RES (18EE653)

IAT-2-Solution

- 1. With a neat schematic diagram, Explain the working of Stirling Engine. (CO3, L1)

Parabolic Dish Stirling Engine System (5M)

- The major Components are

1. Solar dish Concentrator
2. Power Conversion Unit
3. Tracking System

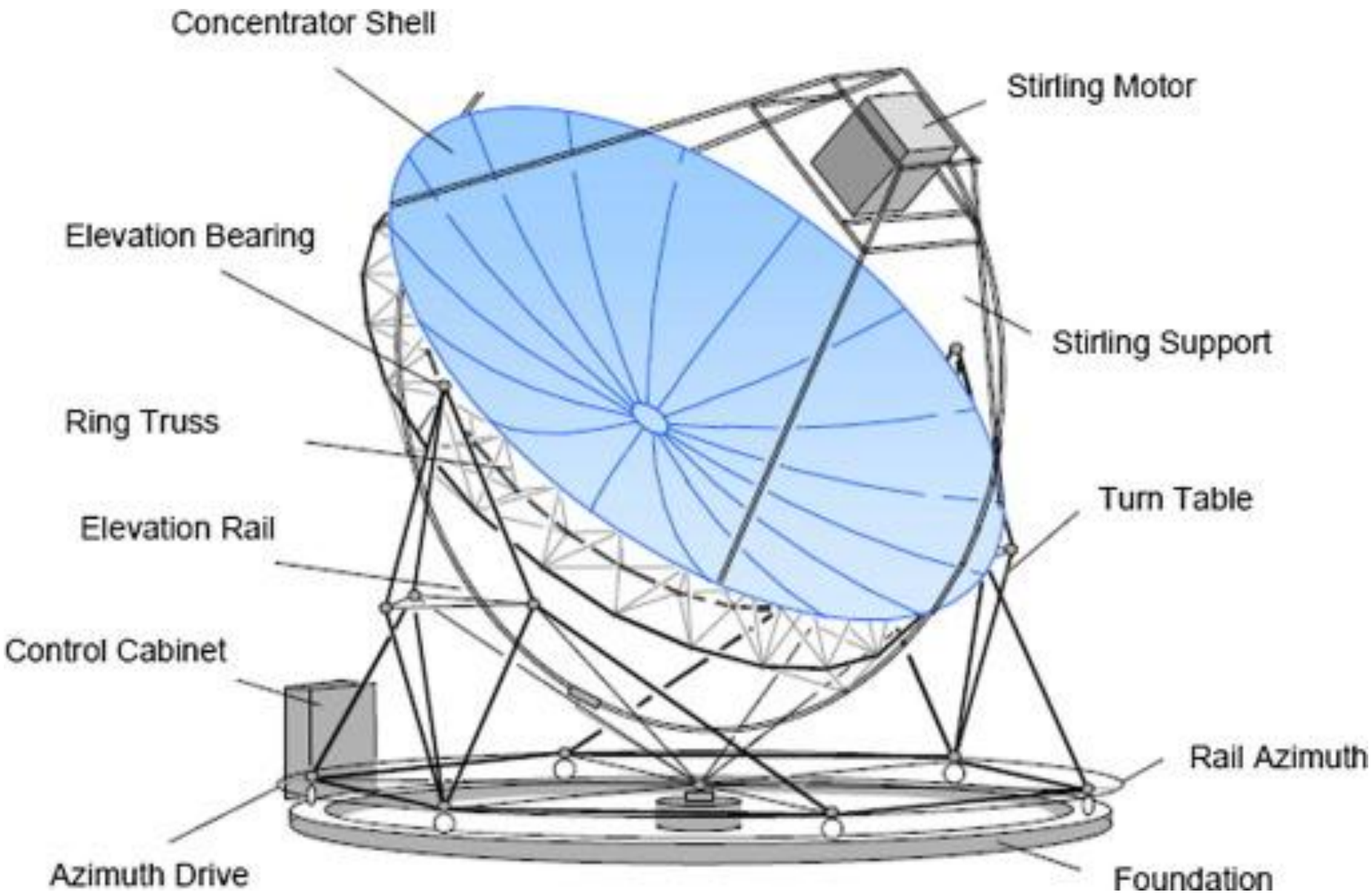
- Power Conversion Unit
- Includes thermal receiver and the heat engine
- Thermal receiver absorbs the concentrated beam of solar energy, converts it to heat and transfers the heat to heat engine
- Heat engine takes heat from the thermal receiver and uses it to produce electricity
- Heat engines use fluids such as Hydrogen and Helium for their working

