air
- Highly efficient and cost effective solution

Unglazed Perforated Flat plate collector



Back Pass Solar Collector

- A large solar absorber is used to heat air
- Collectors that are coated with glaze can also be used to heat air for space heating



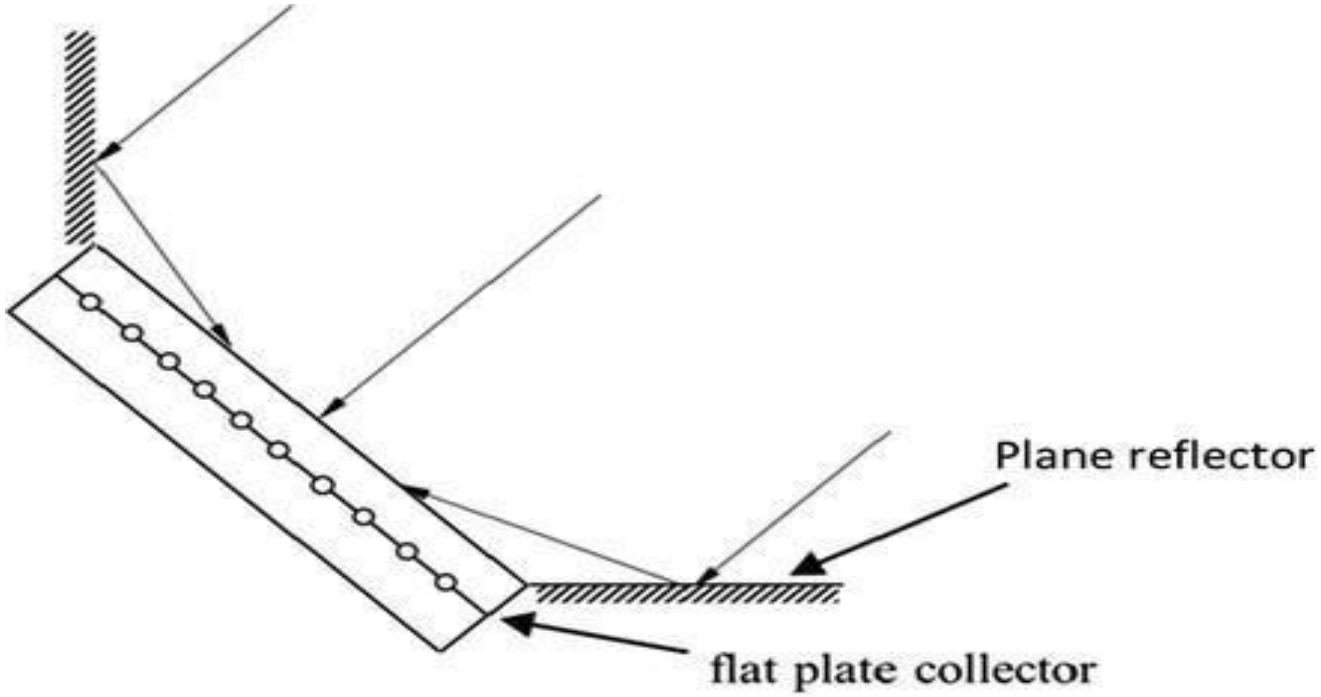
Back-pass Solar Air Collector

Batch Flat Plate Solar Thermal Collectors

- Primarily used for residential water heating
- Earlier, black painted water tanks exposed to sun were used
- Storage tank and solar absorber act as single unit
- Modern batch collectors have a glazing to concentrate solar energy on tank surface

