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UNIT-V

MISCELLANEOUS ENERGY TECHNOLOGIES

CLASS-IV-I SEM

Subject: RENEWABLE ENERGY SYSTEMS

SYLLABUS

UNIT V---> MISCELLANEOUS ENERGY TECHNOLOGIES

Ocean Energy:

Tidal Energy-Principle of working, performance and limitations.

Wave Energy-Principle of working, performance and limitations.

Bio mass Energy: Biomass conversion technologies, Biogas generation plants, Classification, advantages and disadvantages, constructional details, site selection, digester design consideration

Fuel cell: Principle of working of various types of fuel cells and their working, performance and limitations.

OCEAN ENERGY

Ocean energy refers to all forms of renewable energy derived from the sea. There are three main types of ocean technology

- **Ocean Thermal Energy Conversion (OTEC)**
- **Tidal Energy**
- **Wave Energy**

All forms of energy from the ocean are still at an early stage of commercialization.

INTRODUCTION

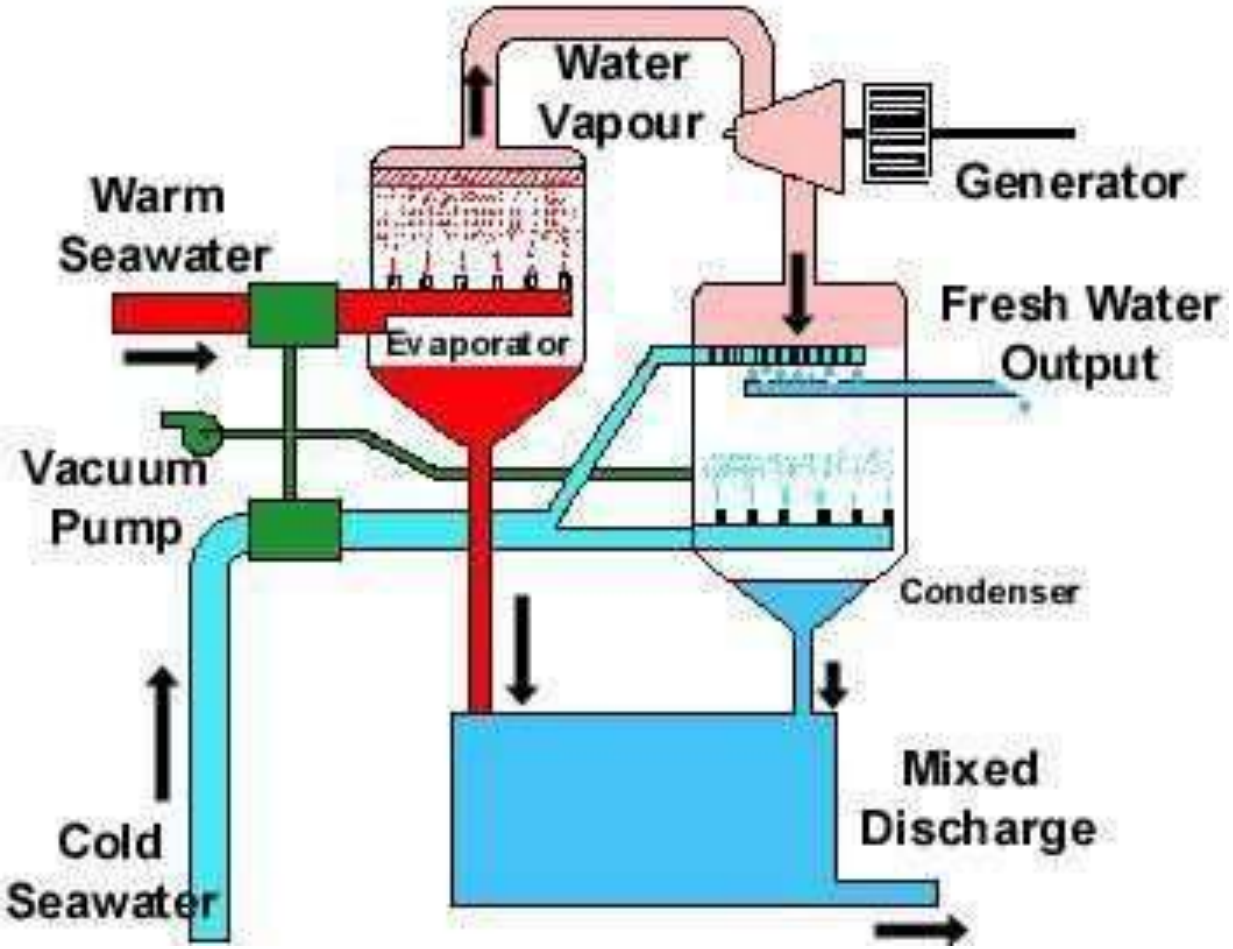
- Ocean thermal energy conversion (OTEC) uses the temperature difference between cooler deep and warmer shallow or surface seawaters to run a heat engine and produce useful work, usually in the form of electricity.

- OTEC is a base load electricity generation system. Even though the temperature differential and the thermal efficiency are low, it is good for power generation.

WORKING PRINCIPLE

- The operation of otec is based on thermodynamic principle.
- If a heat source is high temperature and a heat sink at lower temperature, this temperature difference can be utilized in a machine to convert it into mechanical energy and thereby into electrical energy.
- In the otec system, the warm ocean surface is the heat source and the deep colder water provides the sink.

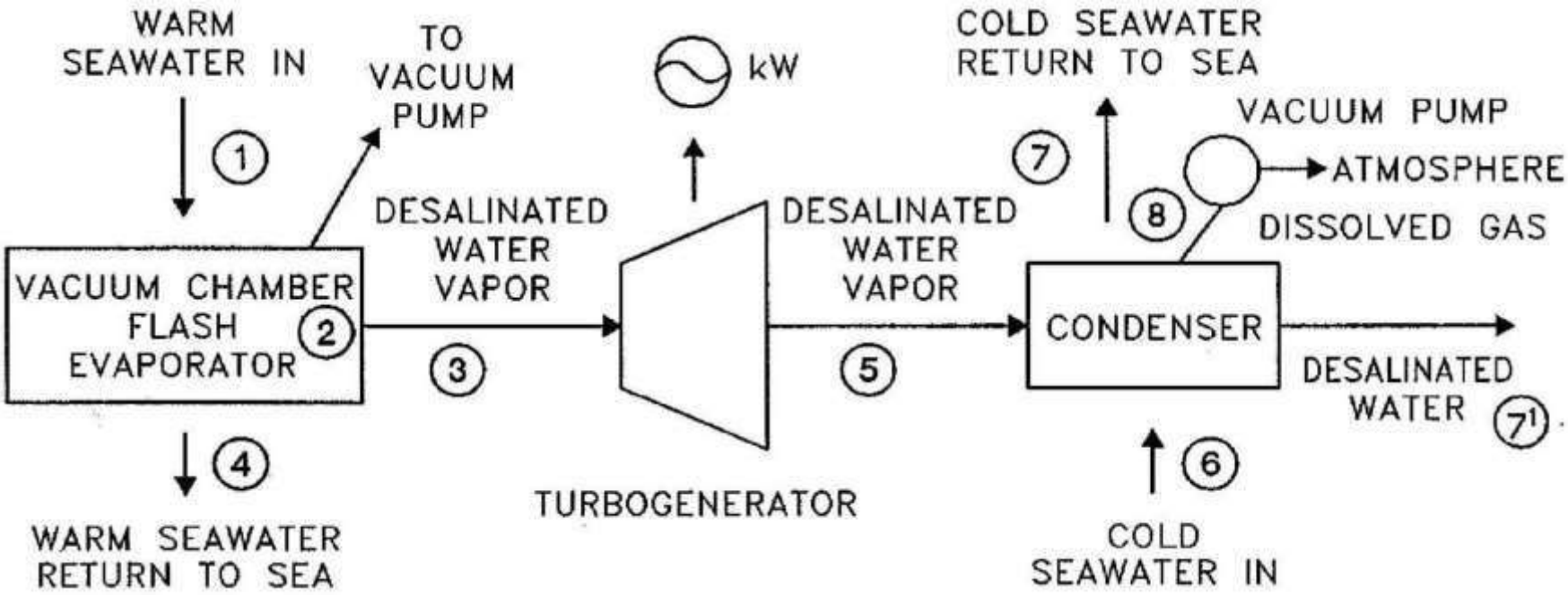
Open Cycle


Water
Vapour
Generator
Warm
Seawater
Evaporator
Fresh Water
Output
Vacuum
Pump
Condenser
Mixed
Discharge
Cold
Seawater

OPEN (CLAUDE) CYCLE

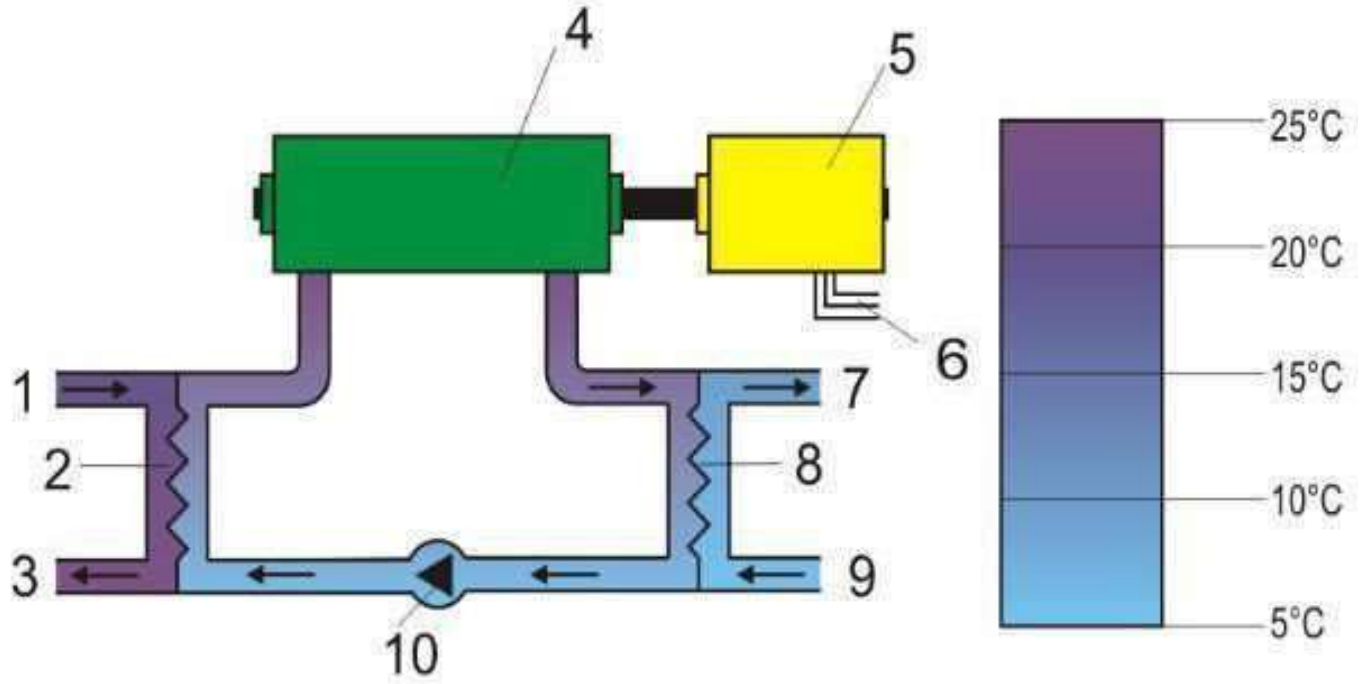
- Open-cycle OTEC uses the tropical oceans' warm surface water to make electricity.
- When warm seawater is placed in a low-pressure container, it boils.
- The expanding steam drives a low-pressure turbine attached to an electrical generator.
- The steam, which has left its salt behind in the low-pressure container, is almost pure fresh water. It is condensed back into a liquid by exposure to cold temperatures from deep-ocean water.

