CBCS SCHEME

USN | 1 | C | R | 2 | 2 | L | 7 | 0 | 7 | 2 | BEE654B

Sixth Semester B.E./B.Tech. Degree Examination, June/July 2025
Technologies of Renewable Energy Sources

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Explain causes of energy scarcity.	06	L1	CO1
	b.	With the help of diagram, define (i) Hour angle (ii) Latitude angle (iii) Solar azimuth angle (iv) Declination angle	08	L2	CO1
	c.	Explain basic Rankine cycle of electricity production.	06	L2	CO1
		OR			
Q.2	a.	Discuss world wide renewable energy availability.	06	L1	CO1
	b.	Classify the energy resources. What are the factors affecting energy resource development.	08	L2	CO1
	c.	Explain various layers of the Sun.	06	L2	CO1
		Module – 2			
Q.3	a.	Write a short note on solar cell materials.	06	L2	CO2
	b.	Explain I-V characteristics of a solar cell. Discuss the efficiency of a solar cell.	08	L2	CO2
	c.	Explain with a neat sketch Heliostat electric power generating plant.	06	L2	CO2
		OR			
Q.4	a.	Explain the operation of solar pond with the help of a neat diagram.	06	L2	CO2
	b.	With neat sketch, explain flat plate solar collector.	08	L2	CO2
	c.	Explain working of Stirling or Brayton engine with a neat diagram.	06	L2	CO2
		Module – 3			
Q.5	a.	Discuss the considerations and guidelines for wind turbine site selection. Also explain world wide wind energy scenario.	10	L1	CO3
	b.	Explain different hydrogen production technologies.	10	L2	CO3
		OR			
Q.6	a.	Mention various advantages and disadvantages of waste recycling.	06	L1	CO3
	b.	With a block diagram, explain waste recovery management scheme.	08	L1	CO3
	c.	With neat diagram, explain working of double flash type geothermal electric power generation.	06	L2	CO3
		Module – 4			
Q.7	a.	With a neat sketch, explain updraft and downdraft gasifiers.	10	L2	CO4
	b.	Explain the single basin and two basin system of tidal power harnessing.	10	L2	CO5
		OR			
Q.8	a.	List the advantages and disadvantages of tidal power.	10	L1	CO5
	b.	Explain construction of biogas plat with a neat sketch.	10	L2	CO4
		Module – 5			
Q.9	a.	Explain the devices used for harnessing wave energy.	10	L2	CO5
	b.	What are the advantages, disadvantages and benefits of OTEC.	10	L2	CO5
		OR			
Q.10	a.	Explain working of oscillating water column device for harnessing sea wave energy.	10	L2	CO5
	b.	Explain open cycle and closed cycle OTEC techniques.	10	L2	CO5

* * * * *

Module - 1

Q1 a. Explain the Causes of Energy Scarcity [06]

*While the whole world is in the grip of energy scarcity, several countries Including india are facing various associated difficulties for its techno-socio-economic develop because of **energy shortages**

*Energy use scenario, as shown in Table 1.3, indicates that how equality (social and economical) can be achieved, when **30% population** is **utilizing 70%** of energy and **70% population** is forced to live with the **30% of the remaining energy**.

I. Increasing Population

*Undoubtedly, only **40–45% population** constitutes **child producing groups**, worldwide population is increasing at an alarming rate.

*It is extrapolated that by the turn of 21st century, **population** will **increase manifold** (Malthusian population model).
These populations are unevenly distributed worldwide.

II. Increasing Energy Usage or Consumption

*The movement of civilization from early man to the present technological man was based on **energy usage**

*Energy is constantly used at <u>home</u>, at <u>work</u>, and for <u>leisure</u> period of enjoyment.
>Energy maintains <u>techno-socio-economic</u> development.
>Energy provides the society with <u>heat</u> and <u>electricity</u> daily and motive power to industry, transportation, and modern way of life.

III. Uneven Distribution of Energy Resources

*It is well understood that very **few wealthy countries** have access to and actually use the largest part of the world's **energy** and **material resources**.

For example, **Middle East** countries are full of **crude oil reserves**, but they are forced to involve in conflicts and wars and their **energy reserves** are **forcefully** used by **wealthy countries**.

*Geographical distribution is the main consideration for an **unevenly distribution of fossil fuels** (coal, oil, gas, and nuclear).

***Renewable energy** flows are also spread out **unevenly**. Cloudiness in equatorial regions reduces solar radiation.

IV. Lack of Technical Knowhow

*Despite the fact that several countries or regions are having energy in abundance, they are **not able to fully utilize** them due to the **lack of knowledge of conversion**, transmission, distribution, and utilization.

*Because of the **lack of technical knowledge**,
>resources are **mined** and processed in **resource enriched countries** and
then **refined** and used in **developed countries**.

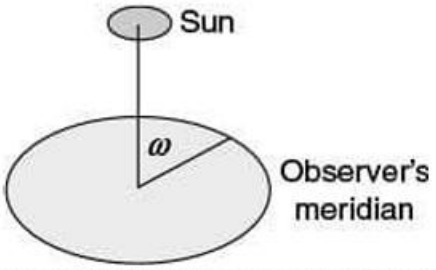
*The price of exported resources is normally inadequate to compensate for the depletion of energy reserves and the environmental burden that is generated by resource extraction and primary processing in energy enriched countries.

*However, resources drive significant economic and environmental benefits in techno-economically developed countries.

Q1 b. With the help of Diagram define i) Hour Angle ii) Latitude Angle iii) Solar Azimuth Angle iv) Declination Angle [08]

i) Hour Angle(ω)

The hour angle is the **angular distance** between the meridian of the observer and the meridian whose plane contains the sun.



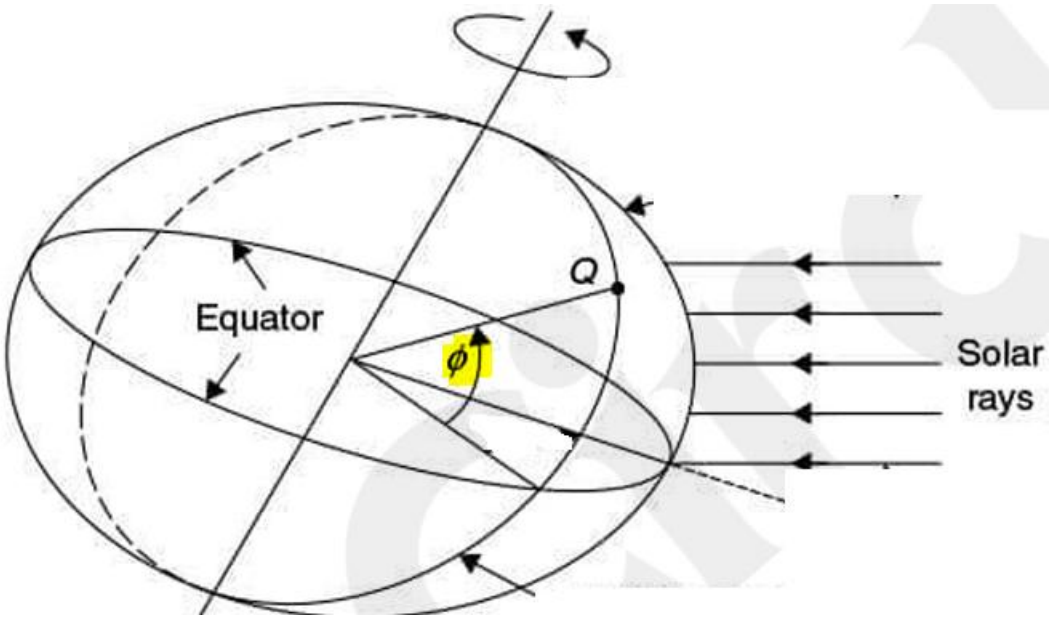
Source: http://www.brighton-webs.co.uk/energy/solar_earth_sun.aspx

Figure 2.3 Hour angle (ω)

*To describe the **earth's rotation** about its polar axis, the concept of **hour angle** is used.

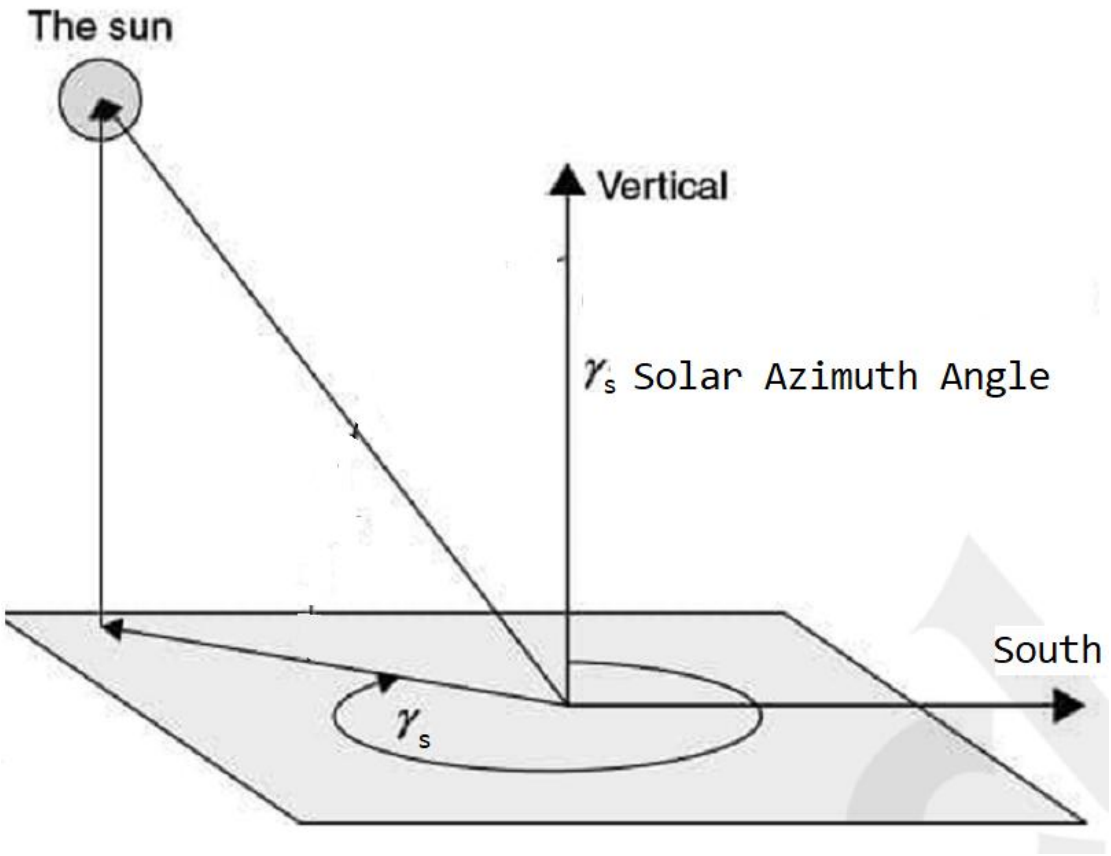
ii) Latitude Angle(ϕ)

The latitude angle(ϕ) is the angle between the
Line drawn from **a point** on the earth's surface **to the centre** of the earth and the earth's **equitorial plane**.



iii) Solar Azimuth Angle(γ_s)

*It is the angle made **in horizontal plane** between the line due south and the projection of line of site of the sun on the horizontal plane.

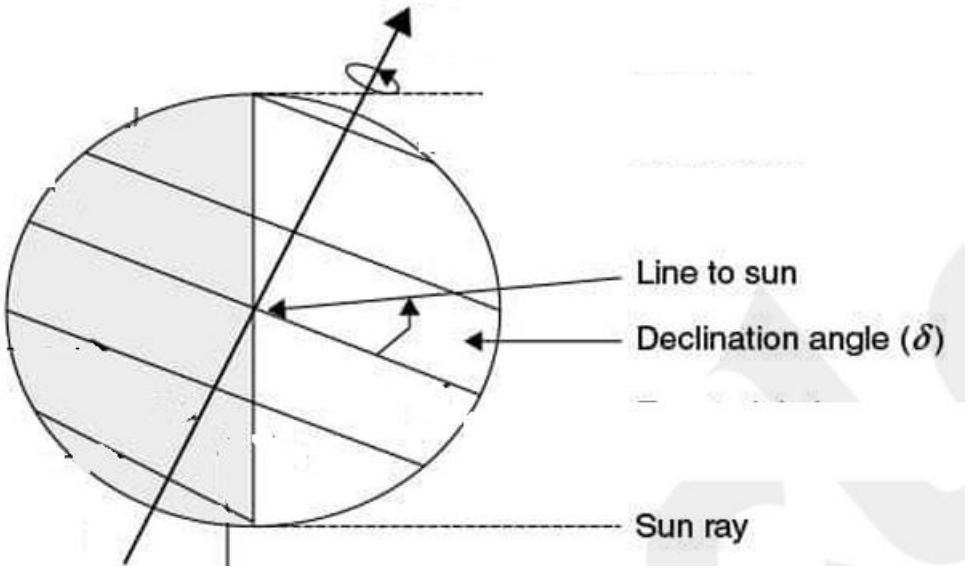


iv) Declination Angle(δ)

*The **declination angle(δ)** of the sun is the angle between the **rays** of the sun and the **plane of the earth's equator**.

*At the moment of each **equinox**, the centre of the sun appears to pass through the equator and the declination angle(δ) is **0^o**.

*In **summer solstice** position when δ = +23.45°.
And in **winter solstice** position when δ = -23.45°.



Q1 c. Explain Basic Rankine Cycle of Electricity Production [06]

Basic Rankine Cycle

*The Rankine cycle is a **thermodynamic cycle** which is used to **produce electricity** in many **power stations**.

*It is the practical approach to the ideal Carnot Cycle.

PROCESS

*Superheated **steam** is generated in a **boiler** and then **expanded in a steam turbine**. *The **turbine drives a generator** to convert the work into electricity. *The remaining **steam is then condensed** and **recycled** as feed water to the boiler.

*A disadvantage of using the water-steam mixture is that **superheated steam** has to **be used**, Otherwise the **moisture content** after expansion might **erode the fan blades**
>Hence sometimes instead of water, an **organic fluid** can be used

*The major advantage is that **these fluids** can be used **below 400^{O}C** and do not need to be overheated.