- The Engine Generator components are

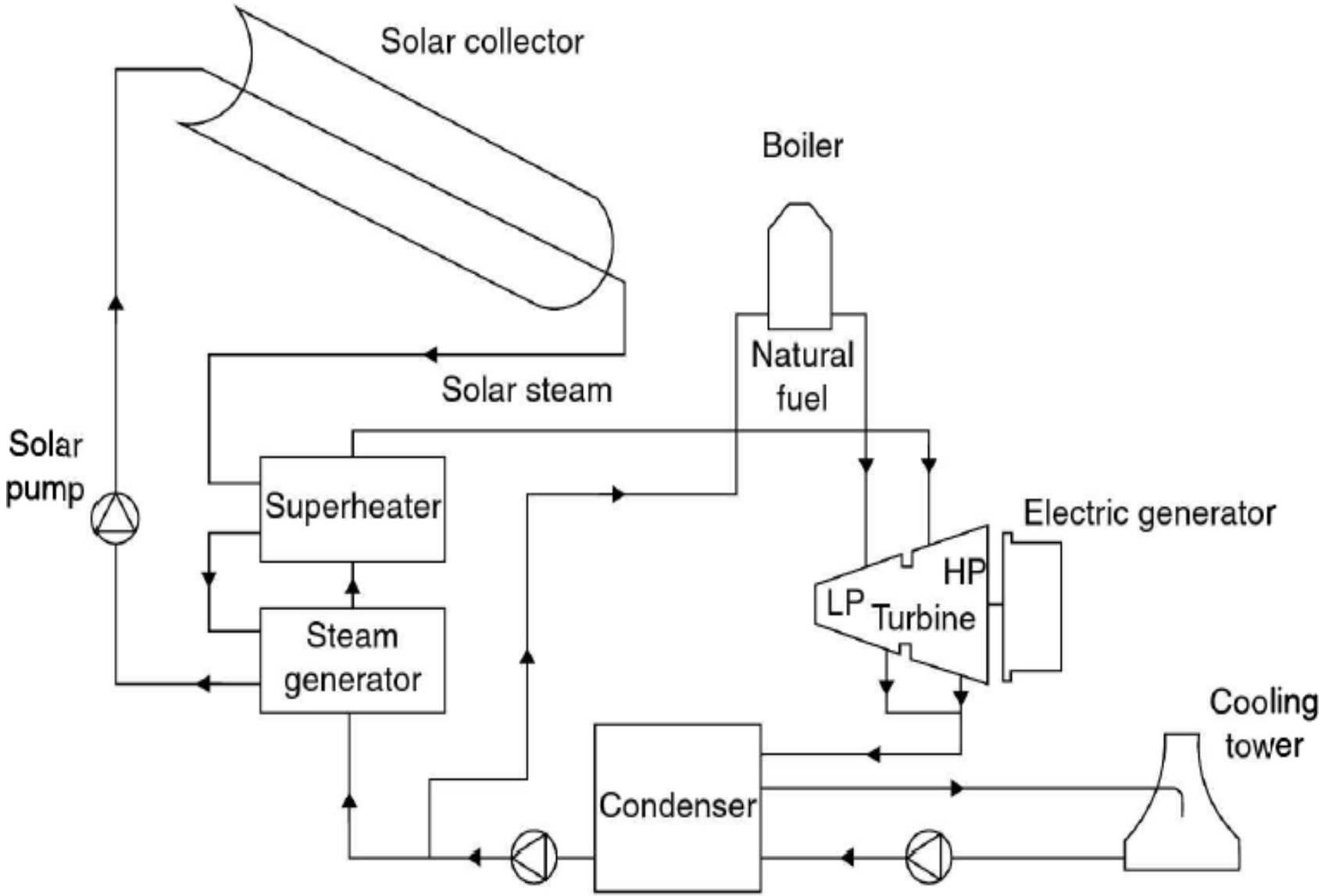
1. A receiver to absorb the concentrated sunlight to heat the working fluid of the engine
2. The engine itselfwhich converts the thermal energy into mechanical work
3. An alternator attached to generate electricity
4. A waste heat Exhaust System
5. A control system to match the engine operation with the available solar energy

- Stirling Engine is the most common type used
- The parabolic dish heat engine system lacks thermal storage capabilities
- It can be hybridised to run on fossil fuels during periods without sunshine
- Tracking System
- Computers are used to track the sun for maximum output

Parabolic Dish Stirling Engine System (3M)