Open cycle


WARM SEAWATER IN
1
TO VACUUM PUMP
kW
COLD SEAWATER RETURN TO SEA
VACUUM PUMP
7
ATMOSPHERE
8
DISSOLVED GAS
VACUUM CHAMBER FLASH EVAPORATOR
2
DESALINATED WATER VAPOR
3
DESALINATED WATER VAPOR
5
CONDENSER
DESALINATED WATER
7'
4
TURBOGENERATOR
6
WARM SEAWATER RETURN TO SEA
COLD SEAWATER IN

CLOSED (ANDERSON) CYCLE

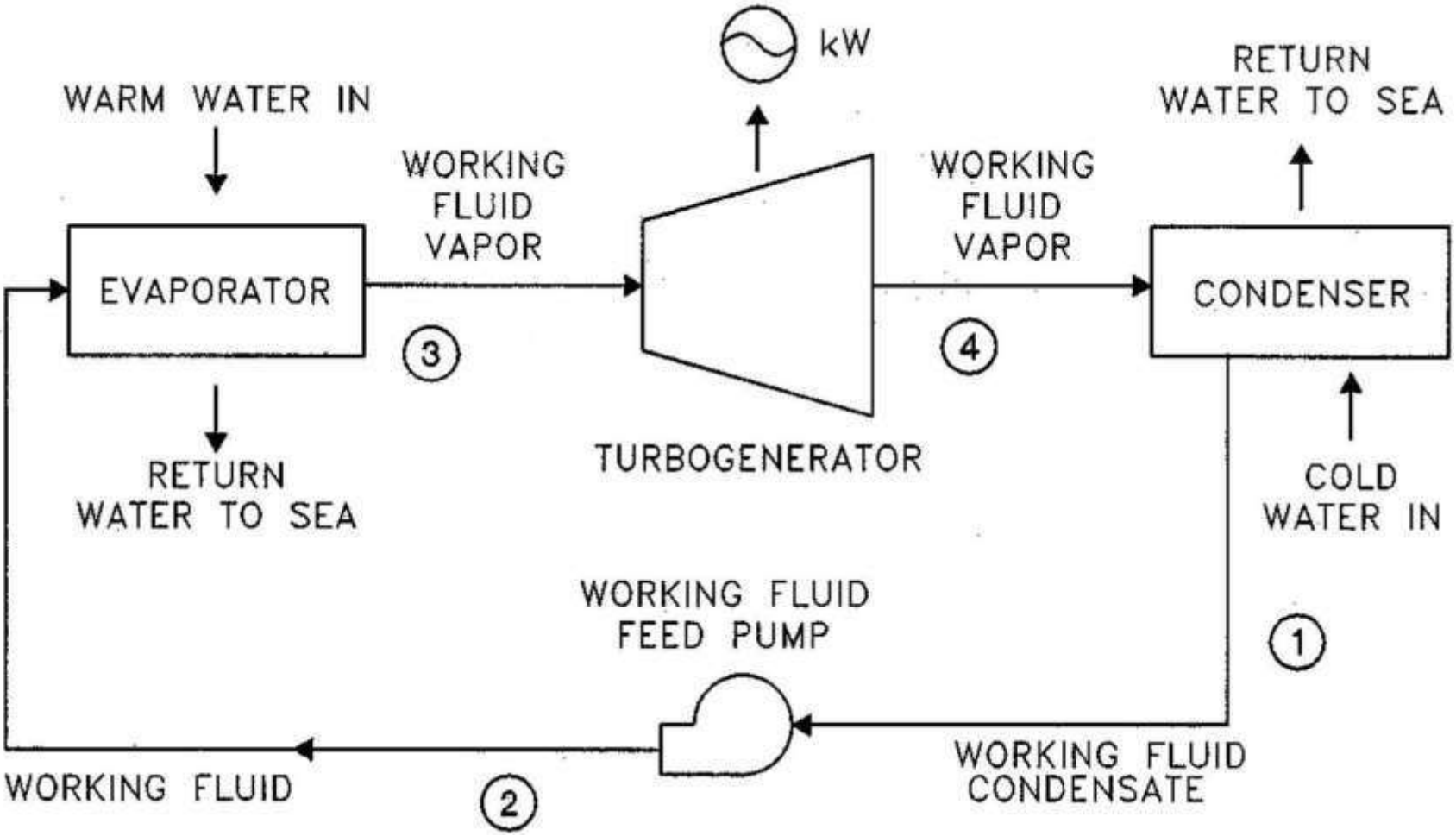
- Closed-cycle systems(Rankine) use fluid with a low-boiling point, such as ammonia, to rotate a turbine to generate electricity.
- Warm surface seawater is pumped through a heat exchanger where the low-boiling-point fluid is vaporized. The expanding vapor turns the turbo-generator. Then, cold deep seawater is pumped through a second heat exchanger which condenses the vapor back into liquid, which is then recycled through the system.



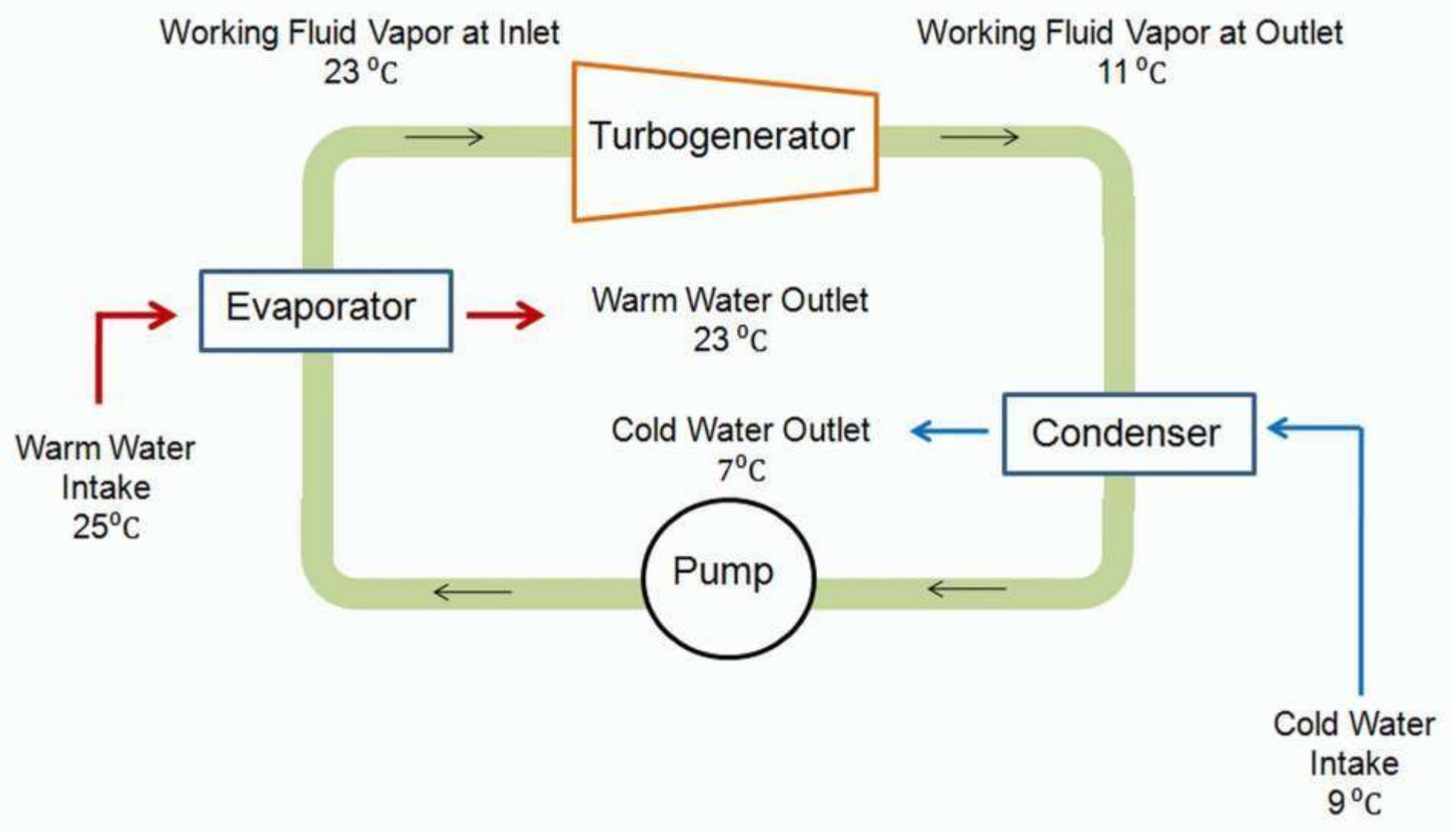
1 Surface water ~ 25°C
2 Evaporator
3 Waste water ~ 23°C
4 Turbine
5 Generator

6 Line to the grid
7 Waste water ~ 7°C
8 Condenser
9 Deep water ~ 5°C
10 Circulation pump

Closed Cycle



- The operation of a closed-cycle OTEC plant, using anhydrous(moisture less) ammonia as the working fluid. Figure shows a simplified flow diagram of the CC-OTEC cycle. The analysis of the cycle is straightforward. Based on a unit mass flow rate of ammonia vapor (kg s^{-1}) in the saturated cycle


Working Fluid Vapor at Inlet
23 °C
Working Fluid Vapor at Outlet
11 °C
Turbogenerator
Evaporator
Warm Water Outlet
23 °C
Warm Water
Intake
25°C
Cold Water Outlet
7°C
Condenser
Pump
Cold Water
Intake
9 °C

Advantages of OTEC

1. OTEC uses clean, renewable, natural resources. Warm surface seawater and cold water from the ocean depths avoid the usage of fossil fuels to produce electricity.
2. Suitably designed OTEC plants will produce little or no carbon dioxide or other polluting chemicals.
3. OTEC systems can produce fresh water as well as electricity. This is a significant advantage in island areas where fresh water is limited.
4. Minimum maintenance compared to other power production plants.
5. The use of OTEC as a source of electricity reduces the dependence on imported fossil fuels.