*This version is called the Organic Rankine Cycle

COMPONENTS OF RANKINE CYCLE

*The major components of a simple, ideal Rankine cycle are depicted in the figure below:-

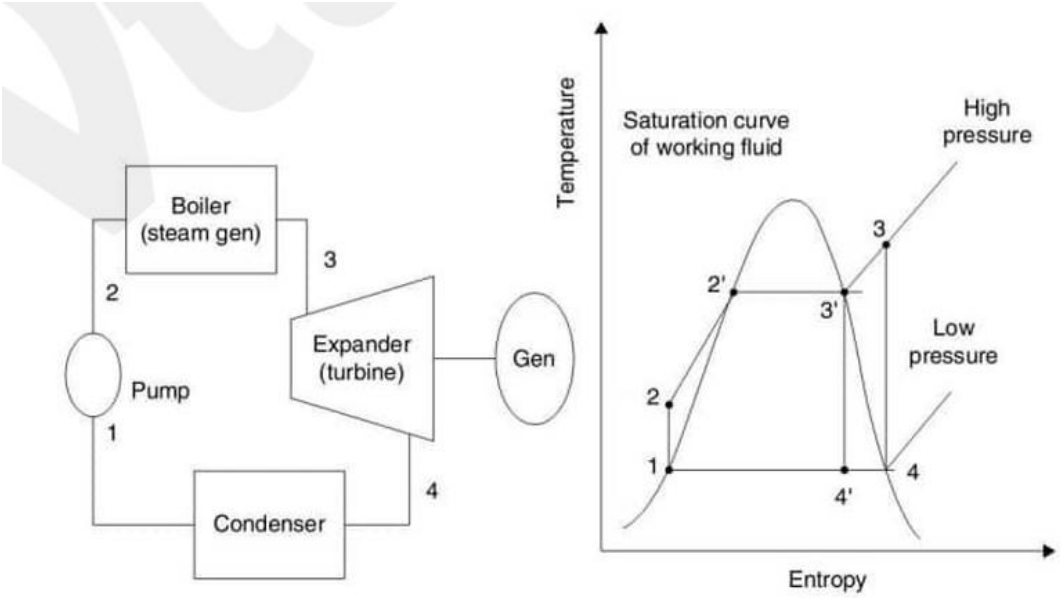


Figure Basic Rankine cycle

THERMO DYNAMIC STATES

*Along with the **thermodynamic** states of the working fluid plotted on **temperature-entropy coordinates**.

*Only ideal processes are depicted.

>The **pressure of saturated liquid** leaving the condenser at state 1 is raised in an **adiabatic**, **reversible process** by the(ideal) pump to state 2 where it enters the vapour generator

>The compressed liquid is heated with constant pressure(often called preheat) until it reaches saturated liquid state 2'.

>Then at constant temperature(and pressure) until all the liquid has **vapourized** to become **saturated vapour** at 3'.

>More heat is added to **superheat** the **saturated vapour** at constant pressure, and its temperature rises to state 3.

>The superheated vapour now enters an **ideal expansion device**(often a turbine) and expands in an **adiabatic, reversible process** to the low pressure maintained by the condenser indicated as **state 4**.

*The condenser converts the vapour leaving the turbine into liquid by extracting heat from it.

Q2 a. Discuss Worldwide Renewable Energy Availability [06]

Worldwide Renewable Energy Availability

*About **16% of global final energy** consumption comes from renewable as shown in Figure 1.14.

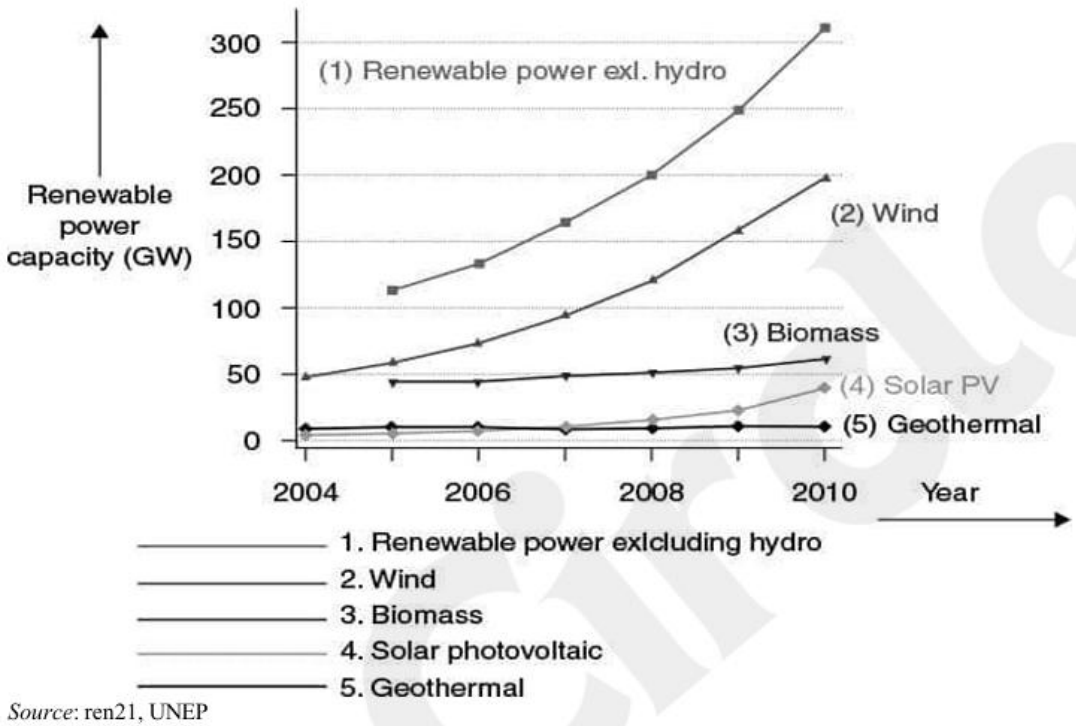


Figure Worldwide renewable power capacity excluding hydro

*10% from Traditional **Biomass**

*3.4% from **Hydro Electricity**

*New **renewable energy**(small hydro, modern biomass, wind, solar, geothermal and biofuel) accounted for another 3% and were **growing very rapidly**

*Potential for Worldwide Renewable Energy

Energy Resource	Energy Amount
Solar energy	1,600 EJ (444,000 TWh),
Wind power	600 EJ (167,000 TWh)
Geothermal	500 EJ (139,000 TWh),
Biomass	250 EJ (70,000 TWh)
Mini hydropower	50 EJ (14,000 TWh)
Ocean energy	1 EJ (280 TWh)

Renewable Energy in India

*Renewable Energy in india is still in it's **infancy**.
*India has an installed capacity of about **22.4 GW** of renewable technology-based electricity, about **12%** of its total. (As of Dec 2011).

India Install Capacity of Renewable Energy

Table India Installed Capacity of Renewable Energy Till August 2011

Type	Technology	Installed Capacity (MW)
Grid connected power system	Wind	14989
	Small Hydro	3154
	Biomass	1084
	Bagasse Cogeneration	1799
	Waste to energy	74
	Solar	46
Off-grid, Captive power	Biomass	141
	Biomass non-Bagasse cogeneration	328
	Waste to energy	76
	Solar	73
	Hybrid/Aerogen	01

Q2 b. Classify the energy resources. What are the factors affecting energy resource development. [08]

Energy Resources and Classification

*The following sections deals with the **classification** of **promising energy resources** of immediate interests:-

Primary and Secondary Resources

1. **Primary energy resources** are derived directly from **natural reserve**.
>They are used either in basic raw energy form or by converting them to usable form (secondary energy).

Eg: chemical fuels, solar, wind, geothermal, nuclear, hydropower, etc.

2. **Secondary energy resources** are usable forms of energy **generated by** means of **suitable plants** to convert the **primary energy**.

Eg: electrical energy, steam power, hot water power, hydrogen energy, etc.

From the above mentioned viewpoints **electrcial energy** is the dominant form
Because it is
cost effective,
highly **efficient**,
good **performance** with
environmentally acceptable and system acceptability index approaching unity

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

1. *Conventional and non-conventional energy resources*:-

a) *Conventional* energy resources and their **technical knowledge** are **known to mankind** to a great extent.

-They are the energy stored within the **earth** and the **sea**.
They include both **fossil fuels** (coal, oil, and gas) and **nuclear energy** (uranium and thorium) and **required human intervention** to **release the energy** from them.

-They are also known as **finite energy resources**.
These sources have formed over hundreds of millions of years ago and **when they are used**, there will be **no more for future generations**.

b) *Non-conventional* energy resources, Their **technical knowledge is little known** and need full exploitation and improved technical understanding.

-They are known as are known as **infinite energy resources**

-They are obtained from the energy flowing through the natural environement

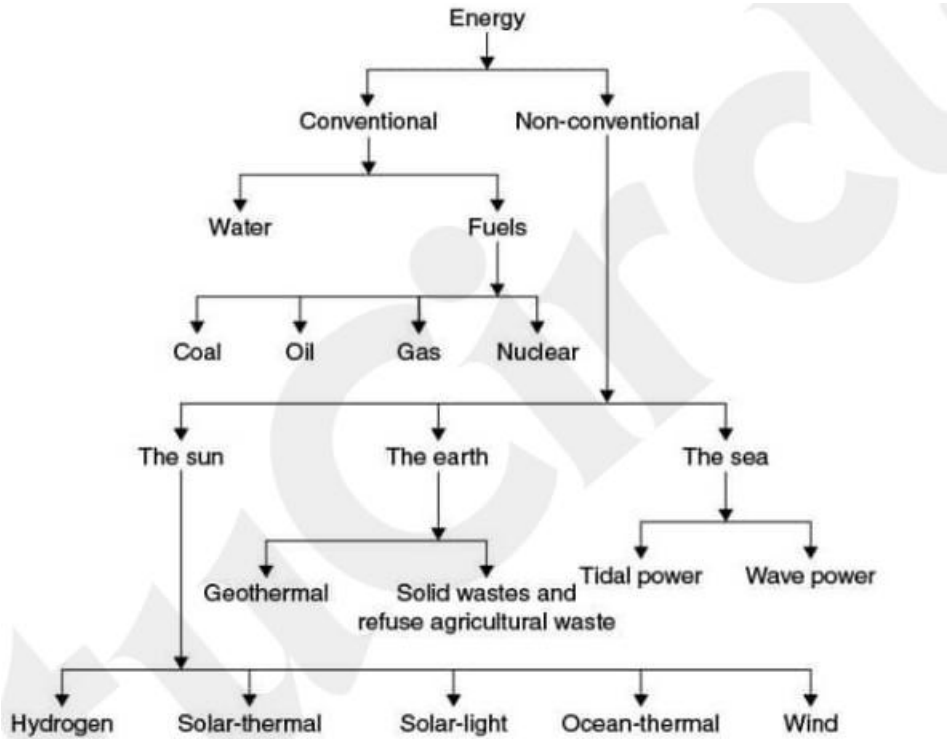
-They have **higher cost factor** and **lower overall performance** and one may only think of fully utlizing them when the conventional resources are fully exploited.

2. *Renewable and Non-Renewable Energy resources*:-

a) Renewable energy resources are **continuosly restored by nature**
Eg: Solar, Water, Wind etc.

b) Non-renewable energy resources are **the reserve** that is once accumulated in nature has **practically ceased** to form under **new geological conditions**.
-They are also known as <u>expendable energy</u>

Eg: Coal, Oil, Gas, Nuclear



Factors Affecting Energy Resource Development

I. Energy or Fuel Substitution or Scale of Shift

*Today, there is **no readily available energy** resources to substitute for **fossil fuels**.
*Undoubtedly, **solar energy** is several orders of magnitude larger than any conceivable global energy demand (about 10^{17}W).
***Practical conversion** to electricity using photovoltaic or large scale industrial heat are quite **negligible**.

II. Energy Density

*"*The **amount of energy** contained in a **unit of material object** (energy resource) is termed as **energy density***"

Eg:-
>Air-**dry crop residue** (mostly straw and agricultural waste) contain only 12–15 MJ/kg
>Good quality **coal** is twice as high (i.e., 25–30 MJ/ kg)

III. Power Density

*"***Power density** *refers to the **rate of energy production** per **unit of earth's area** and usually expressed in watts per square meters(w/m^2).*"

Eg:-
>**Fossil Fuels** - 10^2 to 10^3 w/m^2
>**Water** and **Wind** - below 10 w/m^2
>**Photovoltaic** - above 20 w/m^2

Photovoltaic cost and perforamance are the constraints for mass utilization.

IV. Intermittency

*Growing **demand** for **fuels**, **energy**, and **electricity** fluctuates daily and seasonally in modern civilization.

*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 (775% for the coal-fired stations, 790% for nuclear plants) **meet these needs**.

**Wind* and *Direct solar radiation* are intermittent and far from practicable.
They can **never deliver such high load factors**.

V. Geographical Energy Distrubition

*Due to **uneven distribution** of fossil and non-fossil fuels, energy sources are considered differently.

*For example,
India being in the Tropical Zone is a better candidate for Solar Power than the UK

Q2 c. Explain the various layers of the Sun. [08]

*The sun can be divided into the following six layers as shown in Figure 2.2:-

1. Core
2. Radiative Zone
3. Convection Zone
4. Photosphere
5. Chromosphere
6. Corona.

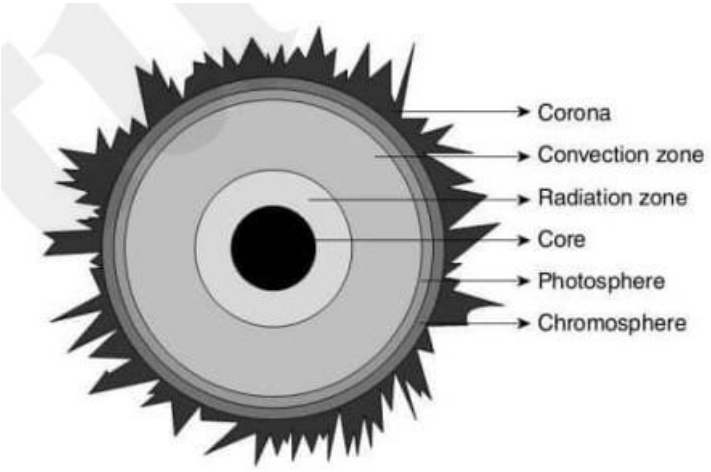


Figure Interior of the sun

1. Core

*The innermost layer of the sun is called the ***core***.
*With a **density of 160 g/cm^3**, ten times that of lead.
*The core's **temperature of 1,50,00,000^{O}C** keeps the core in **Gaseous State**.

*In the core *fusion reactions*, produce energy in the form of **gamma rays** and **neutrinos**.
>Gamma rays are absorbed and re-emitted by many atoms on their journey outside the sun
>Neutrinos are extremely nonreactive.

2. Solar Envelope(Radiative and Convection Zone)

*Outside of the core is the *radiative envelope*, which is surrounded by a *convective envelope*.

*The **density** of the solar envelope is much less than that of the Core.
Core - 40% of the mass in 10% of the volume
Envelope - 60% of the mass 90% of the volume

*The temperature is **4 Million Kelvin**(7 million degrees F)

*As the solar envelope is cooler and more opaque than the core, it becomes less efficient for the energy to move by radiation as a result **heat energy** starts to **build up at the outside**.

*The **energy begins to move** in huge CELLS or **circulating gas** with several hundred kilometers in **diameter**.

***Convection cells** nearer to the outside are smaller than inner cells,
The top of each cell is called a **granule**
>These granules, when observed through a through a telescope, looks like tiny specks of light.
>**Variations in velocity** of particles in granules cause slight wavelength changes in the spectra emitted by the sun.