Flat Plate Collector with Flat Reflectors

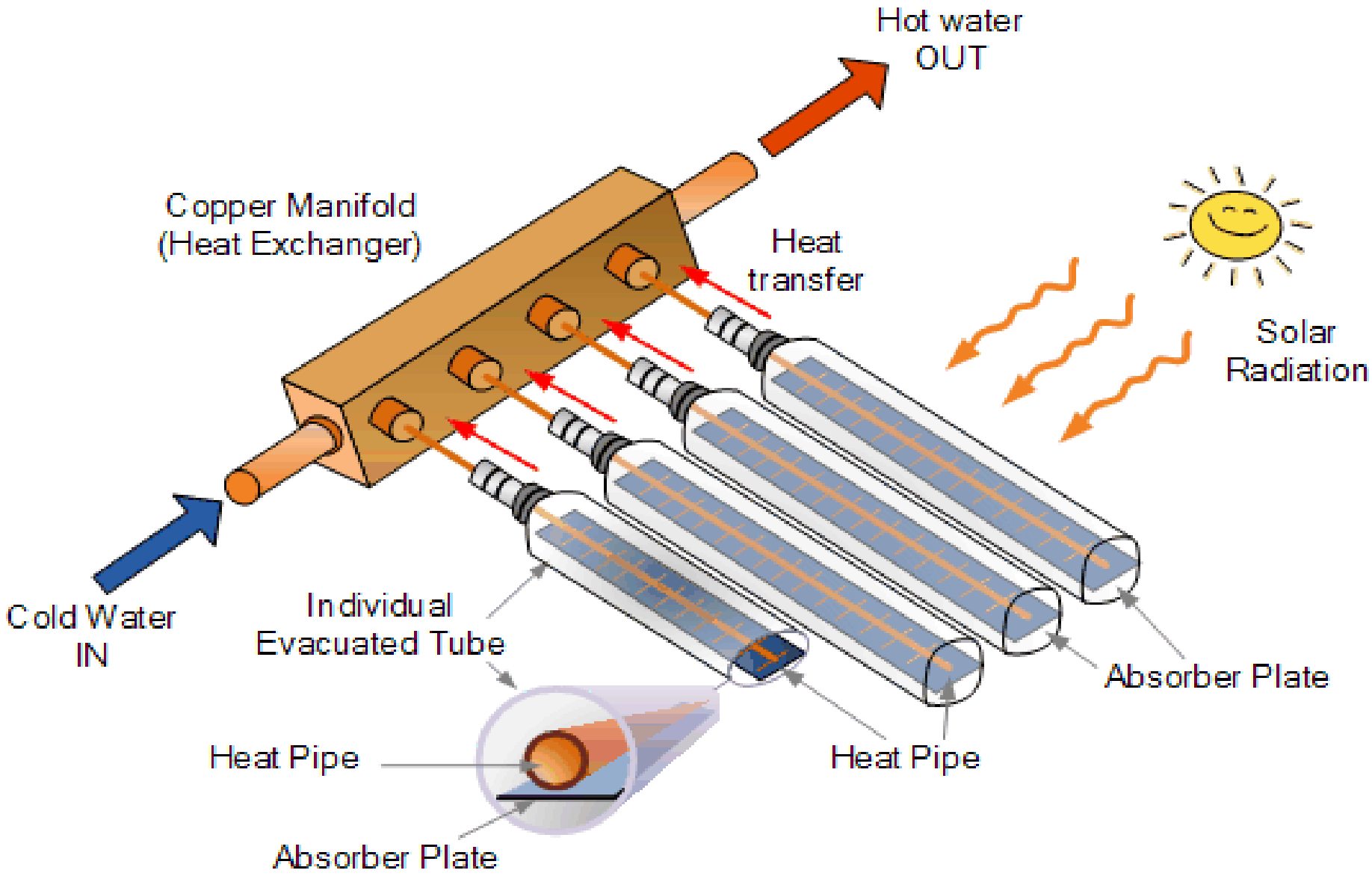
- Addition of a reflector increases solar yield on the collector and the overall performance of the collector
- Enhancement in solar yield is about 44% in winter and 15% in summer



Evacuated tube collector

- Conventional flat plate collectors will be less efficient during cloudy, or cold weather conditions
- Weather influences such as condensation and moisture will deteriorate internal materials resulting in system failure
- Evacuated tube collector will operate in a different manner which makes it suitable for adverse weather conditions as well
- Can achieve high temperatures(75 to 180 degree Celcius)
- Suitable for industrial and commercial applications
- Highly efficient with low thermal losses

Evacuated tube collector



Schematic Evacuated tube solar collectors