Disadvantages of OTEC

1. OTEC-produced electricity at present would cost more than electricity generated from fossil fuels at their current costs.
2. OTEC plants must be located where a difference of about 20^{o}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. No energy company will put money in this project because it only had been tested in a very small scale.
4. Construction of OTEC plants and lying of pipes in coastal waters may cause localized damage to reefs and near-shore marine ecosystems.
5. Construction of floating power plants is difficult.
6. Plant size is limited to about 100 MW due to large size of components.
7. Very heavy investment is required.

OTEC System Applications

- Electricity Production
- Desalinated Water
- Refrigeration and Air-Conditioning
- Mineral Extraction

Tidal power introduction

What is tidal power?

- Tide is periodic rise and fall of the water level of the sea. Tides occur due to the attraction of seawater by the moon. These tides can be used to produce electrical power which is known as tidal power.
- When the water is above the mean sea level, it is called flood tide and when the level is below the mean level, it is called ebb tide. A dam is constructed in such a away that a basin gets separated from the sea and a difference in the water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices and turbine respectively. The Potential energy of the water stored in the basin is used to drive the turbine which in turn generates electricity as it is directly coupled to an alternator.

8.3.2. Tidal Range (R)

The tidal range is the difference between consecutive high tide and low tide water level. It is denoted by R and is measured in metres.

Tidal energy refers to the potential energy in the tidal range.

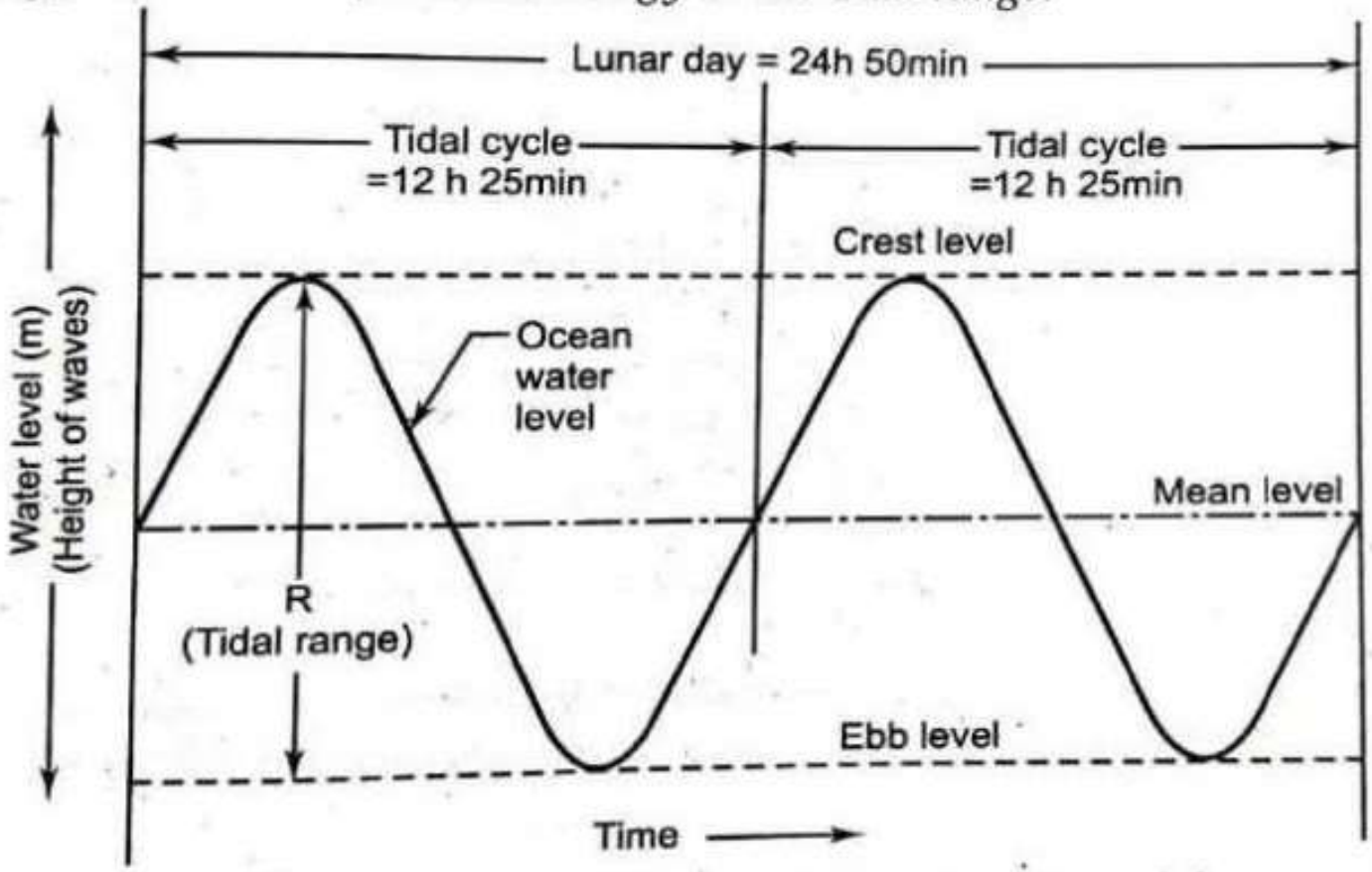


Fig. 8.1. Tidal range [Daily (diurnal) tides].

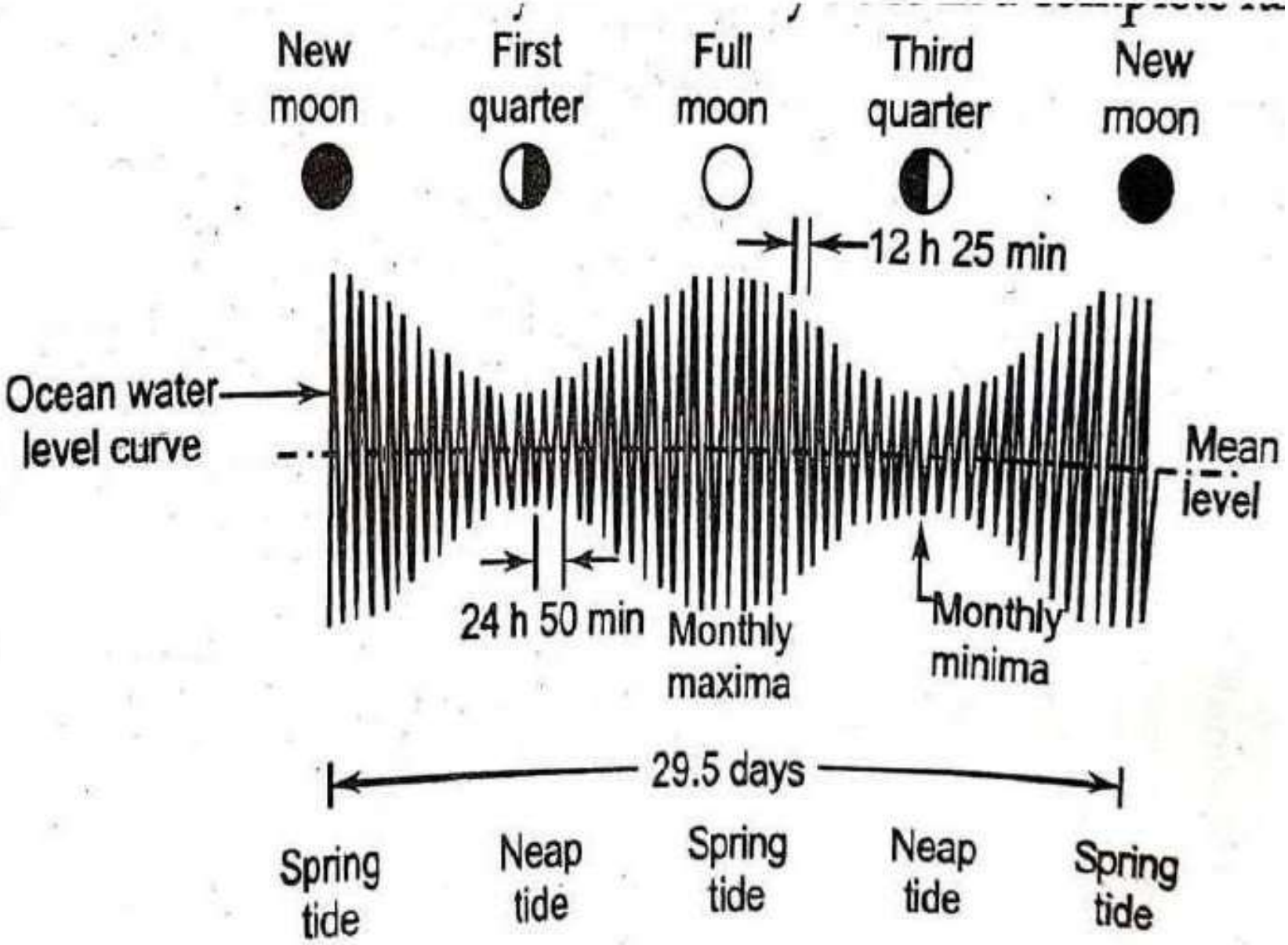


Fig. 8.3. Record of daily and monthly tides.

Note

1. Over a month the daily tidal ranges vary systematically with the cycle of the Moon.

2. Tidal range is also altered by the shape of a basin and sea floor configuration.

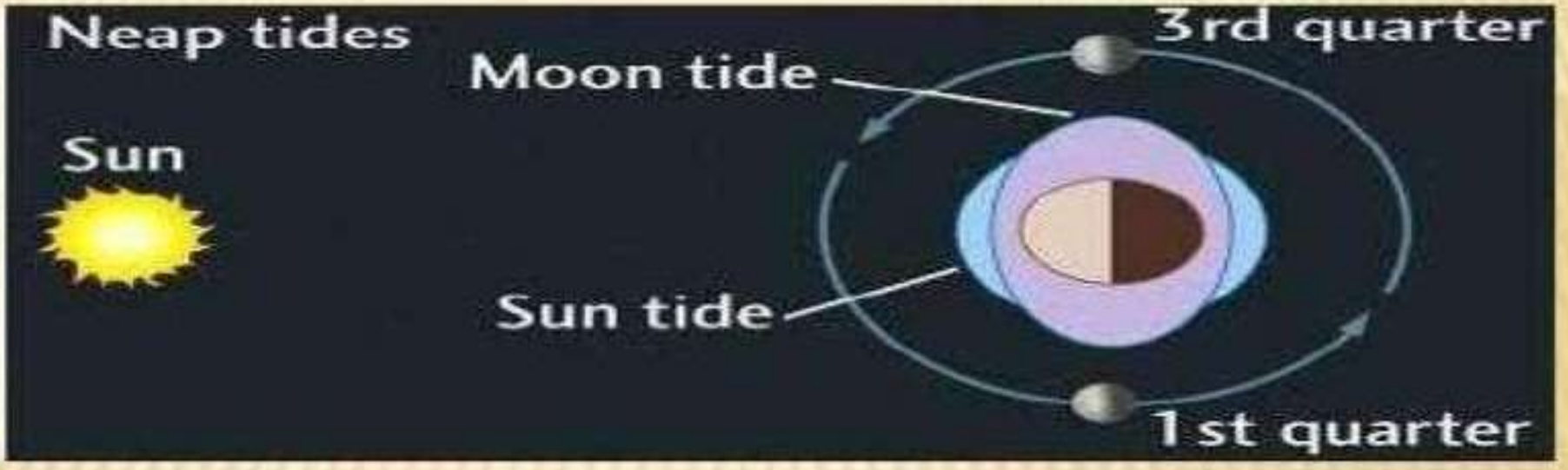
HOW THE TIDES COME AND GO ?