3. Photosphere

*The *photosphere* is the zone from which the sunlight is both **seen** and **emitted**.

*The photosphere is a comparatively **thin layer** of **low-pressure gasses** surrounding the envelope.

*It has a **temperature of 6,000^{O}C**.

*The composition, temperature and pressure of the photosphere are revealed by the **spectrum of sunlight**.

4. Chromosphere

*During an eclipse, a **red circle** can sometimes be seen outside the sun.
This circle is called the ***chromosphere***

*The red color comes from an abundance of **hydrogen**.

*The temperature is **7000K** (despite the trend that temp. decreases as we move away from the core).

5. Corona

*The **outermost layer** of the sun is called the ***Corona*** or the ***Crown***.

*Typically, we can observe the **corona during a total solar eclipse** or by using a coronagraph telescope, which simulates an eclipse by **covering the bright solar disk**

*The corona is very dim, about a **million times dimmer** than the **photosphere**

*It is the hottest at 10^{6}K,
>because the Corona extends several **million kilometers in space**, there is a lot of **room** for the **molecules to move**.
>These movements are the cause of **Solar Winds**.

Module - 2

Q3 a. Write a Short Note on Solar Cell Materials. [06]

Crystalline silicon cells: They dominate the photovoltaic market.
>To reduce the cost these cells are now often made from multi crystalline material.
>The modules have long life time(more than 20 years) and their best production efficiency is approaching 18%.

Amorphous silicon solar cells: They are cheaper.
>They are used to power a variety of consumer products.

Cadmium telluride and copper indium diselenide:
>Thin film modules are now beginning to appear on the market and hold the promise of coming low cost with acceptable conversion efficiencies.

High efficiency solar cells:
>From Gallium arsenide, or their derivatives are used in specialized applications

eg : to power *satellites* or in systems that operate under high intensity concentrated sunlight.

Table 4.1 Efficiency of Different Types of Solar Cells

Cell Material	Theoretical Efficiency (%)	Practical Efficiency (%)	Technology
Mono or multi-crystalline silicon	20–26	12–18	Ingot or wafer
Amorphous silicon	12–14	5 – 10	Thin film
Copper indium diselenide	16–18	8–10	Thin film
Cadmium telluride	15–16	5–8	Thin film
Gallium arsenide	26–32	18–25	Ingot or wafer
Ribbon-grown silicon	10–16	10–12	Ingot or wafer
Ovshinsky silicon	8–10	≤10	Thin film

(The Question is not too clear on what it's asking so I wrote this one in the exam. They could also be referring to 'elements' of a solar cell)

Q3 b. Explain I-V characteristics of a solar cell. Discuss the efficiency of a solar cell. [08]

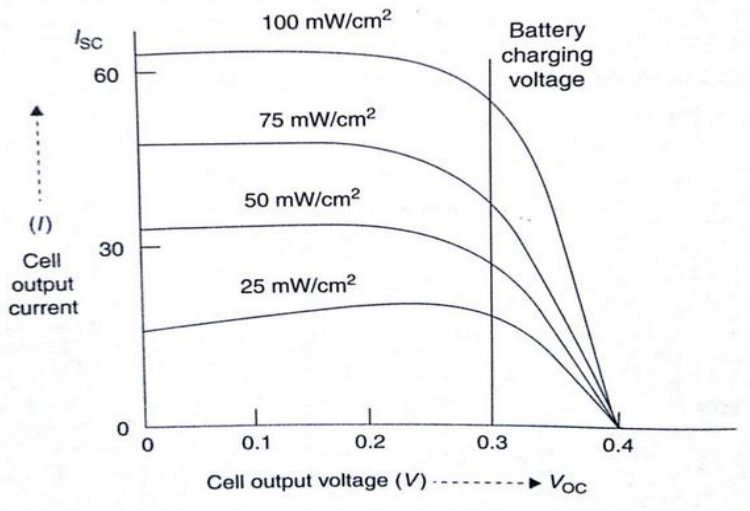
I-V CHARACTERISTICS OF SOLAR CELLS

Output voltage of a solar cell is given by **N-type semiconductors**:-

$$V = (kT/e) \log_e [1 + (I_s - I)/I_0]$$

Where

× I is Load Current
× Is is Supply Current
× I_0 is Reverse Saturation Current
× e is electron charge
× k is Boltzmann's Constant
× T is Absolute Temperature



I-V Characteristics under different illumination level

Irradiance mW/cm²

Typical I-V Curve passes through two points:-

1. Short Circuit Current(I_{sc}):-
*Current produced by short circuiting +ve and -ve terminals of the solar cell.
*Voltage is zero (as R=0 Ω)

2. Open Circuit Voltage(V_{oc}):-
*Voltage across terminals of the cell under open circuit condition.
*Current is zero (as R = ∞)

Output Power of the Cell:-

The output power of a solar cell is given by:

$$P = I \times V$$

The Output Power Depends on the value of load resistance for a given light intensity.

Fill factor:-

*The fill Factor defines behaviour of solar cell. it measures the squareness of I-V charactersitcs
*It is Defined as

$$\times \quad FF = P_{MAX} / (V_{OC} \times I_{SC}) = (V_{MP} \times I_{MP}) / (V_{OC} \times I_{SC})$$

Also given by

$$FF = (\eta \times S \times E) / (V_{OC} \times I_{SC})$$

*It is affected by shunt(R_{SH}) and series(R_S) resistances of the cell
***Increasing R_{SH}** and **decreasing R_S** gives high Fill factor, resulting in a higher efficiency and brings the output power closer to P_{MAX}.

Q3 c. Explain with a neat sketch Heliostat electric power generating plant. [06]

Heliostat Field Solar Collectors

*Heliostat is a **mirror-based system** that is used to **continuously reflect sunlight** onto a central receiver.

*Generally, it is a **two-axis solar tracking flat mirror** that reflects sunlight onto a **fixed receiver** or **target**.

*The geometry between the **sun**, **mirror**, and **receiver** are constantly changing throughout the day.

*These systems can be used for **domesting heating**, **electricity** and **lighting**.

WORKING OF PRACTICAL SOLAR HELIOSTAT

*A practical **solar heliostat** is a mirror that **makes precise movements** up or down and left or right to reflect sunlight onto a fixed spot.

*When **multiple practical solar heliostats** reflect sunlight onto a **single thermal receiver**, the concentrated heat of the sunlight can be used to produce **hot water** or **steam**.

*Relatively cold water flows through the **thermal receiver** and is outputted as hot water.

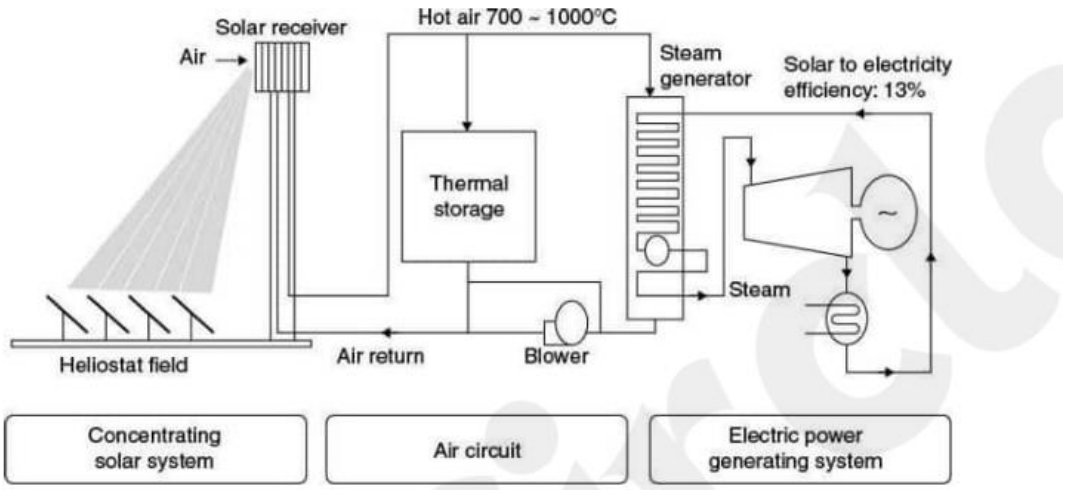


Figure 2.14 Heliostat electric generating plant

*Although such a system can generate temperatures capable of melting steel,
>The temperature of the water is raised to just within a **degree of boiling**.
For the purpose of **heating** and **cooling** a **commercial building**,

>This temperature uses the heat in sunlight at the highest efficiency and lowest cost.

>A higher temperature would mean **more heat loss**, as well as a **more expensive system** to **withstand** the higher temperature and pressure.

*The mirrors on practical solar heliostats have minimal reflection loss,
>So **each heliostat** reflects **approximately its area** in sunlight:
about 1 kW of heat per square meter.

>If 100 practical solar heliostats, each with 2.2m^2 of mirror area,
direct sunlight onto a single thermal receiver, the sunlight will be converted into **220 kw of heat**.

*With practical solar method of heat **storage** and heat **distribution**,
>220 kw is more than enough energy to supply all of the heating needs of a 10,000 square foot commercial building.

*Hot water can be stored cheaply in a thermally insulated tank. As the **volume** of water and **energy stored** increases, the **cost and losses** of thermal energy storage **drop rapidly**.

(Optional, Incase there's 10M version of this question then write this)

ADVANTAGES

1. Although the heliostat solar tower approach to solar power production is not as commercially developed as the solar parabolic trough system,
It is **more commercially developed** than either the **parabolic dish-Stirling engine** or **linear Fresnel systems**.

2. Since the heliostat solar tower system **produces steam** to generate electricity with a conventional **Rankine steam cycle**, this system can be hybridized.

In other words, it can be **designed to use a fossil fuel** (typically natural gas) as a **supplementary fuel**, allowing electricity to be generated when the sun is not shining.

DISADVANTAGES

*The heliostat solar tower system produces a **fluid temperature** greater than that of the **single-axis tracking**, parabolic trough, and linear Fresnel system,
but
less than that of the **two-axis tracking**, **parabolic dish-Stirling engine system**.

*Thus, it cannot **achieve efficiency** for **conversion of electricity** from thermal energy as high as that of the parabolic dish-Stirling engine system.

Q4. a. Explain the operation of solar pond with the help of a neat diagram. [06]

SOLAR POND

*One of the best ways of harnessing solar is through solar ponds.

*It is basically a pool of water that **collects** and also **stores solar energy**.

*The peculiarity of the solar pond is that it has **layers of salt solutions** of differing concentrations, and thus, **different densities** to a certain depth.

*Once this depth is reached, then water with uniform, **high salt concentration is obtained**.

*The solar pond is a relatively **low technology** and **low cost approach** for harvesting solar energy.

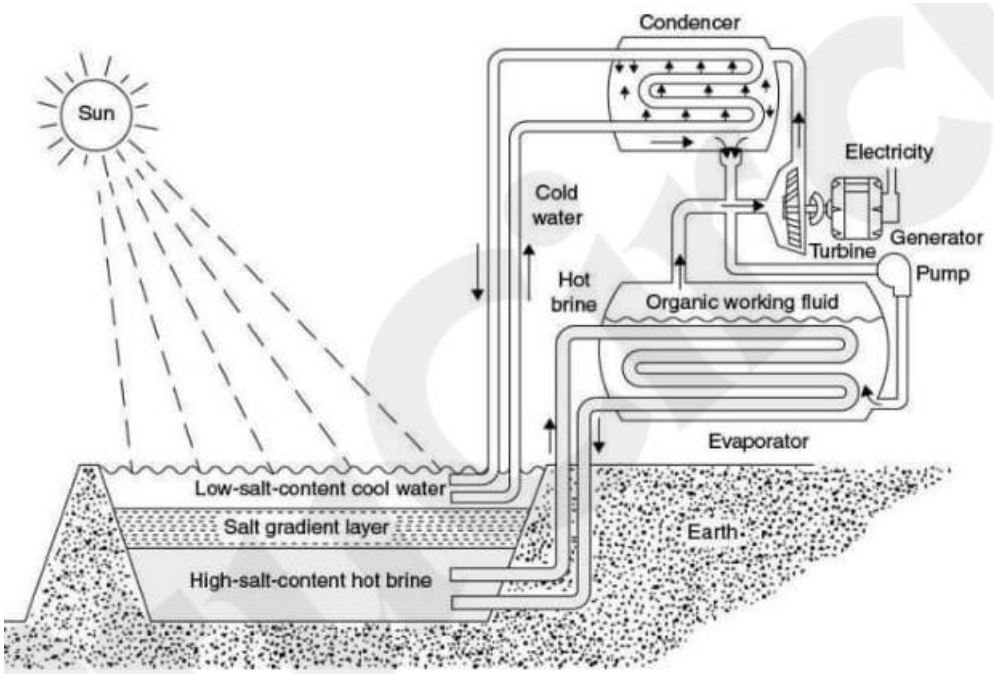


Figure 2.28 Solar pond

*To develop a solar pond, pond is filled with three layers of water:-

1. The *top layer* is **cold** and has relatively **little salt content**.

2. Next is the *intermediate insulating layer* that has a **salt gradient** that maintains a **density gradient**.
It is this density gradient that helps in preventing heat exchange with the natural convection of water.

3. The *bottom layer* is **hot** up to 100°c and has a **high salt content**.

*It is because of these **different salt contents** in the different layers of water that the different layers have **different densities**

*With the different densities in the water, the development of **convection currents is prevented**, which would have transferred heat to the surface of the pond, and then to the air above.

*Without these convection currents, **heat is trapped in the salty bottom layer** of the solar pond,

which is used for **heating of buildings**, industrial **processes**, **generation of electricity**, and other purposes.

*In addition to the abovementioned uses, solar ponds can also be used in **water desalination** and **for storage of thermal energy**.

*In this system, a **large salty lake** is used as a **plate collector**.

>With the right salt concentration in the water, the solar energy can be absorbed at the bottom of the lake.

>The heat is insulated by different densities of the water, and at **the bottom, the heat can reach 90°C**, which is high enough to run a vapour cycle engine

>At the top of the pond, the **temperature can reach 30°C**.

*These systems have a **low solar** to **electricity** conversion efficiency, less than 15% (having an ambient temperature of 20°c and storage heat of 80°C).

*One advantage of this system is that because the **heat is stored,** it can run day and night if required.

*Further, due to its simplicity, it **can be constructed in rural areas** in developing countries.

(Only write this next part if it's for 10 Marks or more)

ADVANTAGES

There are many **advantages of using a solar pond** to meet the energy requirements of a place:-

1. The greatest advantage lies in the fact that it has a **low cost per unit area of collection** and also an inherent capacity for storage purposes.

>In addition to this, it is possible to **easily construct solar ponds** over large areas with which it is possible for the diffusion of solar resources to **get concentrated on a grand scale**.

2. Not only is a solar pond a **great source of generation of electricity**, it produces many **environmental advantages** when compared to the use of other fossil fuels for producing electricity.

>With a solar pond, the greatest advantage to the environment is that the **heat energy** is provided without the **burning of any fuel**, which reduces pollution.