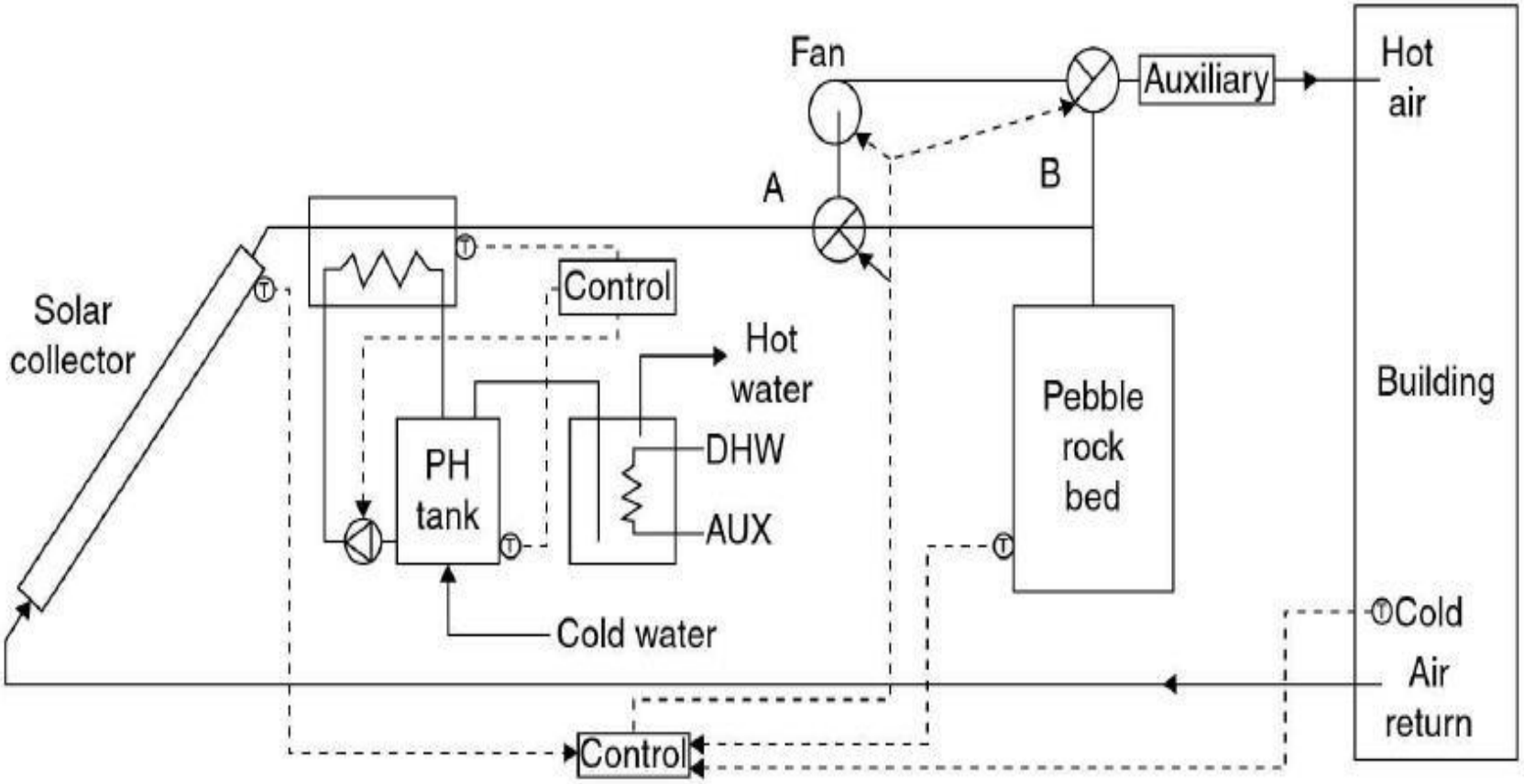


Working of Stirling or Brayton Heat Engine (2M)



2. a. Write short notes on solar Air heating. (CO3, L2)

Solar Air Heating Systems



Schematic of solar air heating system

- Depending on position of Dampers there are 3 modes of operation
- Damper A & B open:
- Normal day time solar heating mode.
- The storage unit is bypassed.
- If the temperature is below a limit ass measured by sensor place in the top of collector, auxillary furnace is turned on automatically
- Damper A open, B closed:
- This mode is used when solar energy is collected ,but no heating is required
- It gets collected in the rock bed(heat storage)
- Damper A closed ,B open:
- Used for cloudy periods or at night
- The return air from the building is passed through rock bed, where it picks up solar heat
- If temperature is insufficient, auxillary furnace is activated

2. b. Give notes on Solar Cookers. (CO3, L3)

Solar Cookers

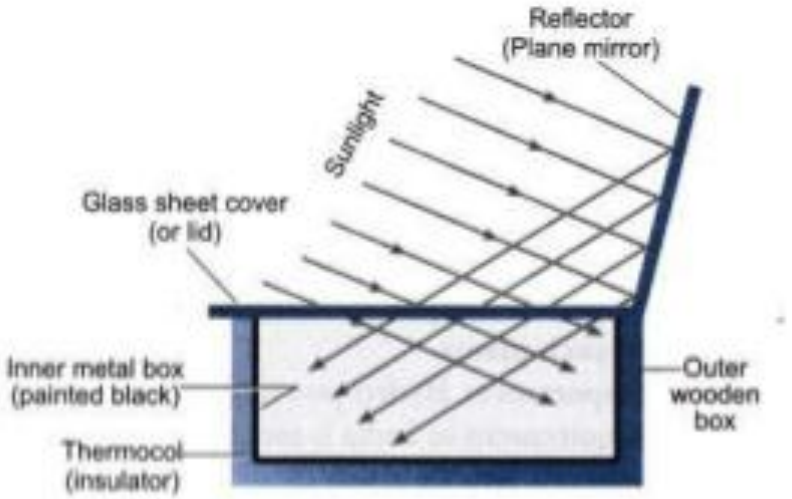
- Basic principles are

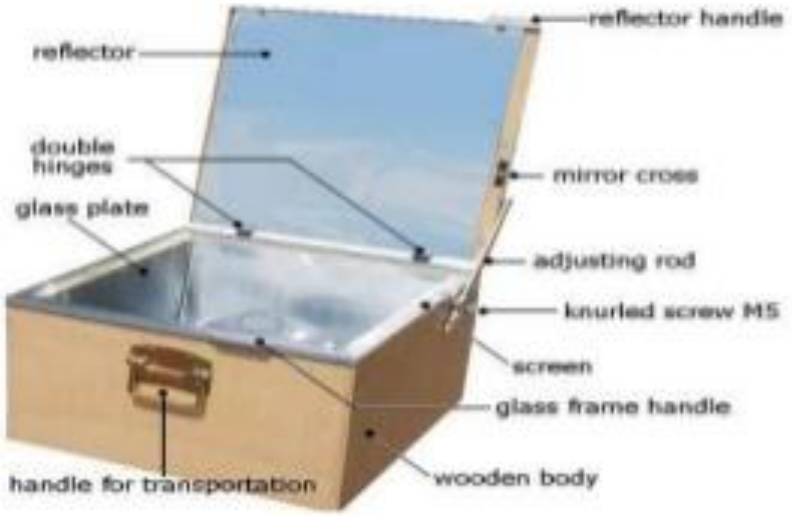
1. Concentrating Sunlight
2. Converting light to heat
3. Trapping the heat
4. Green House effect

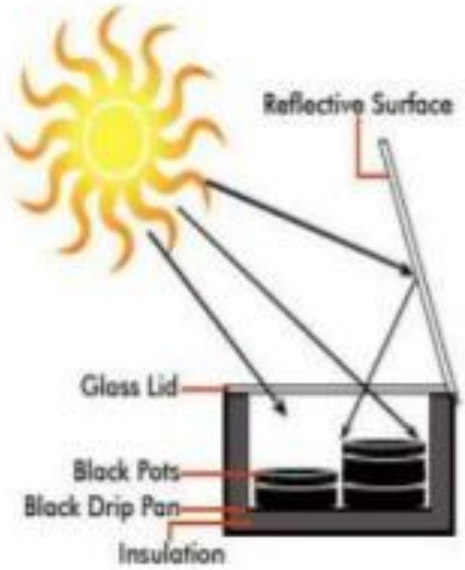
- Types

1. Box Type
2. Reflector Cookers
3. Solar steam and Convection Cooker

Box Type Solar Cooker







A box-type solar cooker consists of the following components:

- **Black Box** – The box is an insulated metal or wooden box which is painted black from the inside to absorb more heat.
- **Glass Cover** – A cover made two sheets of toughened glass held together in an aluminium frame is used as a cove for box B.
- **Plane Mirror reflector** – The plane mirror reflector is fixed to the box B with the help of hinges. The mirror reflector can be positioned at any desired angle to the box. The mirror is positioned so as to allow the reflected sunlight to fall on the glass cover of the box.
- **Cooking Containers** – A set of aluminium containers blackened from the outside are kept in box B.
- The solar cooker placed in sunlight and a plane mirror reflector is adjusted in a way such that the strong beam of sunlight enters the box through the glass sheet. The blackened metal surfaces in the wooden box absorb infra-red radiations from the beam of sunlight and heat produced raises the temperature of a blackened metal surface to about 100°C.

3.a. Explain about efficiency of solar cells and Fill factor. (CO3, L1)

Solar Array Parameters

FF = fill factor – The fill factor is the relationship between the maximum power that the array can actually provide under normal operating conditions and the product of the open-circuit voltage multiplied by the short-circuit current, (V_{OC} x I_{SC}) This fill factor value gives an idea of the quality of the array and the closer the fill factor is to 1 (unity), the more power the array can provide. Typical values are between 0.7 and 0.8.

%eff = percent efficiency – The efficiency of a photovoltaic array is the ratio between the maximum electrical power that the array can produce compared to the amount of solar irradiance hitting the array. The efficiency of a typical solar array is normally low at around 10-12%, depending on the type of cells (monocrystalline, polycrystalline, amorphous or thin film) being used.

Q.3b:

A certain 120V, 60Hz AC motor is to be powered by solar cell array during the day and at night , by a 120V public utility. A DC to DC converter is available that changes the array DC output into a 120V, 60Hz AC with 90% efficiency independent of load phase angle , while running motor has a DC resistance of 300Ω and an inductance of 0.3H. How much power output must the array provide.

Inductive reactance of AC motor, $X = X_L = 2\pi fL = 2\pi * 60 * 0.3 = 113\Omega$

$Z = R + jX_L = 300 + j113$

$|Z| = (300^2 + 113^2)^{1/2} = 320$

Motor current, $I = V/Z = 120/320 = 0.375A$

Power drawn by the motor $P_m = I^2R = (0.375)^2 * 300 = 42.2W$

The array output power = input power of motor = P_m/η_m = 42.2 / 0.9 = 46.9 W

4.a. With a neat schematic diagram, Explain the working of solar water heating systems. (CO3, L3)

Solar Water Heating Systems

- Two main parts

1. Solar Collector
2. Storage tank

- Types
- 1.Active systems
- Rely on pumps to move the fluid between the collector & storage tank