- The gravitational force of the moon causes the oceans to bulge along an axis pointing directly at the moon. The magnitude of this attraction depends on the mass of the object and its distance away .

SPRING TIDES

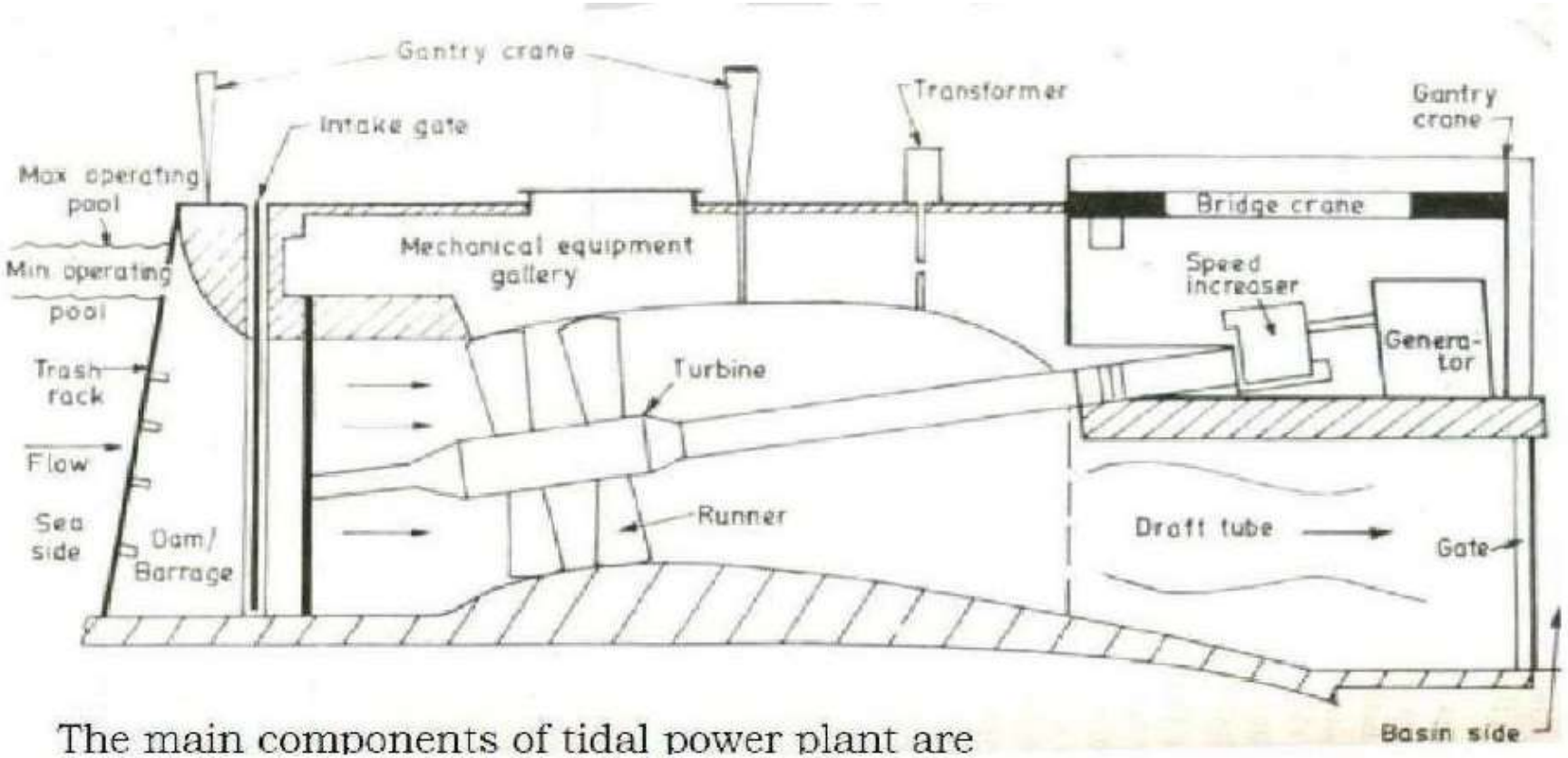
- When the sun and moon are in a line their gravitational attraction on the earth combine and cause a "spring" tides.

NEAP TIDES



- When they are as positioned in 90° from each other, their gravitational attraction each pulls water in different directions, causing a "neap" tides.

Components of a tidal power station



The main components of tidal power plant are

Components of a tidal power station

(i) Power House
(ii) The Dam or Barrage
(iii) Sluice ways from basin to sea and vice versa

DAM (Barrage):

- The barrages store water behind them.
- The barrages should provide channels for the turbines, gates and locks.
- The tidal power barrages should be of shorter length.
- The length should be less than resonant length of tidal waves. The tidal barrages require sites where a sufficiently high tidal range is available.
- The barrages require flat bottom.

POWER HOUSE

- Large size turbines are needed to because of small head available.
- Hence power house will also be large structure.

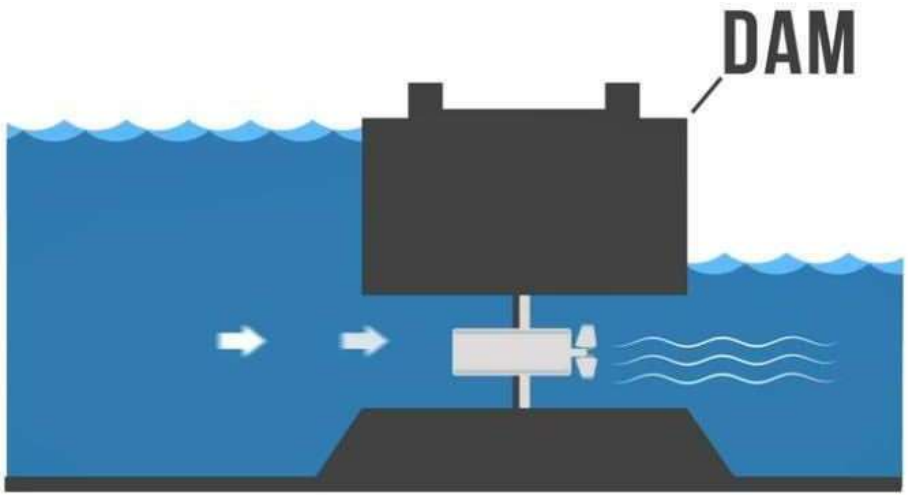
The types of turbines used are

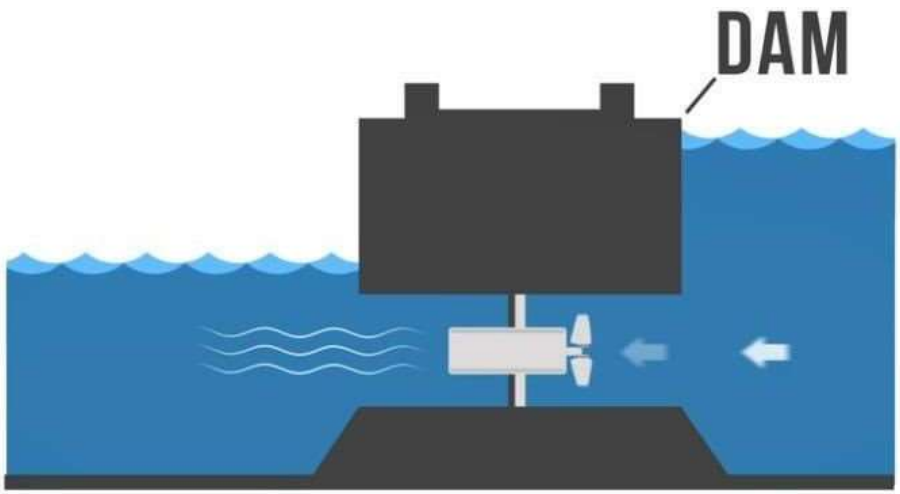
- Bulb type:
- Rim type:
- Tubular type:

Types of tidal power plants

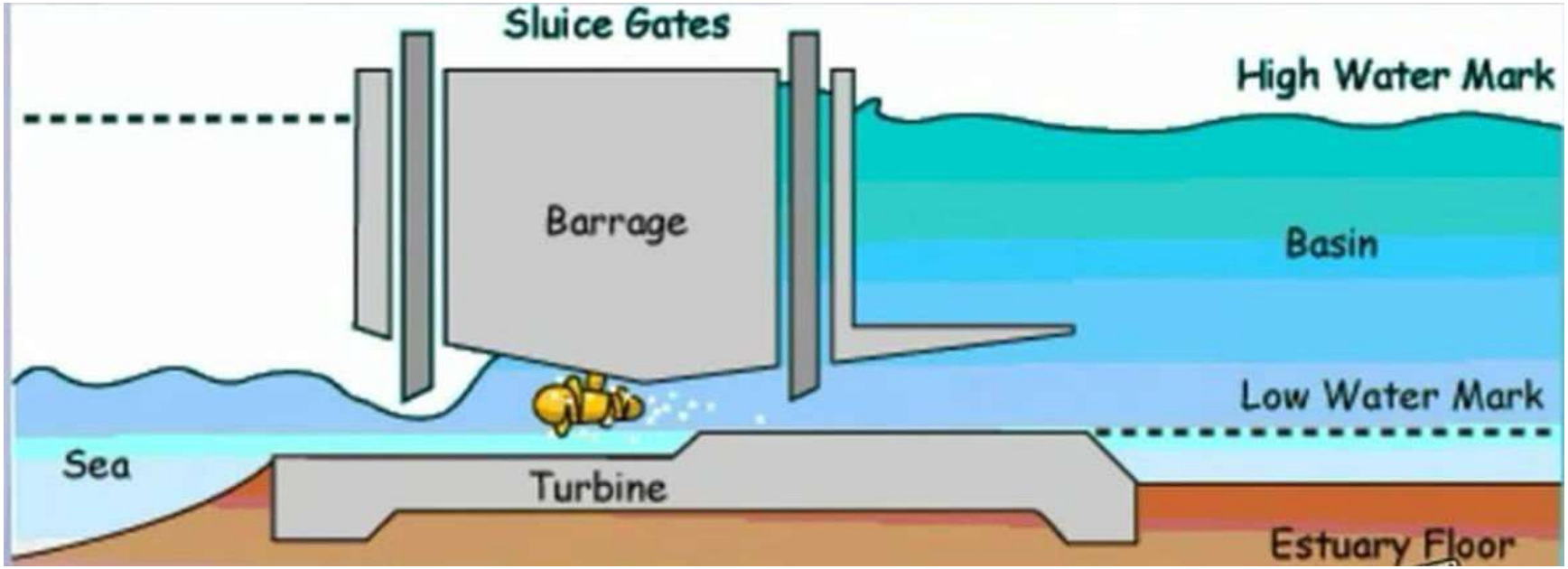
- Tidal barrages
- Tidal fences
- Tidal turbines

Tidal Barrages





Tidal Barrages



Tidal barrage is like a dam. When tide is high, the reservoir fills up. When tide is low, the dam moves the water out. The moving water is so strong and it has enough energy to rotate turbines which create electricity.