3. Another advantage is that because there is no use of conventional energy resources for **creating electricity** in solar ponds, **conventional energy resources are conserved**.

4. Further, it can be coupled with **desalting units** that are used for purifying **contaminated impaired water** while the pond itself is the **receptacle for waste products**.

Q4. b. With Neat Sketch Explain Flat Plate Solar Collectors. [08]

Flat Plate Collectors

*Flat Plate Collectors are the most common type.

*They are also referred to as **non-concentrating collectors**.

*They have the same area for **intercepting** and for **absorbing** solar radiation.

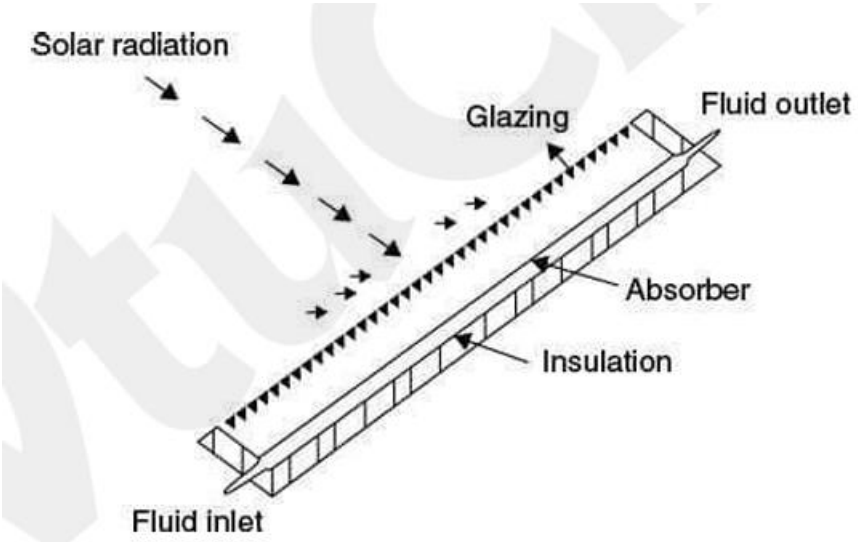


Figure 2.1 Flat plate collectors

*It has five important parts:-

1. *Dark flat plate absorber of solar energy*:
-The absorber consists of a **thin absorber sheet** (of thermally stable polymeric materials such as aluminium, steel, or copper to which a **black or selective coating is applied**) because of the fact that the metal is a good heat conductor.

- Copper is more expensive, but is a **better conductor** and less prone to corrosion than aluminium.

-In locations with average availability of solar energy, flat plate **collectors are sized** approximately **0.5** to **1 square foot** per gallon of daily hot water use.

-The underside of the **absorber plate** and the **side of casing** are well **insulated** to reduce conduction losses.

2. *Transparent cover*:
-This allows **solar energy** to **pass through**, but reduces heat losses.

-The **transparent cover** is used to **reduce convection losses** from the absorber plate through the restraint of the stagnant air layer between the absorber plate and the glass:-

-It also reduces **radiation losses** from the collector as the glass is **transparent** to the **short-wave radiation** received by the sun, but it is nearly opaque to long-wave thermal radiation emitted by the absorber plate.

3. *Heat-transport fluid* (air, antifreeze, or water):
-To **remove heat** from the absorber, **fluid is usually circulated** through tubing to transfer heat from the absorber to an insulated water tank.

4. *Heat insulation backing*:
-Often backed by a **grid** or **coil of fluid tubing**.

5. *Insulated casing*:
-It is made of a **glass** or **polycarbonate cover**.

*When solar radiation passes through a **transparent cover** and
>im- pinges on the **blackened absorber** surface of high absorptivity, a large portion of this **energy is absorbed by the plate**, and
>then **transferred** to the transport medium in the **fluid tubes** to be carried away for **storage or use**.

*For solar water heating systems in home and solar space **heating flat plate collectors** are the most **common type** of solar collector used.

Flat Plate Air Collectors

*Air flat plate collectors are mainly used for **solar space heating**.
*The absorber plates can be made of **metal sheets**, layers of **screen**, or non-metallic materials.

*The air flows past the absorber by using **natural convection** or a **fan**.
Since air does not conductor heat as easily as liquid, air collectors are typically less efficient than liquid collectors

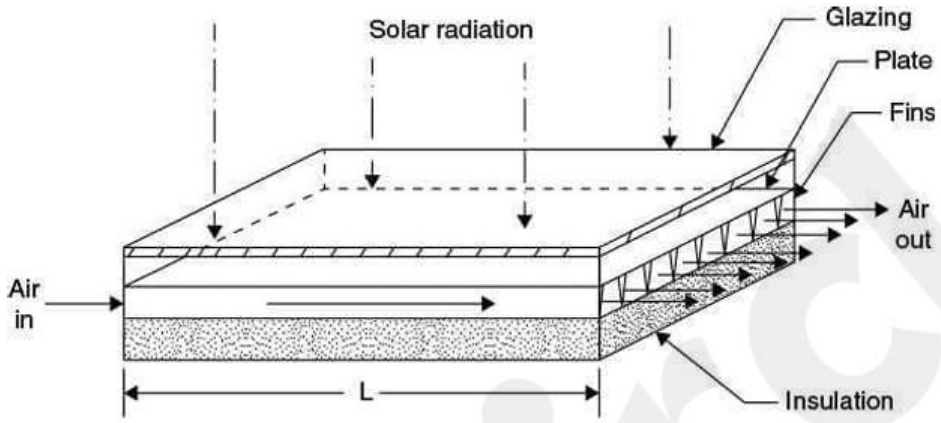


Figure 2.2 Flat plate air collectors

Flat Plate Liquid Collectors

*These collectors use **liquid** for **heat transport medium**.
*Liquid flat plate collectors **heat liquid** as it flows through **tubes** in or **adjacent to the plate**.

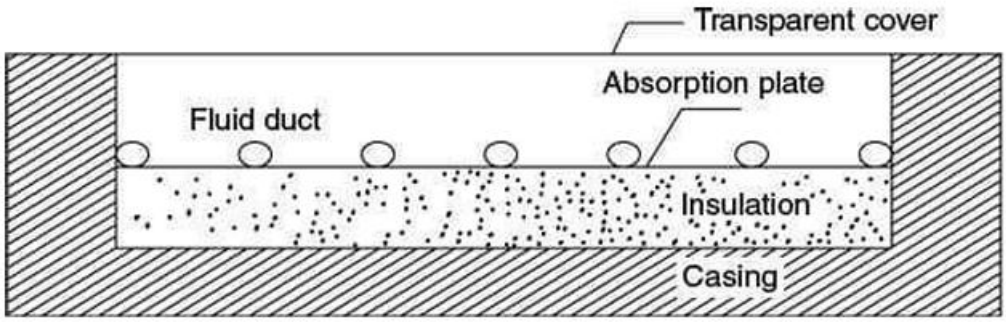


Figure 2.3 Flat plate liquid collectors

Q4. c. Explain working of Stirling or Brayton engine with a neat diagram. [06]

PARABOLIC DISH-STIRLING ENGINE SYSTEM

*The major parts of a parabolic dish-Stirling engine system are as follows:-

1. *Solar dish concentrator*:

-Parabolic dish systems that generate electricity from a **central power converter collect the absorbed sunlight** from
-individual **receivers** and deliver it via a heat-transfer fluid to the **power conversion systems**.

-The need to circulate heat-transfer fluid throughout the collector field raises design issues such as **piping layout**, **pumping requirements**, and **thermal losses**.

2. *Power conversion unit*:

-The power conversion unit includes the **thermal receiver** and the **heat engine**.

-The thermal receiver **absorbs** the concentrated beam of solar energy, **converts it to heat**, and transfers the **heat to the heat engine**.

-A *thermal receiver* can be a **bank of tubes** with a **cooling fluid circulating** through it. The heat transfer medium usually employed as the working fluid for an engine is hydrogen or helium.

-The *heat engine system* takes the **heat** from the thermal receiver and uses it to produce electricity. The engine-generators have several **components**;

>a ***receiver*** to absorb the concentrated sunlight to heat the working fluid of the engine, which then converts the thermal energy into me- chanical work;

>an ***alternator*** attached to the engine to convert the work into electricity,

>a ***waste-heat exhaust system*** to vent excess heat to the atmosphere, and

>a ***control system*** to match the engine operation to the available solar energy.

-This distributed parabolic dish system **lacks thermal storage capabilities**, but can be **hybridized to run on fossil fuel** during periods without sunshine.

-The Stirling engine is the most common type of heat engine used in dish-engine systems.

3. *Tracking system*:

-A parabolic dish system uses **a computer** to track the sun and concentrate the sun's rays onto a receiver located at the **focal point** in front of the dish.

-In some systems, a heat engine, such as a **Stirling engine**, is linked to the receiver to generate electricity.

-**Parabolic dish systems** can reach **1,000°C at the receiver**, and achieve the highest efficiencies for converting solar energy to electricity in the small-power capacity range.

WORKING OF STIRLING OR BRAYTON HEAT ENGINE

*After the array of mirrors focuses the sunlight, the **concentrated sunlight** then **heats up the working fluid** to temperatures of around 750^{O}C within the receiver.

*The heated high temperature working fluid is then used in either a **Stirling** or **Brayton** heat engine cycle to produce mechanical power via rotational kinetic energy and then electricity for utility use with an electric generator.

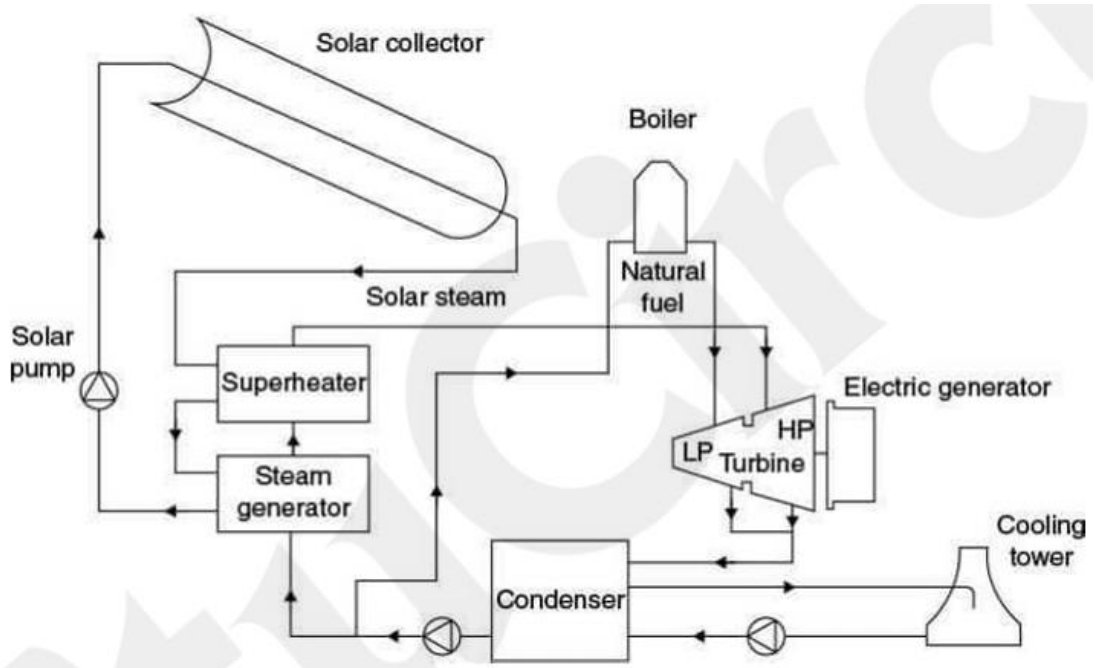


Figure 2.15 Schematic of solar electric generation

*An example of a **Brayton cycle** used to produce electricity for a **parabolic dish power plant** is shown in Figure 2.15.

*In the cycle,

>The **concentrated sunlight** focused on the solar fluid heats up the compressed working fluid of the cycle, i.e., air, **replacing altogether** or **lowering the amount of fuel needed** to heat up the air in the combustion chamber for power generation.

>As with all Brayton cycles, the **hot compressed air** is then **expanded through a turbine** to produce rotational kinetic energy, which is converted to electricity using the alternator.

>A **recuperator** is also utilized to **capture waste heat** from the turbine to preheat the compressed air and make the cycle more efficient.

Module - 3

Q5. a. Discuss the considerations and guidelines for wind turbine site selection. Also explain world wide wind energy scenario. [10]

Considerations and Guidelines for Site Selection:-

CONSIDERATIONS

The following important factors need careful considerations:

• ***Hill effect***: When it approaches a hill, **wind encounters high pressure** because of the wind that has already built up against the hill.
>This compressed air **rises** and **gains speed** as it approaches the top of the hill(crest).
>The installation of **wind turbines** on hilltops takes **advantage of this increase** in speed

• ***Roughness or the amount of friction that earth's surface exerts on wind***:
>Oceans have very little roughness.
>A city or a forest has a great deal of roughness, which slows the wind.

• ***Tunnel Effect***: The increase in air pressure undergoes when it encounters a solid obstacle.
>The **increased air pressure** causes the wind to **gain speed** as it passes between, for example, rows of buildings in a city or between two mountains.

>Placing a **wind turbine** in a **mountain pass** can be a good way to take advantage of wind speeds that are higher than those of the surrounding air.

• ***Turbulence***: Rapid changes in the **speed** and **direction of the wind**, often caused by the wind blowing over natural or artificial barriers are called *turbulence*.

>Turbulence causes not only **fluctuations in the speed of the wind** but also wear and tear on the turbine.
>Turbines are mounted on **tall towers** to **avoid turbulence** caused by ground obstacles.

• ***Variations in wind speed***: During the **day**, winds usually **blow faster** than they do at the night because the sun heats the air, setting air currents in motion.

>In addition, wind **speed can differ** depending on the **season of the year**.
This difference is a function of the sun, which heats different air masses around earth at different rates depending on the tilt of the earth towards or away from the sun.

• ***Wake***: As wind passes over the blades of a turbine, the **turbine seizes** much of the **energy** and **converts it** into **mechanical energy**.

>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**.

>Because of wake, wind turbines in a wind farm are generally **placed about three rotor diameters away** from one another in the direction of the wind,
so that the **wake** from one turbine **does not interfere** with the operation of the one behind it.

• ***Wind obstacles***: Trees, buildings, and rock formations are the main obstacles in the installation of wind turbines.
>Any of these **obstacles** can **reduce wind speed** considerably and increase turbulence.

>Wind obstacles like tall buildings cause wind shade, which can considerably **reduce the speed of the wind**, and therefore, the power output of a turbine.

• ***Wind shear***: It is the <u>differences in wind speeds at different heights</u>.

>When a turbine blade is **pointed straight upward**, the speed of the wind hitting its tip can be, for example, **9 miles** (14 km) per hour,

>but when the blade is **pointing straight downward**, the speed of the wind hitting its tip can be **7 miles** (11 km) per hour.