2.Passive System

- Rely on Gravity and tendency for water to naturally circulate as it is heated

Active solar water heating systems

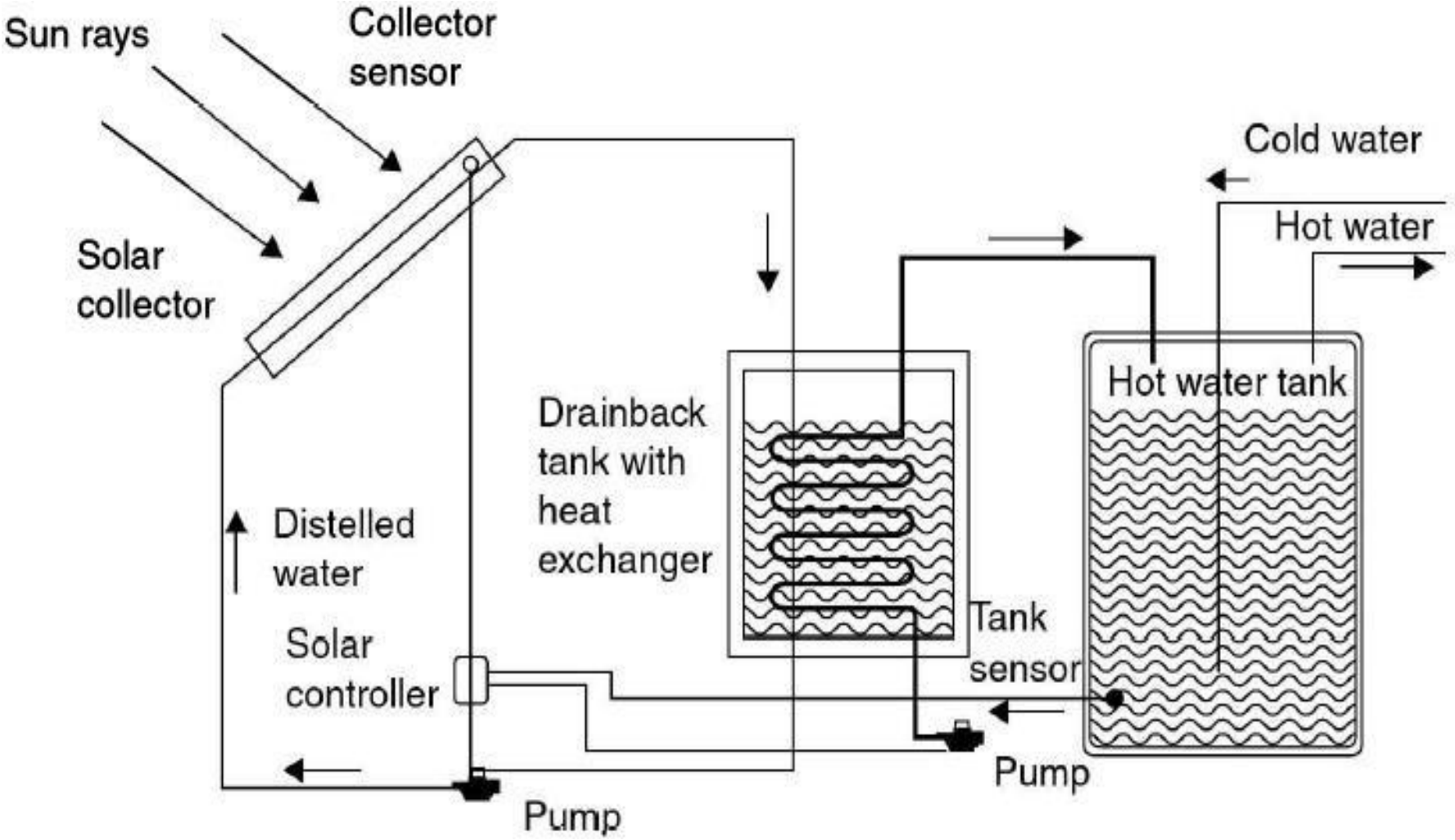
- It can be for

  Water heating

  Space Heating
- Parts of Water Heating Systems

1. Collectors
2. Circulation System
3. Storage tank
4. Backup Heating System
5. Control System

Active solar water heating systems



4.b. Discuss about different solar cell materials. (CO3, L1)

Solar Cell Materials

- Silicon
- Mono crystalline or single crystal Silicon
- Multi crystalline Silicon
- Poly crystalline Silicon
- Amorphous Silicon
- Thin Film
- A few micro meters thickness

5.a. Explain Electrolytic production techniques used to produce Hydrogen energy. (CO4, L1)

Hydrogen production technologies

- **Thermochemical** production technologies
- **Electrolytic** production technologies
- **Photolytic** production technologies

1. Thermochemical production technologies

1. **Steam reforming**

- Methane or methanol reacts with steam over nickel alumina
  - $CH_4 + H_2O + 206kJ/kg = CO + 3H_2$
- Carbon monoxide reacts with water
  - $CO + H_2O = CO_2 + H_2 + 41\ kJ/kg$

Total reaction

$$CH_4 + 2H_2O + 165\ kJ/kg = CO_2 + 4H_2$$

Natural gas 48%
Oil 30%
Coal 18%
Electrolysis 4%

1. Thermochemical production technologies

2. **Partial oxidation** or **ceramic membrane reactor**
   - Natural gas and oxygen at high pressure
   - Carbon and oxygen ratio has to be maintained to avoid soot formation
   - The carbon dioxide formed can be removed by providing oxygen and also purifies hydrogen
   - Catalytic partial oxidation reaction
     - $CH_4 + \frac{1}{2}O_2 = CO + 2H_2$
     - This is exothermic reaction
     - Reduced size and capital cost
     - Less efficient than steam reforming

1. Thermochemical production technologies

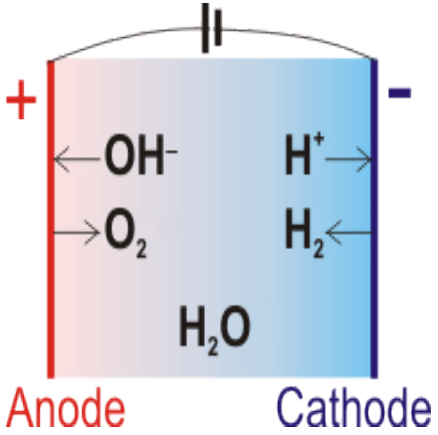
3. **Biomass gasification** or **pyrolysis**

plant material or fossil fuels

- Organic material at high temperatures
- Burning of wood
- Liquid product bio oil is produced

2. **Electrolytic** production technologies

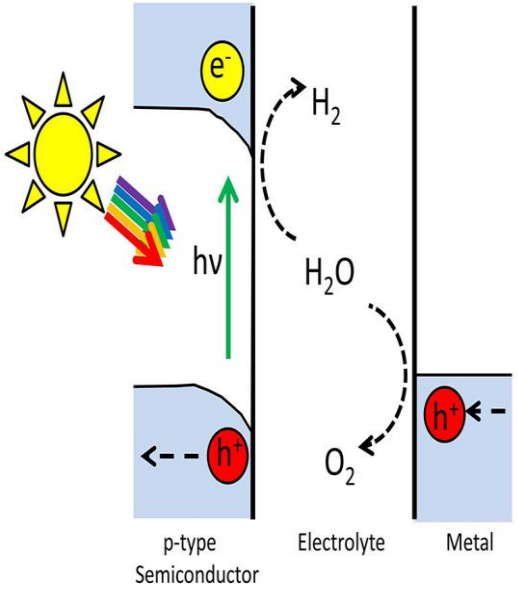
- Water is separated into hydrogen and oxygen by passing electric current through them
- Catalyst is added to improve the efficiency of the process
- Anode attracts oxygen cathode attracts hydrogen
- **Two methods** of electrolysis
- **Alkaline** electrolyser
  - $4H_2O + 4e^- = 2H_2 + 4OH^-$
  - $4OH^- = O_2 + 2H_2O + 4e^-$
- **PEM** electrolyser
  - $4H^+ + 4e^- = 2H_2$
  - $2H_2O = O_2 + 4H^+ + 4e^-$