Types of Tidal BARRAGES

1. Single basin Tidal Plants

- Single cycle/effect plant
- Double cycle/effect plant

2. Double basin Tidal Plants

Double basin, linked basin plant Double basin, paired basin plant

Single Basin Tidal System

- The simplest generating system for tidal plants, known as an ebb generating system involves a dam, known as a barrage across an estuary.

- Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides and to exit through the turbine system on the outgoing tide (known as the ebb tide).

- Alternatively, flood-generating systems, which generate power from the incoming tide are possible, but are less favored than ebb generating systems.

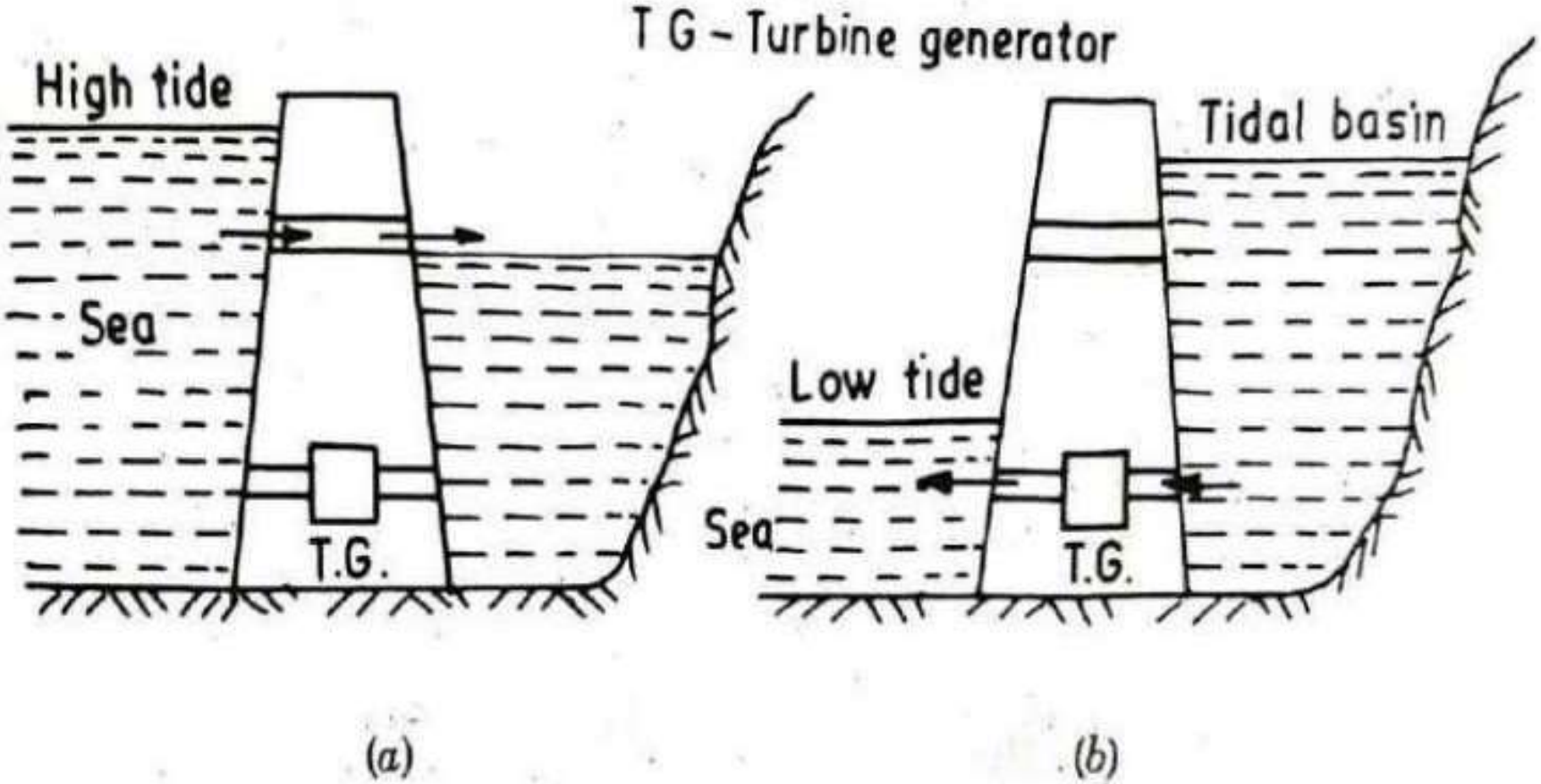
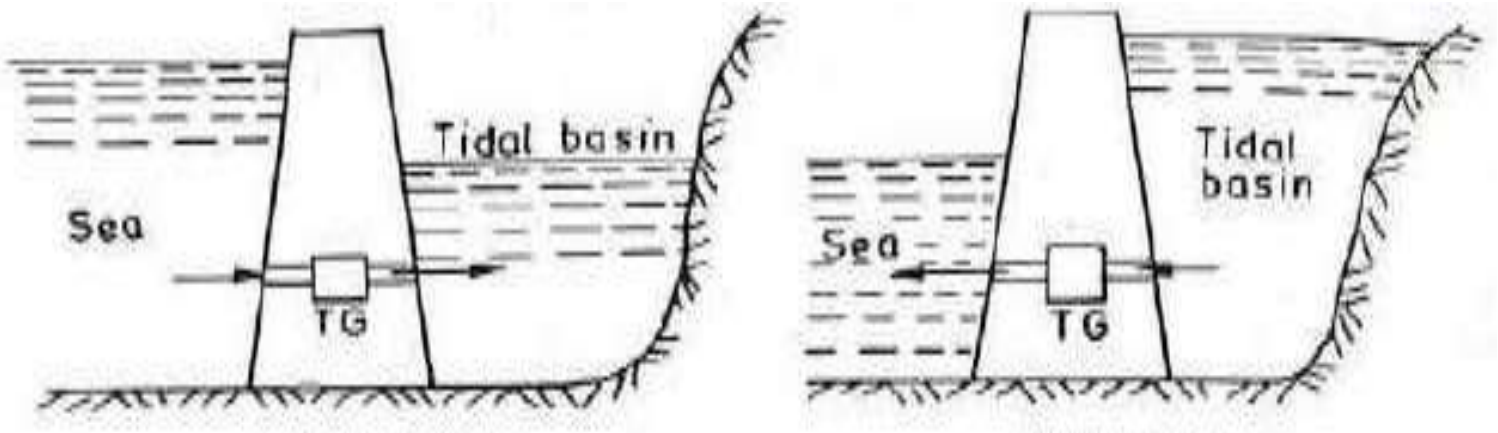


Fig. 9.3.1. Principle of Tidal power generation.

Single basin double cycle plant

- In this arrangement power is generated both during flood tide as well
- as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle.
- However the peak power obtained is less than the one-way cycle.
- The arrangement of the basin and the power cycle is shown in fig.



(a) High tide (b) Low tide

Fig. 9.3.4.2. Double cycle system.

Double basin Tidal System

- Another form of energy barrage configuration is that of the dual basin type.
- With two basins, one is filled at high tide and the other is emptied at low tide. Turbines are placed between the basins.

- Two-basin schemes offer advantages over normal schemes in that generation time can be adjusted with high flexibility and it is also possible to generate almost continuously.
- In normal estuarine situations, however, two-basin schemes are very expensive to construct due to the cost of the extra length of barrage.
- There are some favorable geographies, however, which are well suited to this type of scheme.

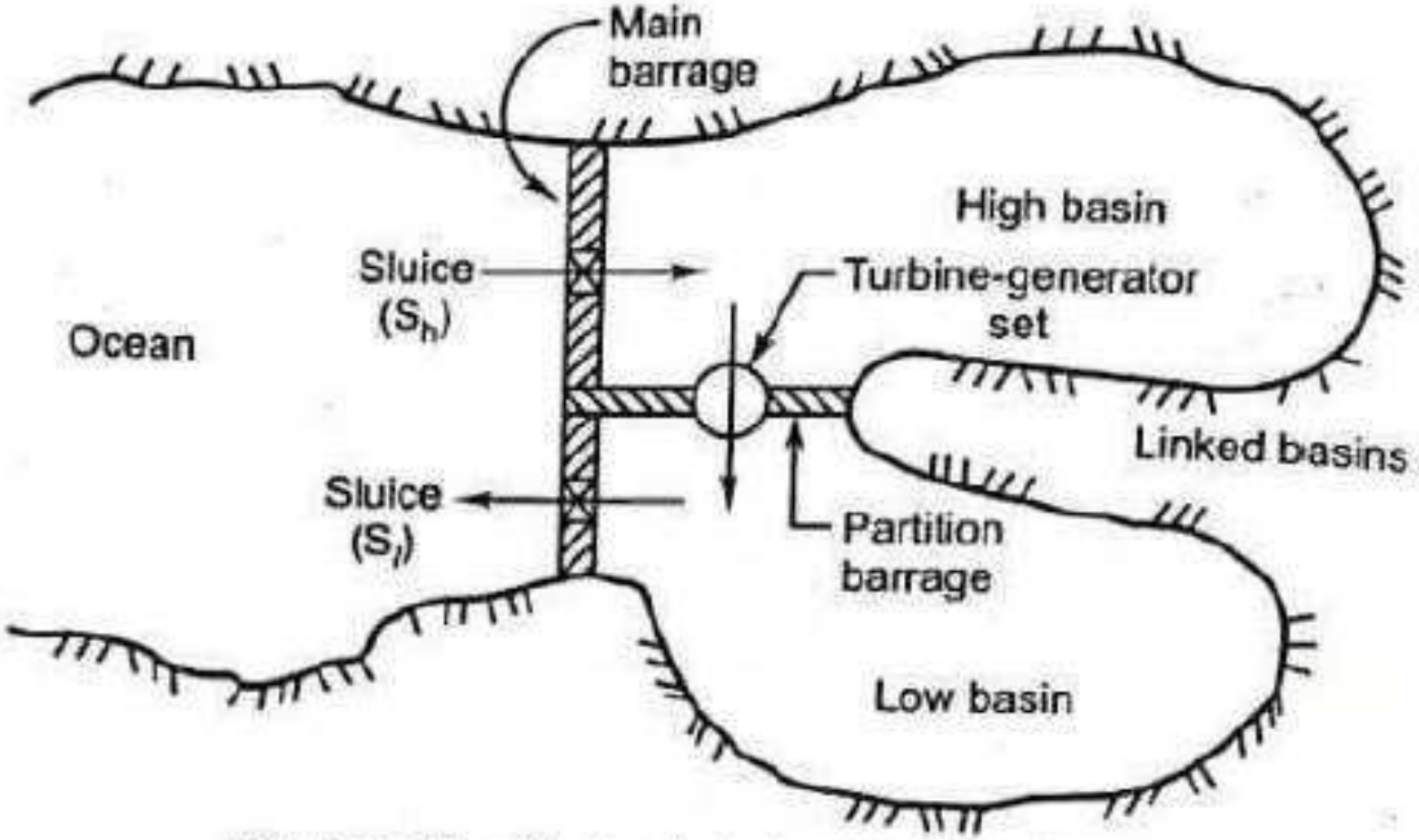


Fig. 8.10. Double-basin, linked-basin scheme.