>This difference **places stress on the blades**.
Further, too much wind shear can cause the turbine to fail.

GUIDELINES

*Choosing the right site for wind turbine is the most important decision. Further, the location plays a vital part in the performance and efficiency of a wind turbine. The following **guidelines** can be followed to evaluate site for the installation of wind turbines: -

1. Turbines work best when on **high** and **exposed sites**. Coastal sites are especially good.

2. Town centres and **highly populated residential areas** are usually **not suitable sites** for wind turbines.

3. **Avoid roof-mounted** turbines as there is no guarantee that these devices will not damage **property through vibration**.

4. The **farther the distance** between the turbine and the power requirement, the **more power will be lost** in the cable.
The distance of the cabling will also impact the overall cost of the installation.

5. **Turbulence disrupts the air flow** that can **wear down the blades** and reduces the lifecycle of the turbine.

>It is recommended that installing a turbine may be considered only when the
-**Distance** between the turbine and the nearest obstacle is more than **twice** the **height** of the **turbine**,
OR
-when the **height** of the turbine is more than **twice** the height of the nearest obstacle.

6. Small turbines require an average **wind speed of over 4.5 m/s** to produce an efficient level of electricity.

7. If site is in **a remote location**, connecting wind turbine to the national grid will be very expensive and it may be worth considering an **off-grid connection** instead using battery storage.

Q5. b. Explain different hydrogen production technologies. [10]

*Hydrogen is the **simplest element** which consists as one proton and electron. **Hydrogen is present in abundant** in different forms like **H_2O, CH_4, H_2SO_4 etc**.

*Hydrogen from **different source** can be **extracted** and can be used to **generate electricity**

***Thermochemical**:-

I. **<u>Steam Reforming</u>**,
-It is the **least expensive** and **most commonly used process**
-Responsible for 90% of hydrogen usage
-Uses Natural Gas for the process

i) **Endothermic Process**:-
-Natural Gas is cleaned from Sulphur compounds.
-Methane (CH_4) is then mixed with high temperature steam (700^0C to 1000^0C) in presence of Nickel-Alumina catalyst in a tubular reactor
-Result is **carbon monoxide** and **hydrogen**

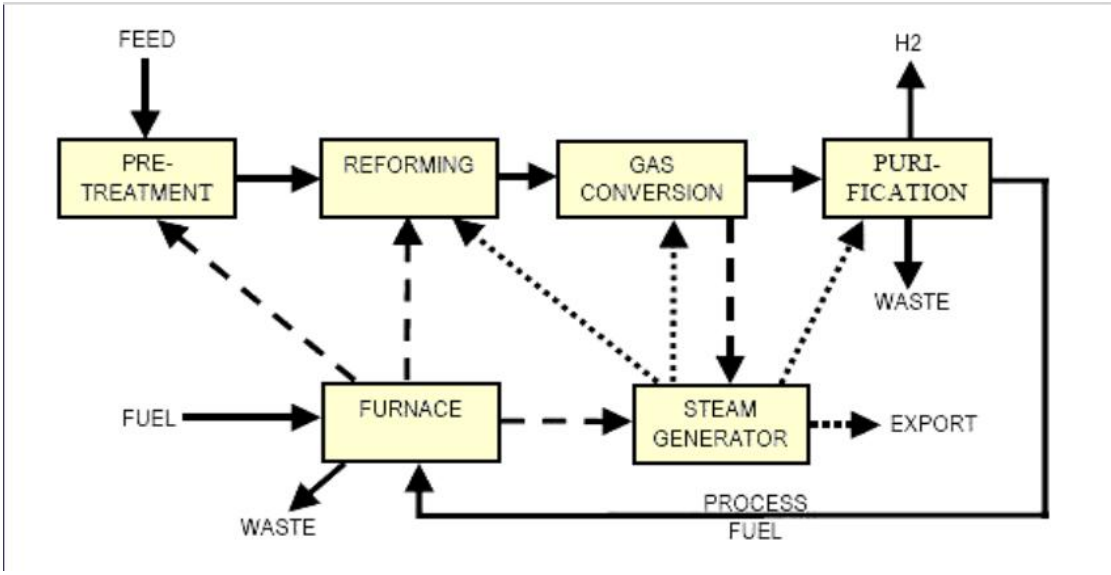
$$CH_4 + H_2O + Heat\ (206\ kJ/kg) \rightarrow CO + 3H_2$$

ii) **Water-Gas Shift Reaction(Exothermic)**:-
-Carbon Monoxide(CO) and steam are reacted to produce **carbon dioxide** and more **hydrogren**

$$CO + H_2O \rightarrow CO_2 + H_2 + Heat\ (41\ kJ/kg)$$

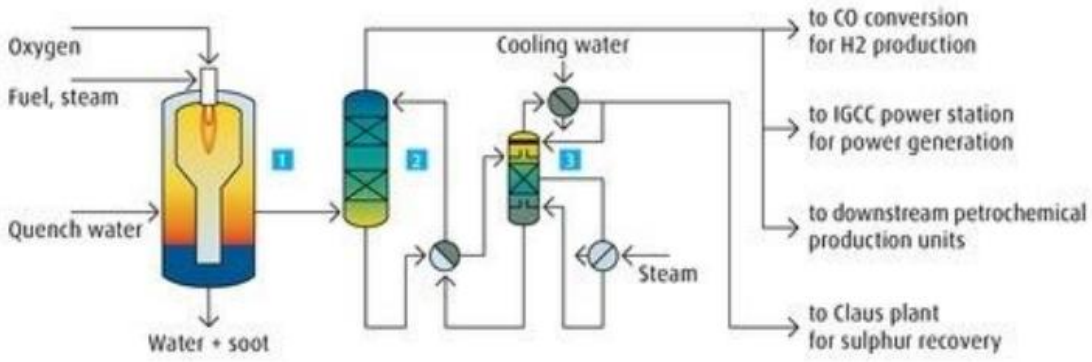
iii) **Pressure Swing Absorption**:-

-Carbon dioxide and other impurities are **removed** to leave pure hydrogen
-This step can reduce cost of production by 25% to 30%



II. **Partial Oxidation or Ceramic Membrane Reactor**:-

-Oxygen is separated from air,
-Natural or other **hydrocarbons** are reacted with **oxygen in a high-pressure reactor**
-Ratio of oxygen to carbon is set to avoid formation of soot.
-Reaction results in **CO** and **H2**
-Water-gas shift reaction yields more hydrogen
-Pressure-swing absorption results in pure hydrogen



1 Gasifier for residues, 2 Washing column for gasification gas, 3 Regeneration column

Partial oxidation reaction of natural gas

$$CH_4 + \tfrac{1}{2}\, O_2 \rightarrow CO + 2H_2 + Heat$$

Water-gas shift reaction

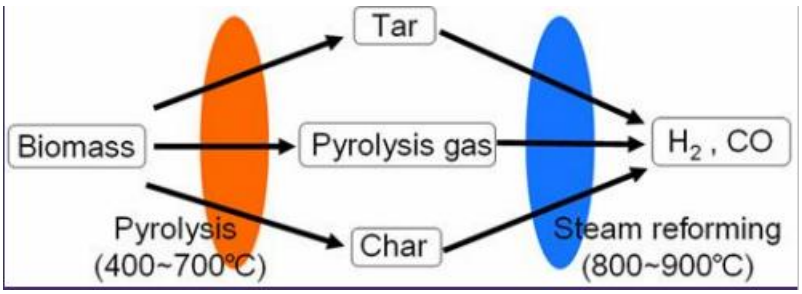
$$CO + H_2O \rightarrow CO_2 + H_2 + Heat$$

-Partial Oxidation process is an **exothermic process**
-Less efficient

.

III. **Biomass Gastrification and Pyrolysis**:-

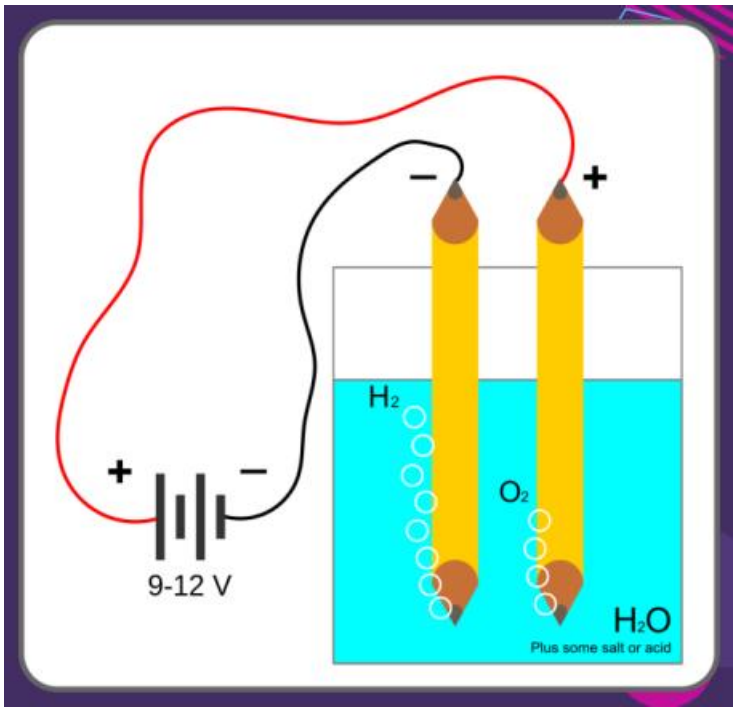
-**Biomass** is fed into the pyrolysis reactor
-This produces **organic vapours which are condensed** in the pyrolysis process
-In two-stage gastrification process **vapours are reformed into clean gas**.
-Gas is then **cooled to room temperature**.



*Electrolytic Production:-

I. **Water Electrolysis**:-

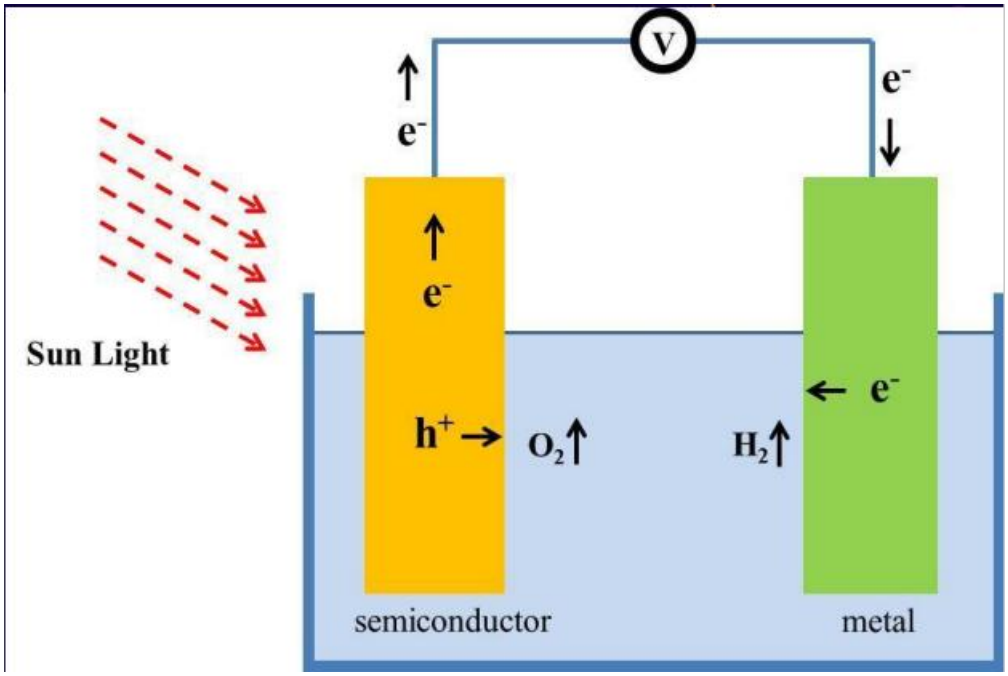
-Can be used with Photovoltaic and Wind with **electrolyser to produce hydrogen**.
-Supply from Photovoltaic or Wind is applied to electrodes immersed in an **electrolytic tank**.
-Hydrogen accumulates at cathode and oxygen at anode.
-Hydrogen is used as fuel for energy storage



- Can also be used on Steam, called '**Steam Electrolysis**'

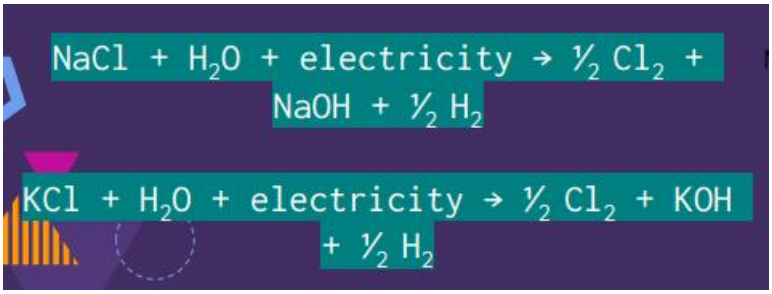
II. **Photo-Electrolysis**:-

-Photoelectrochemical(PEC) **light harvesting system is a multi-junction cell**.
-It produces **voltage** to split water into **hydrogen** and **oxygen**.
-Direct conversion hydrogen generation system,
-Highly Efficient

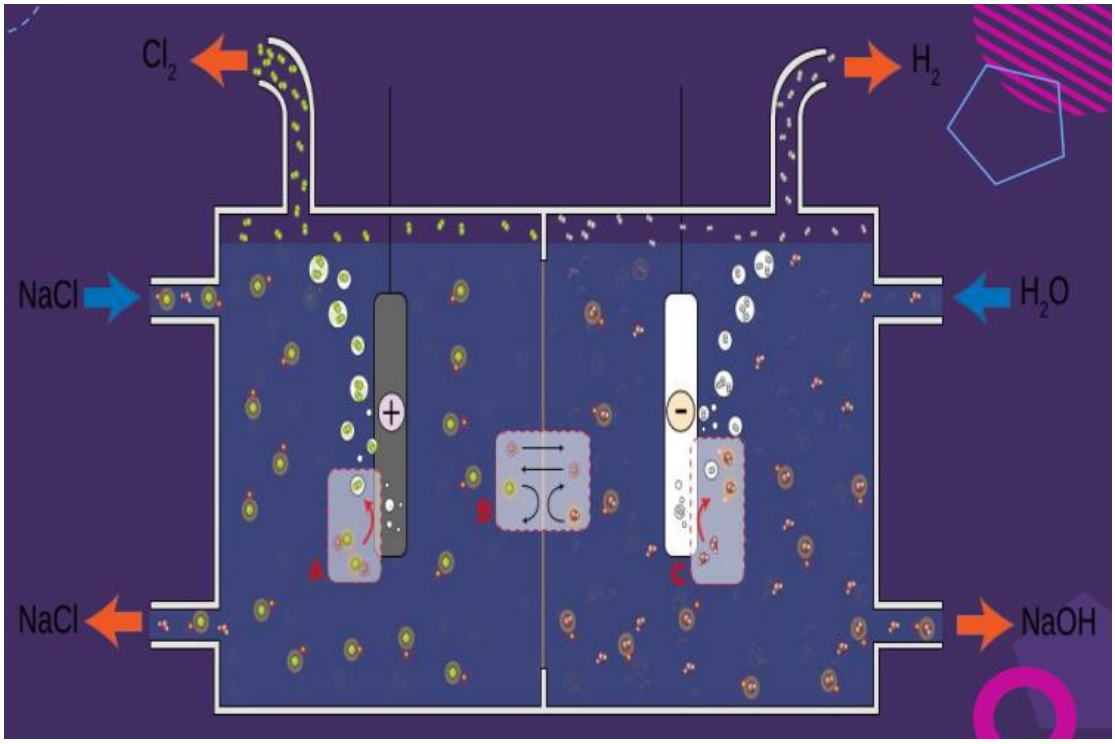


III. **By-Product of Sodium or Potassium Chloride Electrolysis**:-

-Chlorine is abundantly available.
-Hydrogen is a byproduct of sodium or potassium chloride on electrolysis



-This electrolysis produces caustic soda or potash



*Photolytic Production:-

I. **Photochemical Processes**:-

Uses two types of electrochemical system:-

Soluble Metal Complex dissolves and absorbs solar energy,
Results in electricity production which splits water same as photosynthesis process

Semiconductor Surface absorbs solar energy and act as electrodes.
When put in a photochemical cell they convert optical energy to chemical energy.
Light-induced corrosion limits life of semiconductor

II. **Biological and Photobiological Processes**:-

Uses algae and bacteria to produce hydrogen

Algae absorbs solar energy under specific condition.
Enzyme in cell acts as **catalyst to split water**

Bacteria requires substrate to grow on to **produce hydrogen**.
They clean pollution

Using **waste aluminium as catalyst** can produce **hydrogen** with alumina.
Alumina is used to produce back aluminium

Q6. a. Mention Various Advantages and Disadvantages of Waste Recycling. [06]

Recycling

• It is a heart of **waste to heath programme.** Waste disposal is a huge problem

•The **used** and **discarded materials** can be processed into **new product**.
>This will reduce the use of **primary source** and **waste collection**.
>It creates more local revenue, job collection, business expansion.