Types of **Electrolysis**

1. **Water** electrolysis: highly pure hydrogen and oxygen is produced. **PV** and **Wind** energy.
2. **Steam** electrolysis: at high temperatures of 2500^0C energy used is **heat** instead of electricity.
3. **Photo** electrolysis : Multi junction cell technology, sufficient voltage to split water, highly efficient. Using of a-Si increases efficiency.(7.8%)
4. **Thermochemical** Water splitting: Iodine or Bromine. (3 Steps and equations)
5. **By-products** of **Na** or **K** chloride electrolysis: Equations.
6. **Reversible** Fuel cells or **Electrolysers**:

Electrolysis



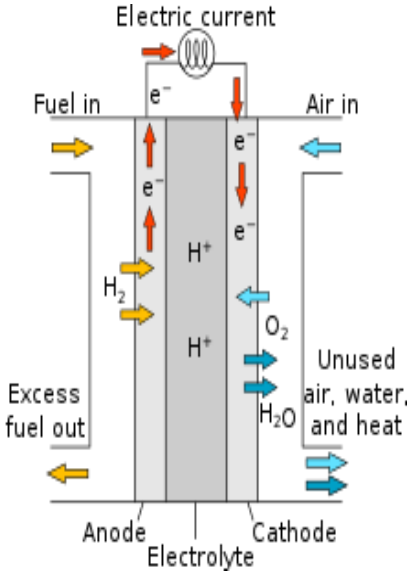


Photo electrolysis

Fuel cell

3. Photolytic production technologies

- Solar energy used directly to split water.

1. **Photo-electrochemical** Processes: 2 methods, **Soluble metal** (photosynthesis)

Semiconducting electrodes

serves **two** functions:

absorb solar energy, **electrode**

2. **Photo-Biological** Methods: algae, photosynthetic bacteria

reduce pollution

5.b. Discuss about the factors or guidelines for wind turbine site selection. (CO4, L1)

Considerations & guidelines

Factors to be considered

1. Hill effect – wind pressure increases as it reaches the hill top and increases speed

2. Roughness or amount of friction that earth's surface exerts on wind – Oceans have very little roughness, but city or forest has a great deal of roughness, which slows the wind.

3. Tunnel effect – high wind pressure and speed

4. Turbulence – It causes fluctuations in the wind speed and wear and tear on the turbine

5. **Variations in wind speed-** During day sun heats the air so the wind blow faster compared to night. Wind speed varies on Season as well.

6. Wake: the air coming out of the blade sweep has less energy because it has been slowed. The abrupt change in the speed makes the wind turbulent, a phenomenon called wake. Wind turbines in the wind forms are placed 3 rotor diameter away

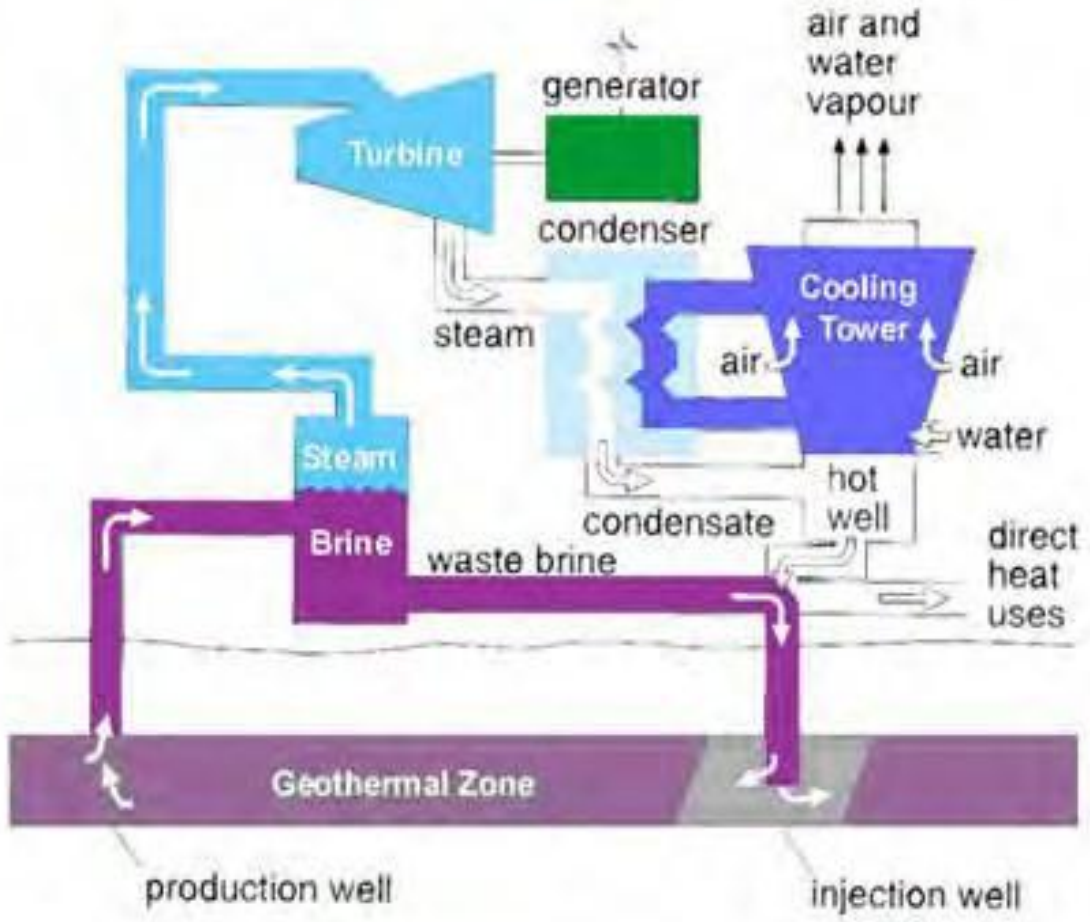
Guidelines

1. Turbines work good on high and exposed sites. costal sites are good.
2. Town and highly populated area
3. roof mounted turbines
4. Distance of caballing, more power loss in cables
5. Turbine height is twice obstacle distance
6. Speed of wind must be 4.5 m/s to produce electricity
7. Remote location sites are expensive as it is required to connect it with grid

6.a. Explain with the help of neat diagram, single flash geothermal electric power plant. (CO4, L2)

2.Flash Geothermal Power Plant

- use hot water above 182°C (360°F) from geo



- **The fluid is sprayed into a flash tank, which is held at a much lower pressure than**
  the fluid, causing it to vaporise (or flash) rapidly to steam.