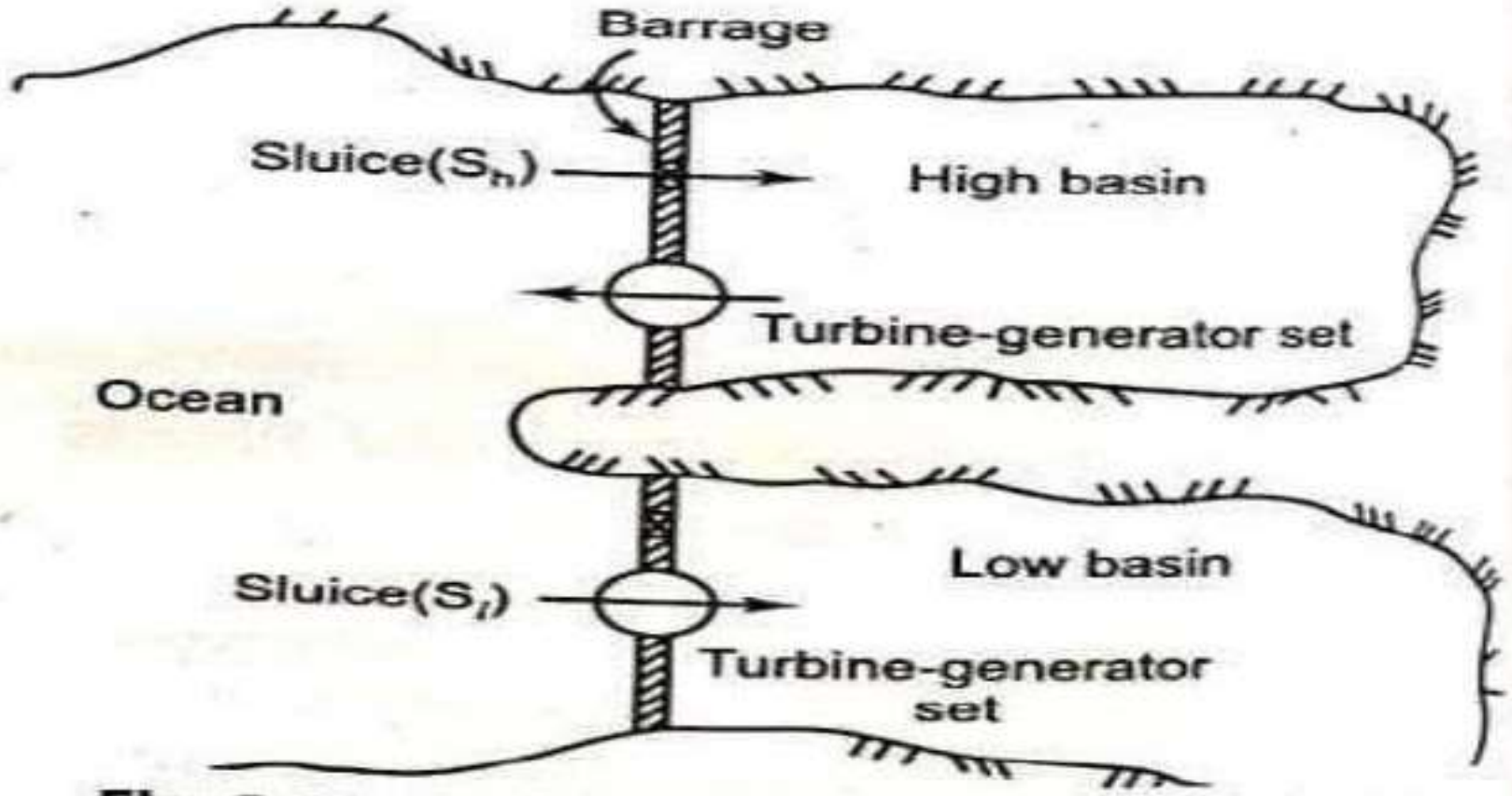
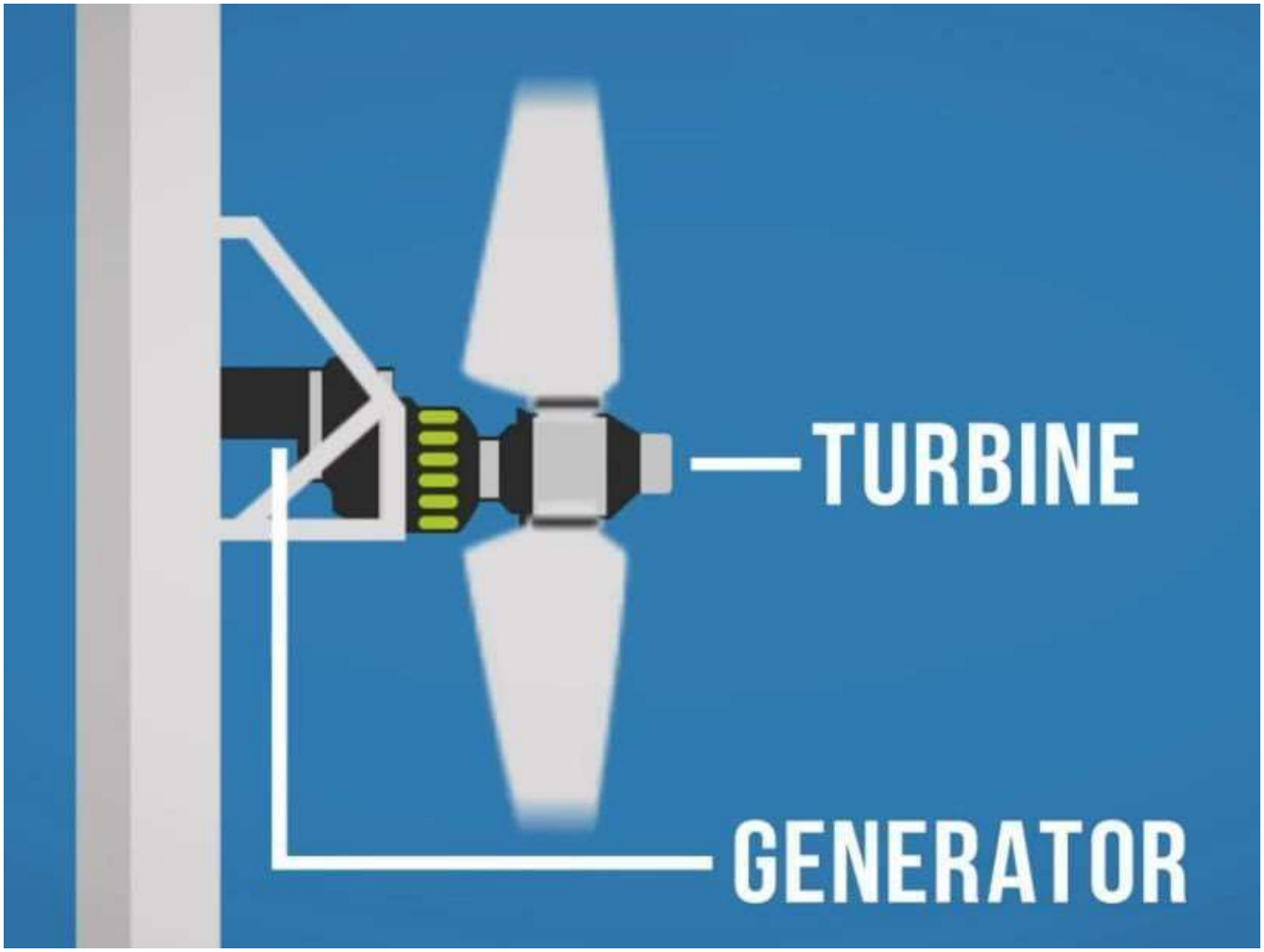
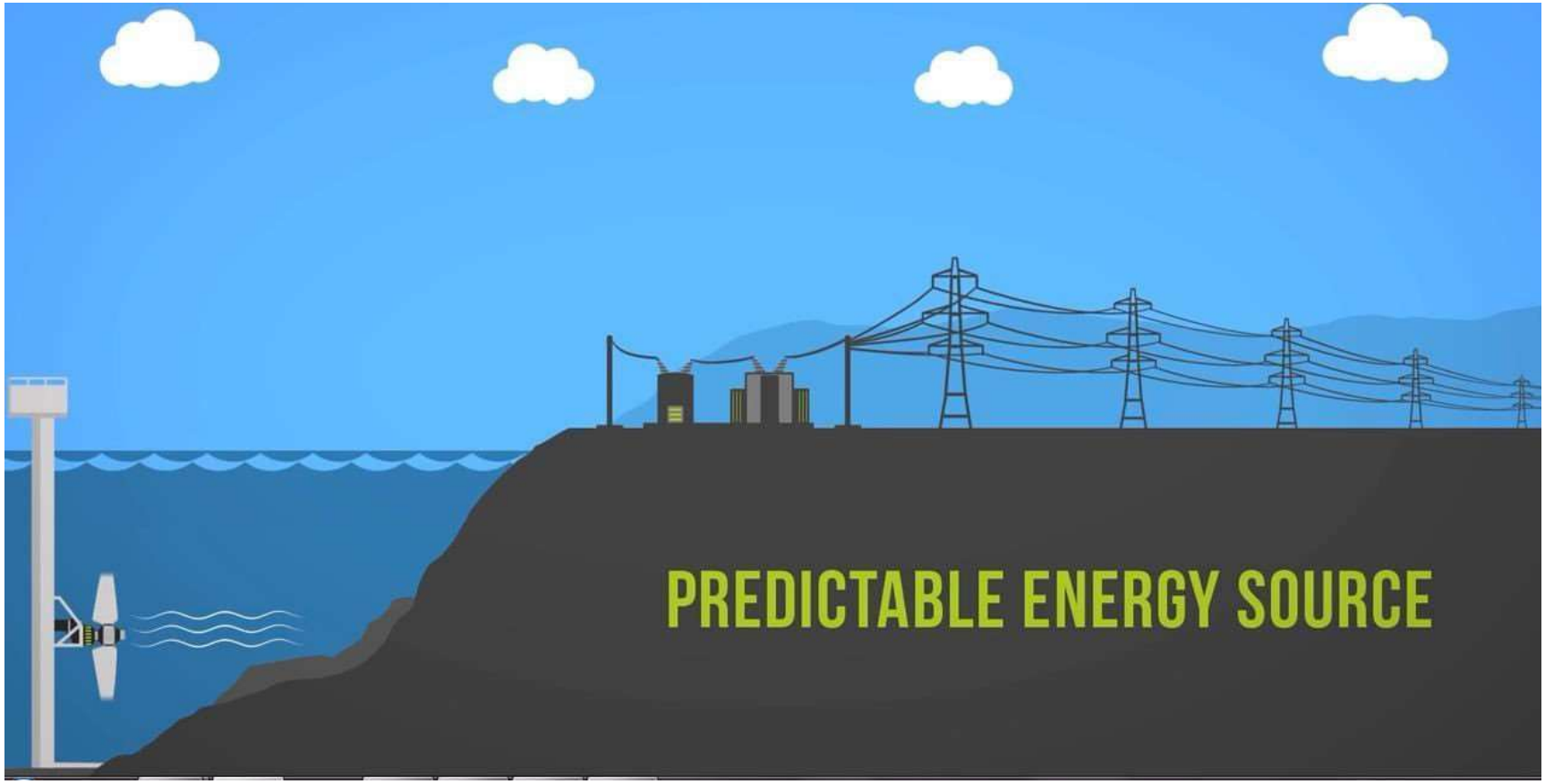