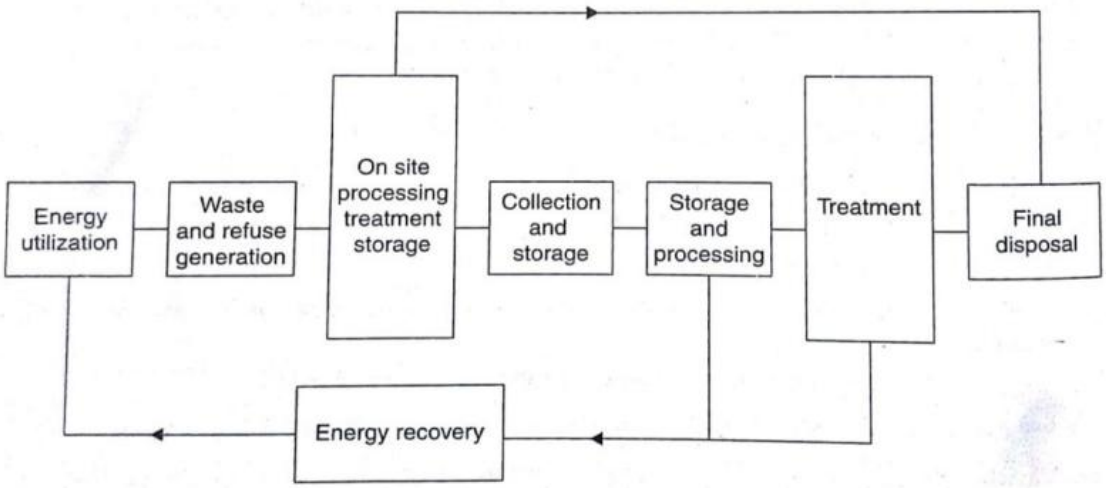
• Environment friendly and has many social benefits

Advantages	Disadvantages
Reduced damage to environment - Recycling used papers to reduce deforestation and conserving natural	High Cost of **recycling**

resources	
Reduces consumption of energy - excess energy is required to produce new products,recycling saves this energy by reducing use of raw materials and saves money	Durability and **small life span** of recycled items
Reduced environmental impact and pollution – recycling industrial polluting waste such as plastic and cans to save landfill space and keep surrounding clean	**Unsafe and unhygienic process** and sites
Mitigate global warming – recycling helps in controlling greenhouse gas emissions which are caused due to burning of fuel	
Promotes sustainable utilization of resources – recycling promotes sustainable and wide useof resources	

Q6. b. With a block diagram, explain waste recovery management scheme. [08]

WASTE RECOVERY MANAGMENT SCHEME



*Energy utility **generates non-organic waste**
*Through onsite processing treatment **waste is identified** and **separated** for efficient energy recovery.

***Collecting** and **transporting waste** is expensive and requires careful **cost analysis**

***Storing waste** and finally **disposing** it after treatment requires careful storage site selection.

*Two types of energy recovery systems are used:-

o **Separating metals**, papers and glass from remaining waste by size reduction, screening, vibrating sorting and electronic scanning processes

o **Converting** remaining **waste** to **usable form of energy**. Conversion includes:-
i. Generation of methane gas(biogas conversion) or other fuels(biological conversion)
ii. Generating electricity from (i) or by thermo-mechanical process
iii. Composting of fertilizers

TREATMENT

*Incineration or **pyrolysis methods of treatment**
*Final waste is systematically **buried in the ground**

Q6. c. With a neat diagram, explain working of double flash type geothermal electric power generation. [06]

Flash Geothermal power Plant:-

• Uses hot water above **180^{O}C -260^{O}C**

• The hot water at **high pressure** from the underground is **pulled using a pipeline** and when it reaches the surface it has **low pressure** then atmosphere this cause fluid to vaporize rapidly.

• The hot water is **flashed to flash tank** by lowering the pressure causing vaporized steam.

• Then this **steam is passed** to the **turbine** coupled to a generator.

Advantages	Disadvantages
+Very **low emission**	-High **initial cost**
+Safe, **Reliable**	-Increased risk of **seismic sensitive**
+Immune to change in **weather**	-Risk of over **exploiting resource**
+**Cost Effective**	
+**Sustainable**	
+Small **footprint**	
+No Fuel **Cost**	

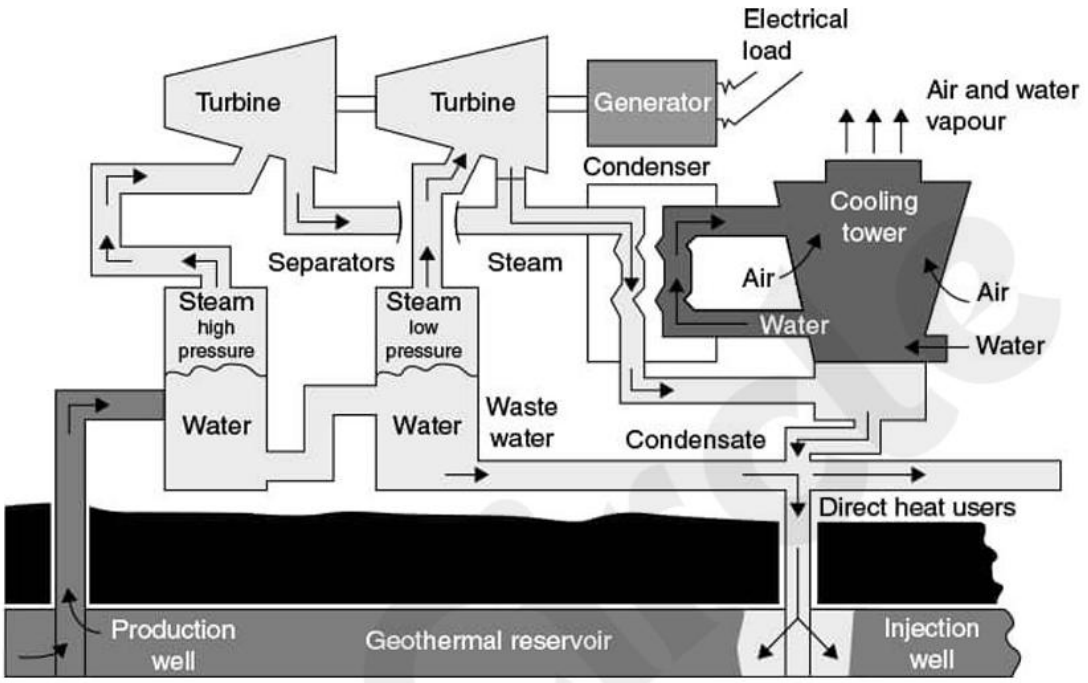


Figure 3.8 :Double-flash geothermal steam-electric power plant

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Module - 4

Q7. a. With a neat sketch explain updraft and downdraft gasifiers. [10]

*Gasification is an **incomplete combustion** of carbonaceous fuel.
*The process partially combusts **solid biomass**(pieces of wood or agricultural residue) **into combustible gases**.

*There are two distinct types of gasifiers:-
i) ***Fixed Bed Gasifier***:-
>In this gasifier, biomass fuels move either counter current or concurrent to the flow of gasification medium (steam, air, or oxygen) as the fuel is converted to fuel gas.
>They are relatively simple to operate and the air acts as the transfer medium.

ii) ***Fluidized Bed Gasifier***:-
>Sand, ash or char bed acts as the heat transfer medium

Fixed Bed Gasifier

Consists of three types:-

i) Updraft Gasifier

ii) Downdraft Gasifier

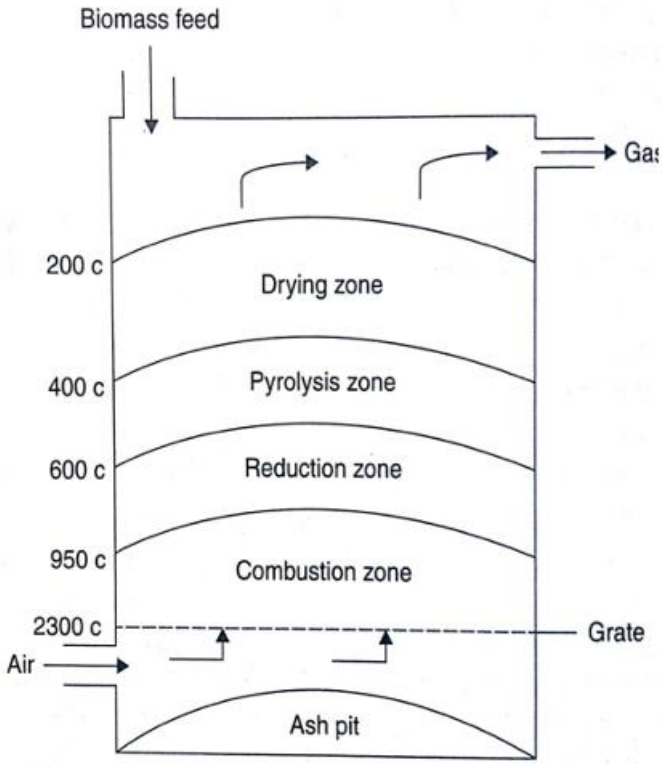
iii) Cross Draft Gasifier

i) Updraft Gasifier:-

-Also called counter current gasifier
Oldest, most efficient and simplest method of gasifier

-Reactive agent (steam i.e., **air**) is injected at **bottom** which ascends to top

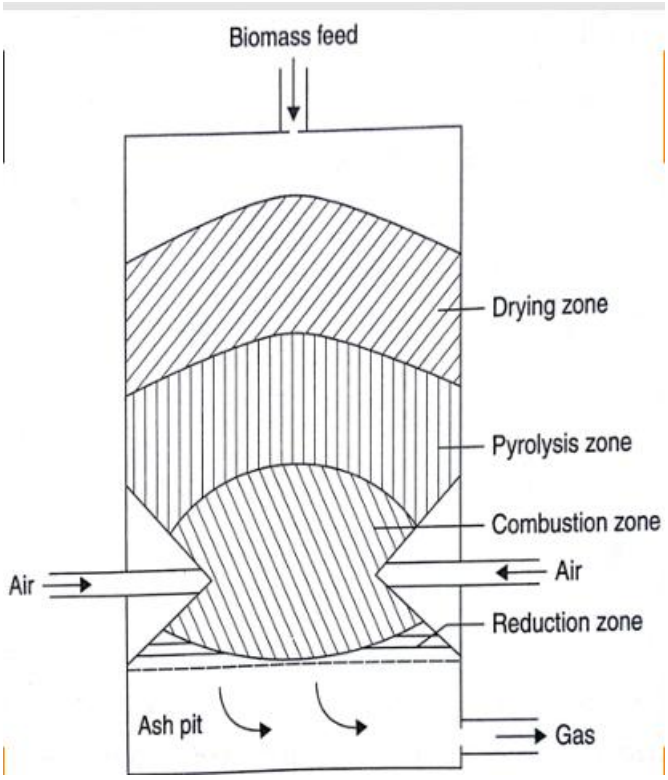
-**Biomass** is fed from **top** and descends to bottom
-**Combustion** occurs at the **bottom** (grate)
-**Reduction** follows it in **upper part** heating and pyrolysis takes place
-Gas and tar are dispersed to **top** of reactor
-Ash is removed from **bottom**
-Suitable for fuel with moderate dust
-**Not suitable for low density** fuels



*Used in:-
-Packaged Boilers
-Thermal fluid Heaters
-Alumnium melting
-All kinds of fryer roaster

ii) Downdraft Gasifier:-

- **Biomass** is fedfrom **top**
- **Air** is fed **above combustion zone**
- **Gases** are removed from bottom
- Air and biomass flow in **downward direction**
- **Raw product** is passed through **high temperature** zone to crack tar and oil into gaseous hydrocarbons
- This results in **clean gas** (good quality)
- 5 to 10 min start up time required to bring plant to operating temperature



Used in:-

o Continuous **baking ovens** (bread, biscuits and paint)
o Batch type baking oven (rotary oven for bread)
o **Dryers** and **curing** (tea, coffee, mosquito coil and paper drying)
o **Boilers**
o Thermal **fluid heaters**
o **Annealing** furnaces
o Direct feed **rotary kilns**
o ICE(Internal Combustion Engine)

Q7. b. Explain the single basin and two basin system of tidal power processing [10]

TIDAL POWER BASIN

*Basins are the most practical method to harness tidal energy
*It is created by **enclosing a portion of sea** behind erected dams

*When **High tide** the sluice is opened to allow the water to flow into the basin
*When **Sea water** level drops, water flows through **hydro turbine placed at the bottom** of the basin generating electricity

i) Single Basin System

• **Single water reservoir** is closed by constructing a dam or barrage
• **Gates (sluice)** are provided for **admitting water in the barrage** during high tide

1. *One-way single-basin system*:-
*The basin is **filled by seawater** passing through the **sluice gate** during the high tide period.