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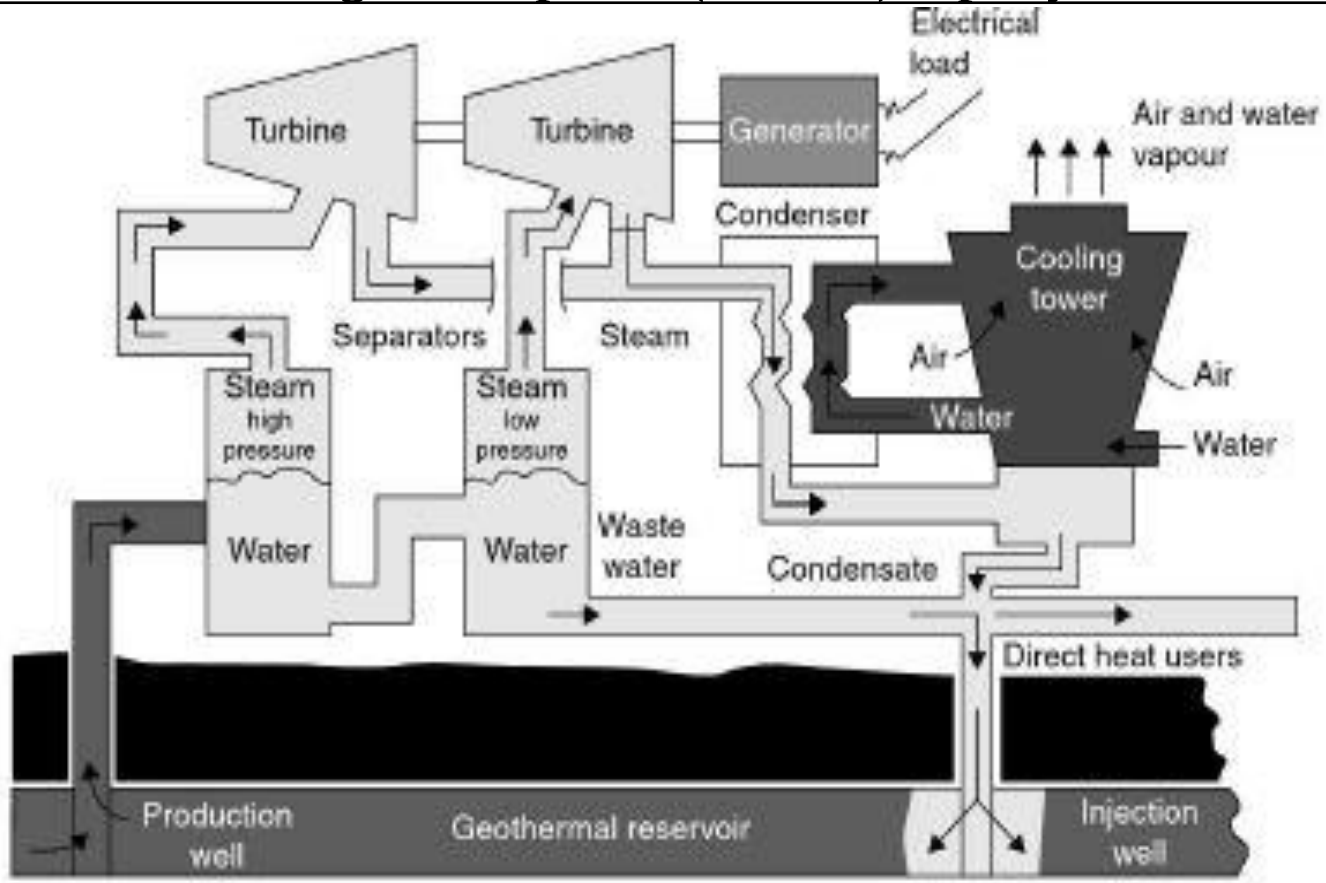


Double-flash geothermal steam-electric power plant

Flash geothermal plants

Advantages

- Safe and reliable
- Low emissions
- No fuel cost
- Sustainable
- Small footprint(space occupied)
- Immune to varying weather conditions
- Cost effective over life of plant

Disadvantages

- High Initial cost
- Increased risk of sesmic activity
- Over exploiting of resources
- Location sensitive

- 6. b. List the advantages and Disadvantages of Hydrogen energy. (CO4, L2)

Advantages of Hydrogen energy

- Storage is easy compared to storing of electricity
- Easily available
- Decentralized production, remote areas
- Efficient when used in fuel cell
- Safe energy(only for few applications)
- Environmental friendly