Fig. 8.11. Double-basin paired-basin scheme.

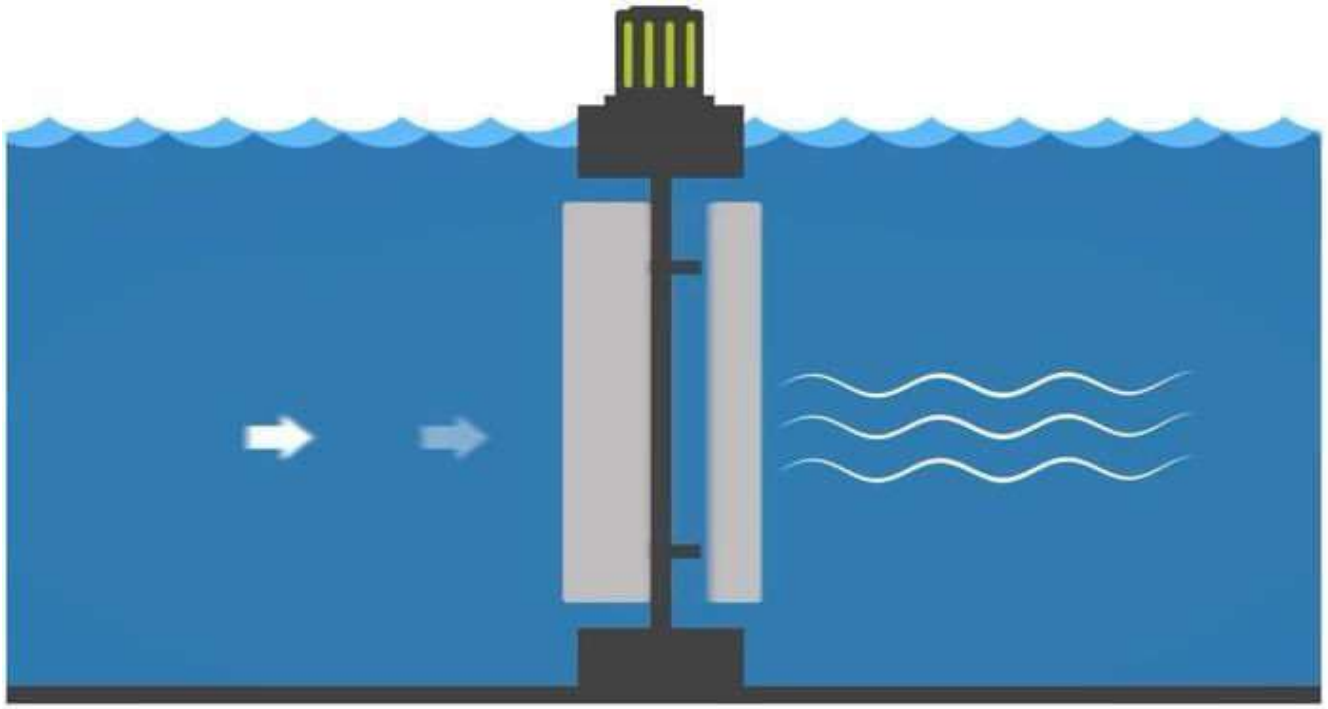
Tidal turbines



Tidal turbines

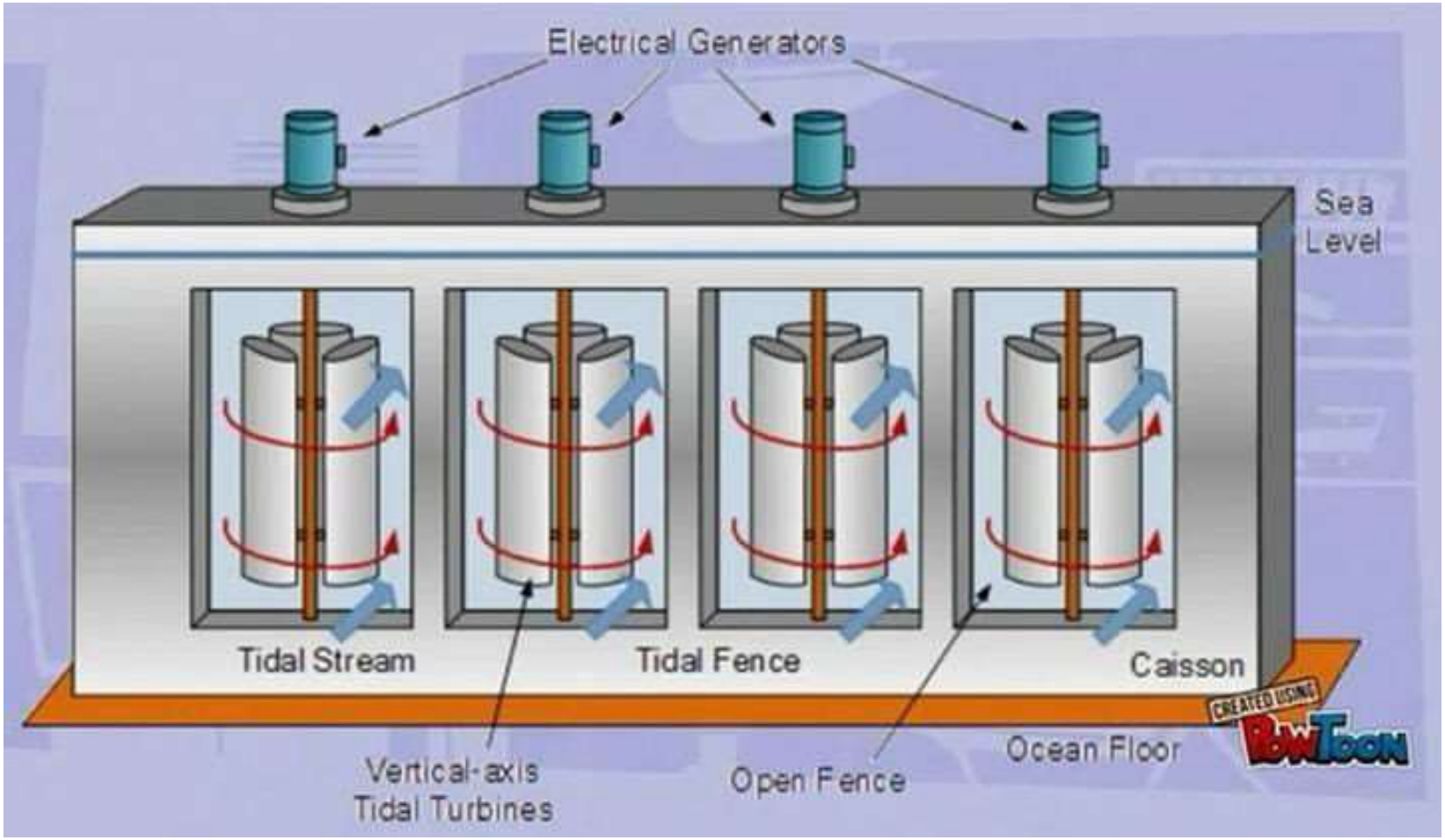


Tidal fences



These are smaller than barrages and they provide vertical blade arrangement. When water moves in and out, the blades rotate and power generates.

Tidal fences



Advantages of Tidal Power

- No fuel & No Pollution
- Inexhaustible/ Renewable
- Once you built, Tidal energy is free
- Not dependent on Rain
- As 70 % of the earth is covered by water, there is a scope to generate more energy
- Large area of valuable land is not required
- Life of power plant is very long.
- Tides behavior is more predictable compared to Solar & Wind
- Efficiency is high compared to Coal , Solar & Wind plants
- Water density is 1000 times greater than air, results in very large amount of power production.

Disadvantages of Tidal Power

- Tides only happen twice a day/Tidal power is not continuous.
- Because of variable tidal range, power is variable/efficiency is not constant
- Cost of construction is high.
- Difficult to carryout the construction
- Sea water is corrosive.
- High transmission cost
- High transmission losses
- Few suitable sites are available
- Lack of Studies , Research & Development
- Sedimentation & Siltation of the basins are the main problems
- Sedimentation –Particles settling at the bottom
- Siltation – Blocking the system with sand/soil

WAVE ENERGY

- Wave energy is generated by converting the energy within ocean waves (swells) into electricity.
- ✓There are many different wave energy technologies being developed and trialled to convert wave energy into electricity.

How Waves Form?

- Differential warming of the earth causes pressure differences in the atmosphere, which generate winds.
- As winds move across the surface of open bodies of water, they transfer some of their energy to the water and create waves.