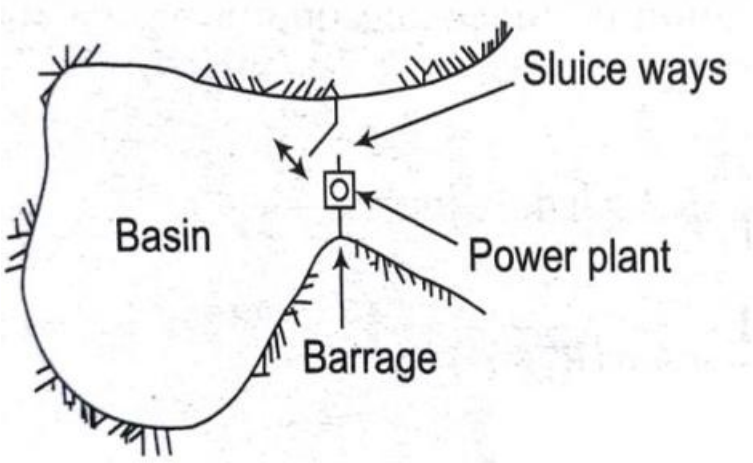
*When the water level in the basin is higher than the **sea level** at **low tide period**, then power is generated by emptying the basin water through turbine generators.

*This type of systems can allow power generation **only 7 for about 5 h** and is followed by the refilling of the basin.

*Power is generated till the **level of falling tides** coincides with the level of the next **rising tide**.

2. *Two-way single basin*:-
*This system allows power generation from the **water** moving **from the sea** to the basin, and then, at low tide, **moving back to the sea**.

*This process requires **bigger** and more **expensive turbine**.

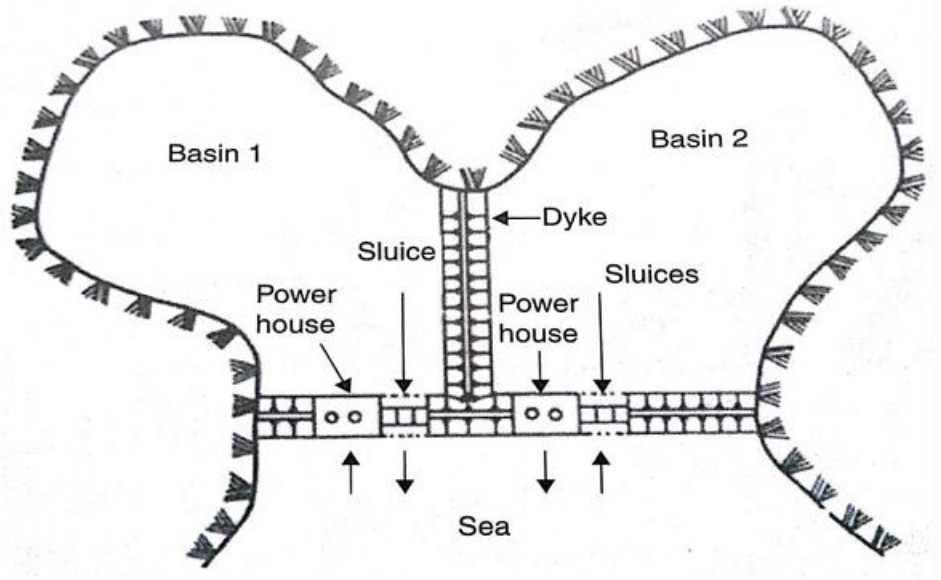


FLOOD GENERATION CYCLE

• Generates power during **filling of basin** with seawater
• **Sloping nature of basin** makes this method less productive
• Output is increased by pumping water during high tide to increase level of basin
• Excess energy including the energy used for Pumping energy is obtained during ebbing giving **net energy gain**.

ii) Two Basin System

*The two basins close to each other, operate alternatively.
>**One basin** generates power when the **tide is rising** (basin getting filled up) and the
>**other basin** generates power while the **tide is falling** (basin getting emptied).



FLOOD GENERATION CYCLE

-Inward, Sluicing to fill the Basin. Water is let into the **basin using the sluicing**
-Water is held(Holding Period)
-**Ebb Generation:** Power is generated on the Ebb
-Outward Sluicing to empty the Basin
-Water is held again (Holding Period)
-**Flood Generation**: Power is generated on the Flood

Cooperating Two-basin Systems:-

*This scheme consists of two **basins** at **different elevation** connected through the turbine
*The sluices in the high- and low-level basin **communication with seawater directly**

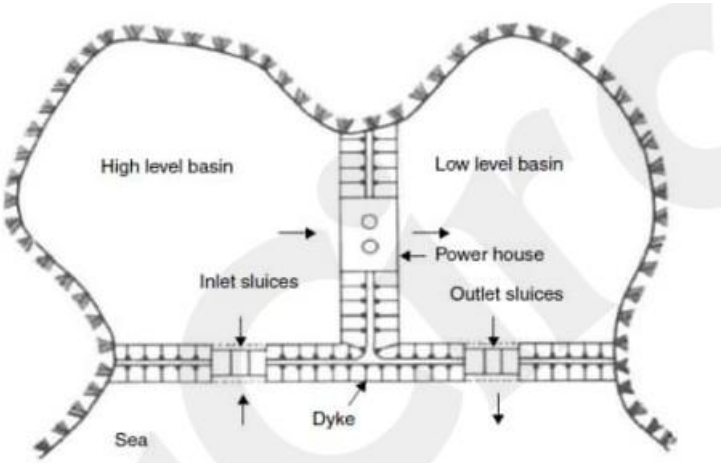


Figure 11.3 Co-operating two-basin systems

The basic operation of the scheme is as follows:

1. The **rising tide** fills the **high-level** basin through the sluiceways.

2. When the **falling seawater level** is EQUAL to the **water level in the high-level basin**, the sluiceways are CLOSED to prevent the outflowing high-level basin water back to the sea.

3. The water from **high-level basin** is then **allowed to flow** through the turbine generators to the **low-level basin**.

4. When the **falling seawater level** becomes **lower than the rising water level** in the low-level basin,
>The sluiceways are opened to **allow water to flow into the sea** from the low-level basin.
>This process continues until the water level in the **low-level basin** equals to the **rising sea level**.
Then, the sluiceways are closed to prevent the filling of low-level basin from the seawater.

*With two basins, one is **filled at high tide** and the other is **emptied at low tide**.
>**Turbines** are placed **between the basins** and between the basin and the sea.
>These two basin systems allow continuous **power generation**.

*However, they are very **expensive** to construct due to the cost of the **extra length**.

Q8. a. List the Advantages and Disadvantages of Tidal Power [10]

*Tides are periodic rises and falls of large bodies of water.
Gravity is one **major force** that creates **tides**.

ADVANTAGES & DISADVANTAGES OF TIDAL ENERGY

Advantages	Disadvantages
As 2/3rd of earth is covered with water so there is scope for large scale tidal energy	Capital and Investment cost is high
Prediction techniques for rise and fall of tides are well established	**Location specific** mostly on coastal regions
Tidal Energy have high energy density compared to other renewable sources.	Unpredictable intensity of sea waves can cause damage to power generating units
Clean source of energy	Influences aquatic life disrupting **migration of fish**
No need of harnessing from other source and does not require much land	Energy generated is not much as high since low and high tides occur **only twice a day**
Inexhaustible source of energy	More technological advancement needed for commercial usage
Environmentally friendly with no greenhouse effects	Can produce electricity for **12h 25m**
80% efficiency; Far Greater compared to coal, solar and wind.	

Running and maintenance cost is low	
Very long plant life	

Q8. b. Explain the Construction of Biogas plant with a neat sketch [10]

*Anaerobic processes either occur naturally or created in a controlled environment, namely a biogas plant in which organic wastes are put in an **airtight container** called **digester** to perform **anaerobic digestion process**.

CONSTRUCTION OF BIOGAS PLANTS

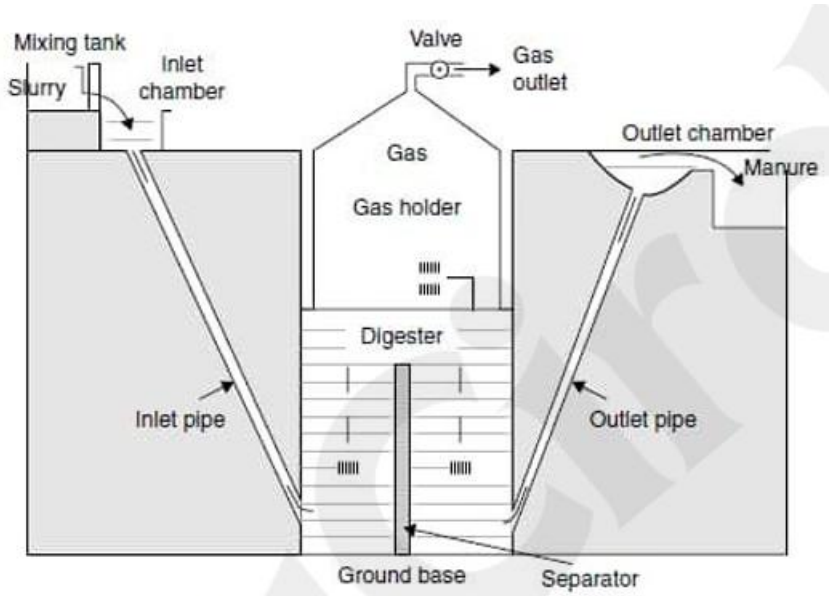


Figure 10.2 A typical biogas plants

Figure shows various parts of a typical biogas plant.
it is a brick and cement structure having the following five sections:-

1. Mixing Tank
2. Digester Tank
3. Dome or Gas Holder

4. Inlet Chamber
5. Outlet Chamber

Mixing Tank

*It is the first part of biogas plants located above the ground level in which the >**water** and **cow dung** are mixed in **equal proportions** (the ratio of 1:1) to form the *slurry* that is fed into the inlet chamber.

Digester Tank

*It is a deep underground **well-like structure** and is divided **into two chambers** by a partition wall in between.

*It is **cylindrical in shape** and made up of **bricks**, **sand**, and **cement** built underground over the solid foundation.

*Two **openings are provided** on the opposite sides and at the specified height of digester for
>**inflow** of **fresh cow dung slurry** and
>outflow of used **slurry** as manure:-

1. **Inlet pipe** opening into the inlet chamber for **inputting the slurry** in digester tank

2. **Outlet pipe** opening into the **overflow tank**(outlet chamber) for the **removal of spent slurry** from the digester tank.

A ***separator*** is also placed in the middle of digester tank to improve effective fermentations of feedstock

Dome or Gas Holder

-The **hemispherical top portion** of the digester is called *dome*.
-It has fixed height in which all the **gas generated** within the digester is **collected**.
-The gas collected in the dome exerts pressure on the slurry in the digester.

-The dome or gas holder is made either **fixed dome** or **floating dome type**:-
>Cement and bricks are used in the construction of **fixed dome**, and it is constructed using approximately at the ground surface.

>Floating dome type is an **inverted steel drum** resting on the digester above the ground surface.
The drum **floats over the digester** and moves up and down with **biogas pressure**.

Inlet Chamber

*The **cowdung slurry** is supplied to the digester of the biogas plant via **inlet chamber**, which is made at the ground level so that the slurry can be poured easily.

*It has **bell mouth sort of shape** and made up of bricks, cement, and sand

Outlet Chamber

*The **digested slurry** from the biogas plants is **removed through the outlet chamber**.
-The opening of the outlet chamber is also at the ground level.
-The slurry from the outlet chamber flows to the pit made especially for this purpose

Gas Outlet Pipe and Valve

*The **gas holder** has an **outlet at the** top which could be connected to **gas stoves** for cooking or gas-lighting equipment or any other purpose

*Flow of the gas from the dome via gas pipe can be **controlled** by the **valve**.

*The gas taken from the **pipe** can be **transferred to** the **point of use**.

Foundation

*The foundation forms the base of the digester where the most important processes of biogas plant occur.

*It is made of **cement**, **concrete** and **bricks** strong enough so that it should be able to provide stable foundation for the digester walls and be able to sustain the **full load** of slurry filled in it.

*The foundation should be **waterproof** so that there is **no percolation** and leakage of water.

Module - 5

Q9. a. Explain the devices used for harnessing wave energy [10]

*The energy in ocean waves mainly comes in an **irregular** and **oscillating** form at all times of the day and night.

*Solar energy causes **winds to blow over vast ocean areas**, which in turn **cause waves** to form, gather and travel huge distances to the shoreline of continents

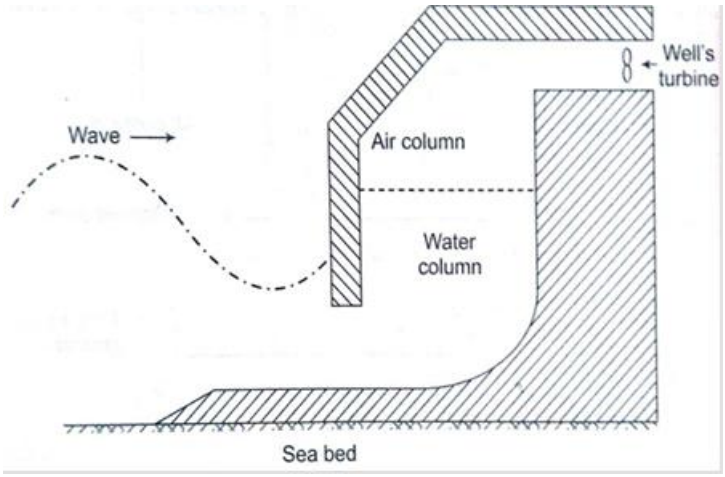
DEVICES FOR HARNESSING WAVE ENERGY

There are different technologies for converting wave energy to electricity.