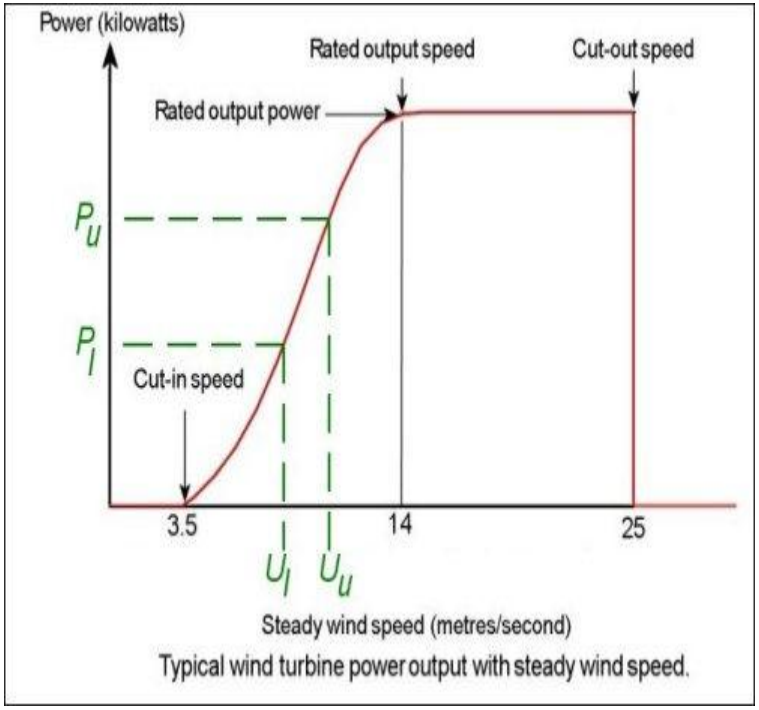
Disadvantages

- Overall efficiency of electricity production is less compared to fossil fuels
- High pressure and very low temperature requirement for storage
- Safety problems (Hindenburg syndrome & Apollo challenger space)
- No existing infrastructures for transportation distribution & storage
- High cost

- 7.a. Discuss about wind characteristics. (CO4, L2)

Wind speed characteristics

1. **Start up speed** – speed at which rotor begins to rotate
2. **Cut- in speed** – Speed at which machine begins to produce power
3. **Design wind speed**(efficiency) – speed at which windmill reaches its maximum efficiency
4. **Rated wind speed**(Pout) – speed at which the machine reaches its maximum output power
5. **Furling wind speed** – speed at which machine furls to prevent damage at high wind speeds

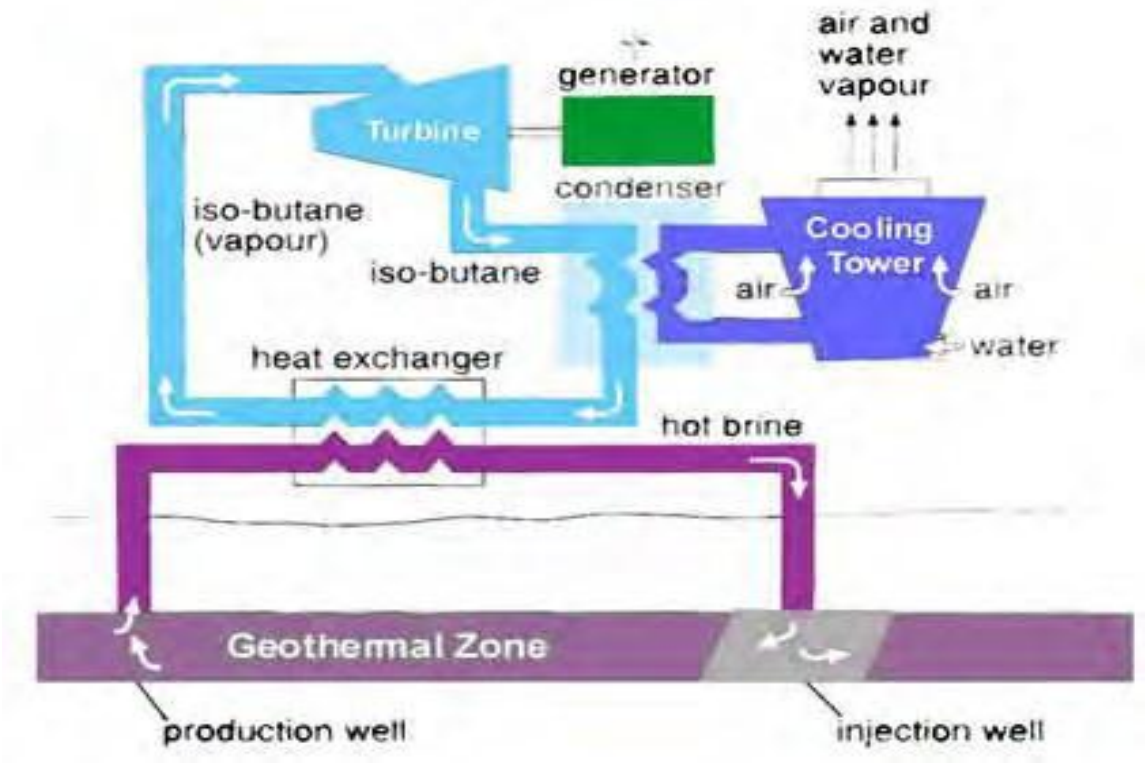


Typical wind turbine power output with steady wind speed.

- 7.b. Explain with the help of neat diagram, the binary cycle geothermal electric power plant. List its disadvantages. (CO4, L2)

3. Binary Cycle Power Plant

- Insufficiently hot resource to efficiently produce steam
- Too many chemical impurities to allow flashing.



Binary Cycle Power Plant:

- **In the binary cycle process, the geothermal fluid is passed through a heat exchanger.**
- **The secondary fluid, which has a lower boiling point than water (eg isobutane or pentane), is vaporised, and expanded through a turbine to generate electricity.**
- **The working fluid is condensed and recycled for another cycle.**
- **All of the geothermal fluid is reinjected into the ground in a closed-cycle system. Binary cycle power plants can achieve higher efficiencies than flash steam plants, and they allow the utilisation of lower temperature resources.**
- **In addition, corrosion problems are avoided.**
- **However, binary cycle plants are more expensive, and large pumps are required which consume a significant percentage of the power output of the plants.**