Four basic technologies exist for converting wave energy to electricity

TERMINATOR DEVICES

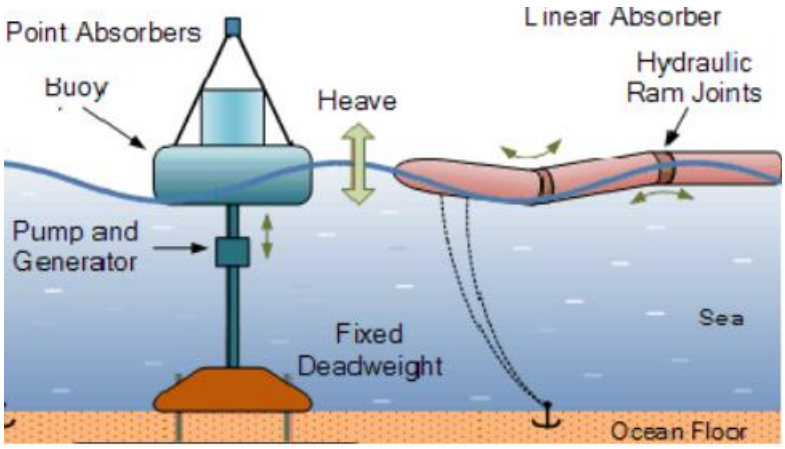
• Device is oriented **perpendicular to the direction of the wave**
• It has **one stationary and one moving part**
• Moving part **moves up and down** like a car piston in response to ocean waves and pressurizes air or oil to drive a turbine
• **Oscillating Water Column (OWC)** converter is an example
• Power rating– 500 kW to 2 MW



ATTENUATOR DEVICES

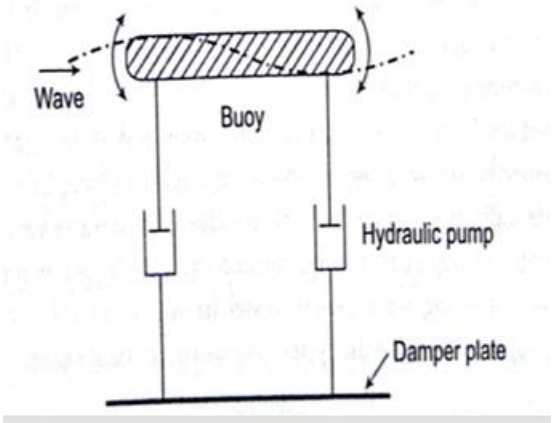
• Long **multi-segment floating structures**
• Oriented parallel to the direction of waves
• Long cylindrical floating devices connected to each other with hinges and anchored

to the seabed
• They **ride the waves like a ship**
• They extract **energy by using restraints at the bow of the device** and along its length
• The segments are connected to hydraulic pumps or other converters to generate power
• Pelamis wave energy converter is an example



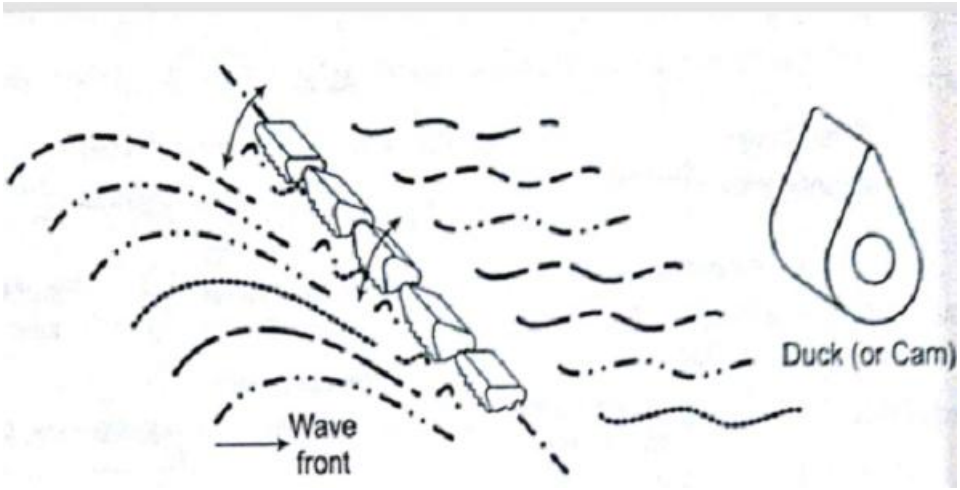
POINT ABSORBER

• Floating structure with **parts moving relative to each other** owing to wave action
• Absorbs wave energy coming from any direction (no orientation)
• Uses **rise and fall of wave height at a single point** for energy conversion
• Pressurized water creates up and down bobbin type motion and drives a built-in turbine generator system to generate electricity
• AquaBuOY WEC(WaveEnergy Converter) is an example



OVERTOPPING DEVICES

• They have **reservoir like dams** that are filled by incoming wave
• It causes slight **built-up of water pressure**
• Gravity causes released water from reservoir **to flow back into the ocean through turbine coupled** to an electric generator.
• Salter Duck WEC is an example



Q9. b. What are the advantages, disadvantages and benefits of OTEC. [10]

***Ocean Thermal Energy Conversion(OTEC)** is a technology that uses the temperature difference between warm surface water and cold deep ocean water to produce electricity.

ADVANTAGES AND DISADVANTAGE

Advantages	Disadvantages
1. Ocean thermal energy is a **renewable**, clean **natural resource** available in abundance.	1. ***High cost***: Electricity generated by OTEC plants is **more expensive** than electricity produced by chemical and nuclear fuels.
2. It is **pollution-free** and has no	2. ***Complexity***: OTEC plants must be

greenhouse effects.	located where a difference of about 20°C occurs year round. Ocean depths must be available fairly **close to shore-based facilities** for economic operation. Floating plant ships could **provide more flexibility**.
3. It is a good source of **freshwater** and **portable water**.	3. ***Acceptability***: For the large-scale production of electricity and other products, OTEC plants are **poorly acceptable** due to their high costs.
	4. ***Ecosystem damage***: It is obvious by setting OTEC plants.
	5. ***Lower efficiency***: A higher temperature difference between ocean surface warm water and cold deep ocean water is required for highly efficient operation of plant.

BENEFITS OF OTEC

*Economic and other benefi ts are the value of OTEC plants. These include the following:-

1. It is a **clean**, **renewable** natural resource available in **plenty**.

2. It has **no environmental problems** and greenhouse effects.

3. It is a source of **base load electricity** and fuels such as **hydrogen**, **methanol**, and **ammonia**.

4. It provides **freshwater** for **drinking**, **agriculture**, and **industry**.

5. It encourages **chilled agriculture** and **aquaculture**.

6. **Self-sufficiency**, **no environmental effects**, and **improved sanitation** and **nutrition** are the added benefits for island.

Q10. a. Explain the working of oscillating water column device for harnessing sea wave energy. [10]

*The energy in ocean waves mainly comes in an **irregular** and **oscillating** form at all times of the day and night.

*Solar energy causes **winds to blow over vast ocean areas**, which in turn **cause waves** to form, gather and travel huge distances to the shoreline of continents

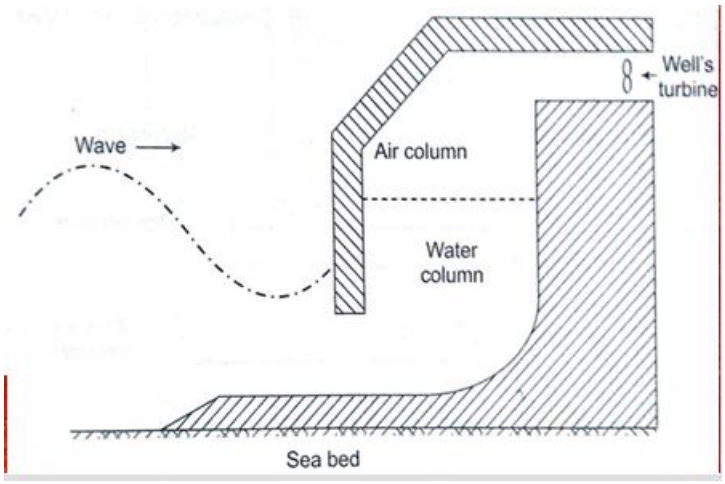
*The wave **height**, **period**, and **direction** are primarily dependent:-
>The **wind properties** (speed, direction, and duration) and
>The **geometry of the sea** (fetch length and depth).

OSCILLATING WATER COLUMN

• **Shoreline** based device
• Concrete structure **partially submerged** in sea water
• Encloses a **column of air** on top of a **column of water**
• When water columns in the chamber rise and fall it compresses and depressurizes column allowing it to flow **to** and **from** the atmosphere through **turbine**

• Axial flow well's turbine which operates with **either direction of flow** (and rotates in same direction irrespective of direction of air flow)

• This **turbine** drives the **generator** which is used to **extract energy**



ADVANTAGES

• **Air velocity** is **increased** by **reducing cross section** area of air channel.
>Thus **slow wave** motion can be coupled to **high speed turbine** motion

• Generating equipment's are kept **away** from **immediate saline water** environment

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Q10. b. Explain open cycle and closed cycle OTEC techniques. [10]

***Ocean Thermal Energy Conversion(OTEC)** is a technology that uses the temperature difference between warm surface water and cold deep ocean water to produce electricity.

*The sun **heats the surface of the ocean**, especially in tropical regions between Tropic of Cancer and Tropic of Capricorn.
Meanwhile, **deep ocean water stays cold**

*So, OTEC works best in warm ocean areas, and it turn the ocean's heat into a renewable source electricity.

*The Rankine Cycle is a thermodynamic cycle of a **constant pressure heat engine** that converts **heat into electricity**.

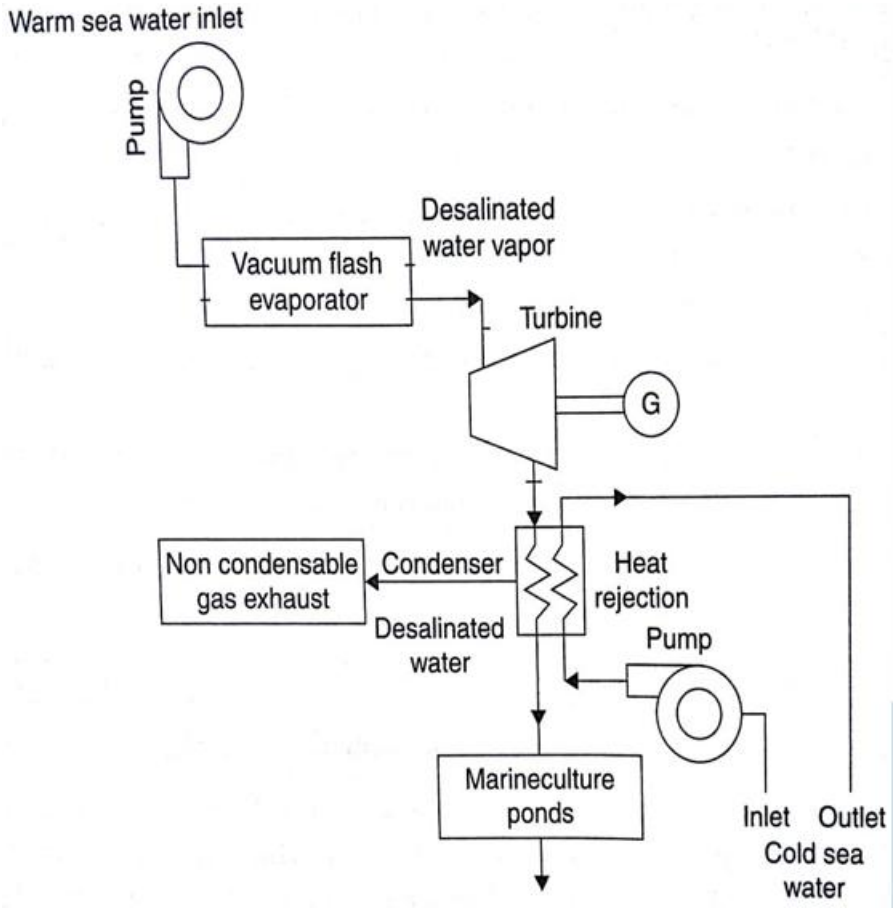
There are two variations of the Rankine Cycle:-

i) *Open Cycle OTEC* and
ii) *Closed Cycle OTEC*

OPEN CYCLE OTEC

*An open-cycle OTEC uses the warm ocean surface water as working fluid.
It is a **non-toxic** and **environment friendly fluid**.

The major components of this system



*<u>The working principles of open-cycle OTEC plants are explained as follows</u>:-

1. The **warm ocean surface water** is pumped into **flash evaporator** where it is **partially flashed into steam** at a very **low pressure**.
>The remaining warm sea water is discharged into the sea.

2. The **low-pressure vapour(steam)** expands in **turbine** to drive a coupled **electrical generator** to produce electricity.

>A portion of electricity generated is consumed in plants to run pumps and for other work, and the remaining large amount of electricity is stored as net electrical power.

3. The **steam** with many gases (such as oxygen, nitrogen, and carbon dioxide) **released** from the turbine separated from sea water in an evaporator is **pumped into condenser**.
The steam is **cooled in a condenser** by cold **deep sea water**.

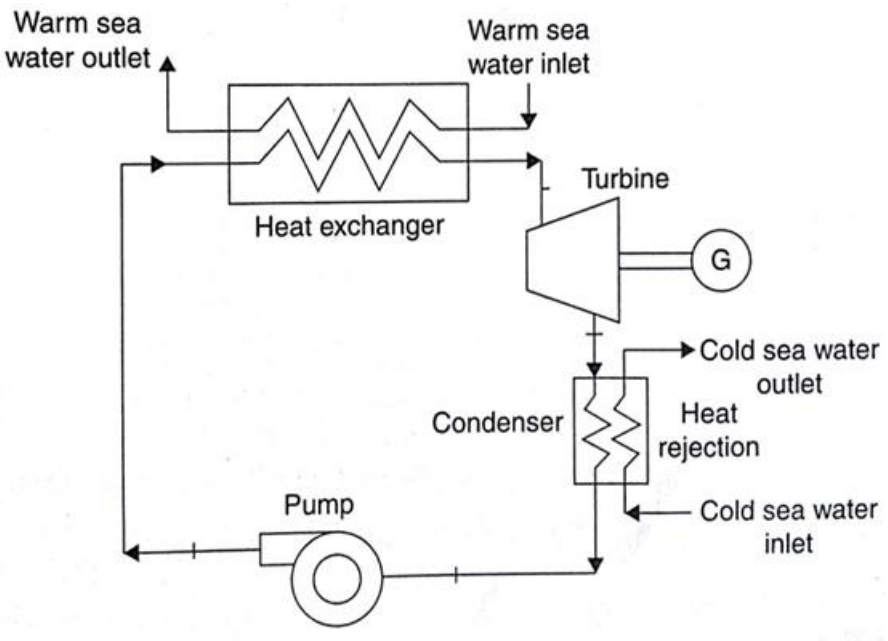
4. The **condensed non-saline water** is **discharged** either directly in deep sea cold water or through the marine culture pond.

5. The **non-condensable gases** are compressed to pressure and **exhausted simultaneously**.

6. The **warm ocean** surface water is continuously pumped into **evaporator** and **cycle repeats**.

CLOSED CYCLE OTEC

*The schematic of closed-cycle OTEC is shown in the FIgure, It has a different arrangement when compared to open-cycle OTEC



*Working principles of closed-cycle OTEC are as follows:-

1. Working **fluid is pumped** through **heat exchangers** in a closed loop cycle which is perfectly leakage proof.

2. Warm **sea surface water** is pumped through **separate pipe** in heat exchanger in close contact with fluid closed loop cycle

3. Warm sea water transfer its **heat energy to working fluid** in heat exchanger and working **fluid vaporizes**.

4. The **fluid vapour makes the turbine to rotate** and drive an electrical generator to produce electricity.

5. Fluid vapour **leaving the turbine** is **cooled** and condensed as liquid fluid and is pumped again to repeat cycle.

6. **Cold deep-sea water** is pumped through a **separate pipe** in **condenser** for providing **efficient cooling** of **working fluid**.