Wave Power

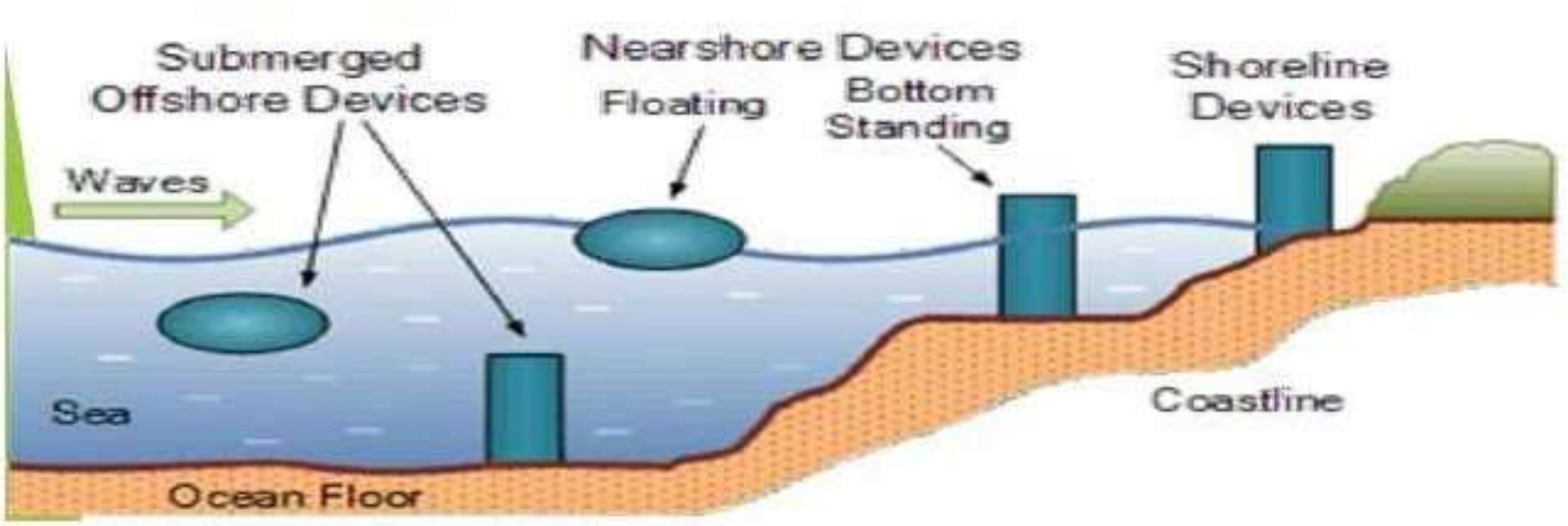
Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work –

for example,

- ✓ Electricity Generation,
- ✓ Water Desalination, Or The
- ✓ Pumping Of Water (Into Reservoirs).

Three Basic Kinds of Systems

- **Offshore** (deals with swell energy not breaking waves)
- **Near Shore** (maximum wave amplitude)
- **Embedded devices** (built into shoreline to receive breaking wave – but energy loss is occurring while the wave is breaking)



WAVE ENERGY DEVICES

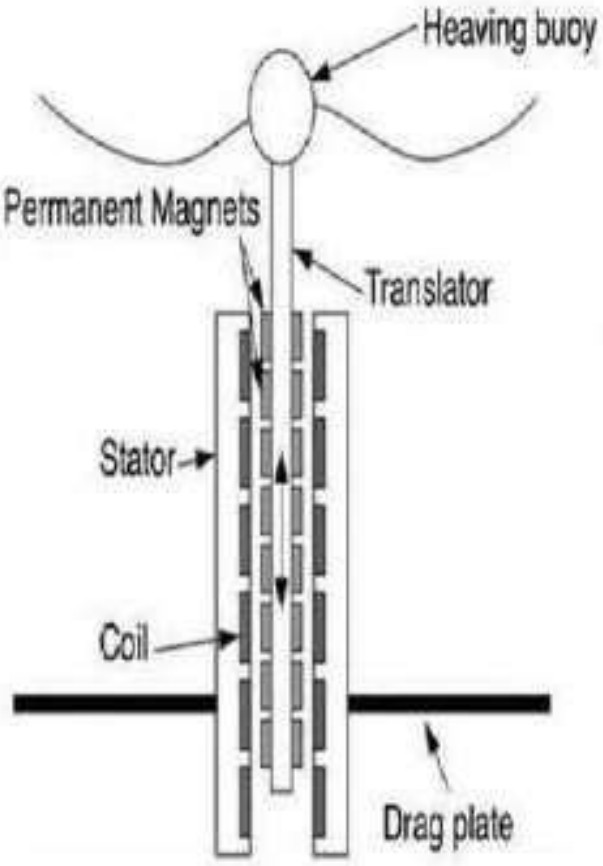
❖**Wave Profile Devices:** They turn the oscillating height of the oceans surface into mechanical energy.

❖**Oscillating Water Columns:** They convert the energy of the waves into air pressure.

❖**Wave Capture Devices:** They convert the energy of the waves into potential energy.

Wave Profile Devices

- If the physical size of the wave profile device is very small compared to the periodic length of the wave, this type of wave energy device is called a "point absorber".
- If the size of the device is larger or longer than the typical periodic wavelength, it is called a "linear absorber“.


Heaving buoy
Permanent Magnets
Translator
Stator
Coil
Drag plate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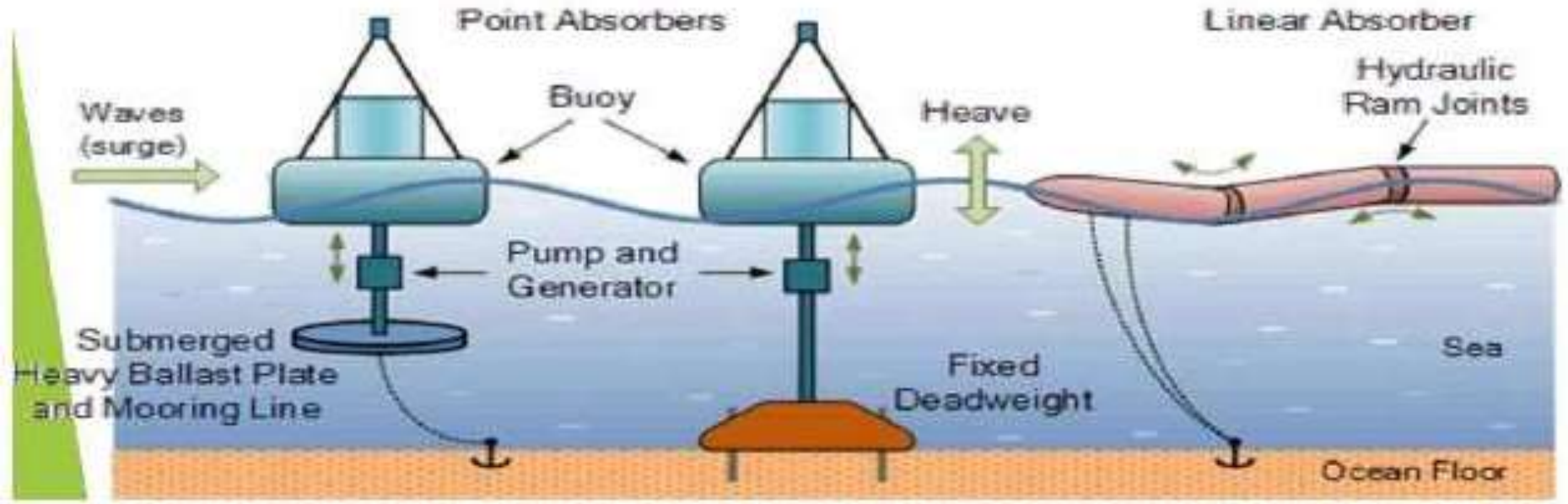
Working

The waves energy is absorbed using

- ✓Vertical motion (heave)
- ✓Horizontal motion in the direction of wave travel (surge)
- ✓Angular motion about a central axis parallel to the wave crests (pitch) or, angular motion about a vertical axis (yaw) ⁻ **or a combination of all four**

The energy being generated by reacting these different movements against some kind of fixed resistance called a **reaction point.**

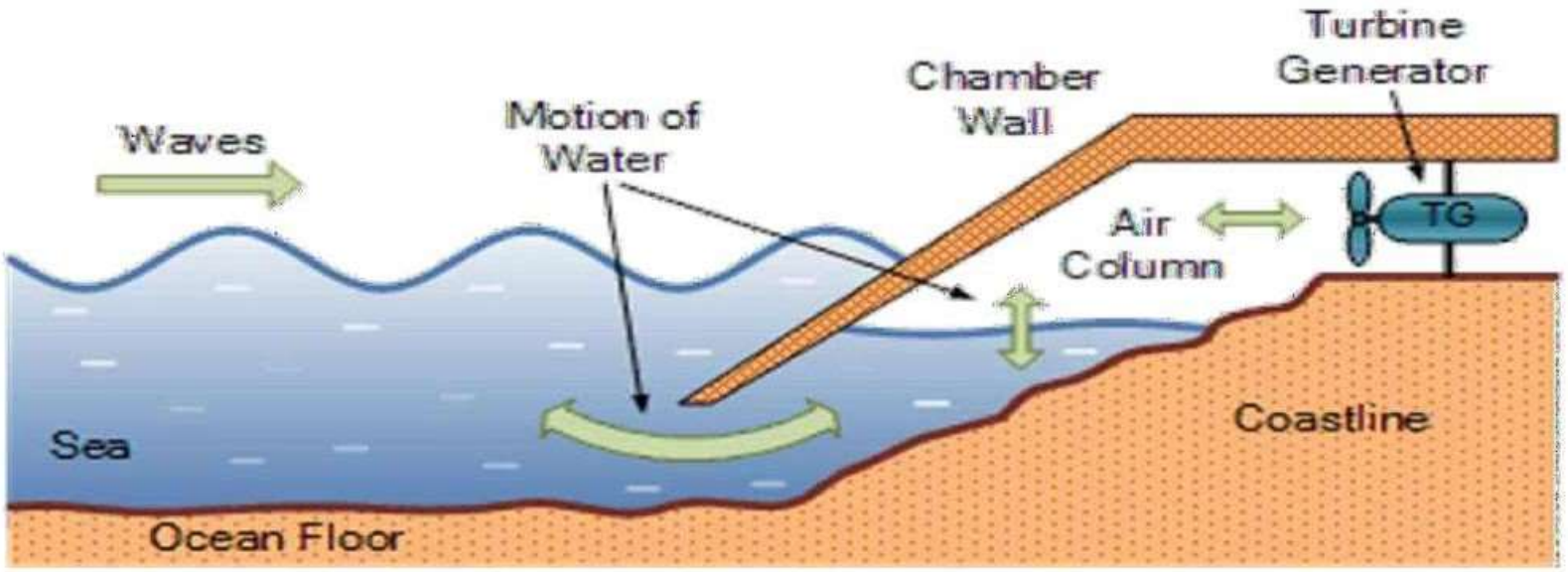


Oscillating Water Column (OWC)

- The Oscillating Water Column, (OWC) is a popular shoreline wave energy device normally positioned onto or near to rocks or cliffs which are next to a deep sea bottom.
- They consist of a partly submerged hollow chamber fixed directly at the shoreline which converts wave energy into air pressure.

OWC- Working

- As the incident waves outside enter and exit the chamber, changes in wave movement on the opening cause the water level within the enclosure to oscillate up and down acting like a giant piston on the air above the surface of the water, pushing it back and forth.
- This air is compressed and decompressed by this movement every cycle.
- The air is channeled through a wind turbine generator to produce electricity


Turbine
Generator
Chamber
Wall
Motion of
Water
Waves
Air
Column
TG
Sea
Coastline
Ocean Floor

Wave Capture Device

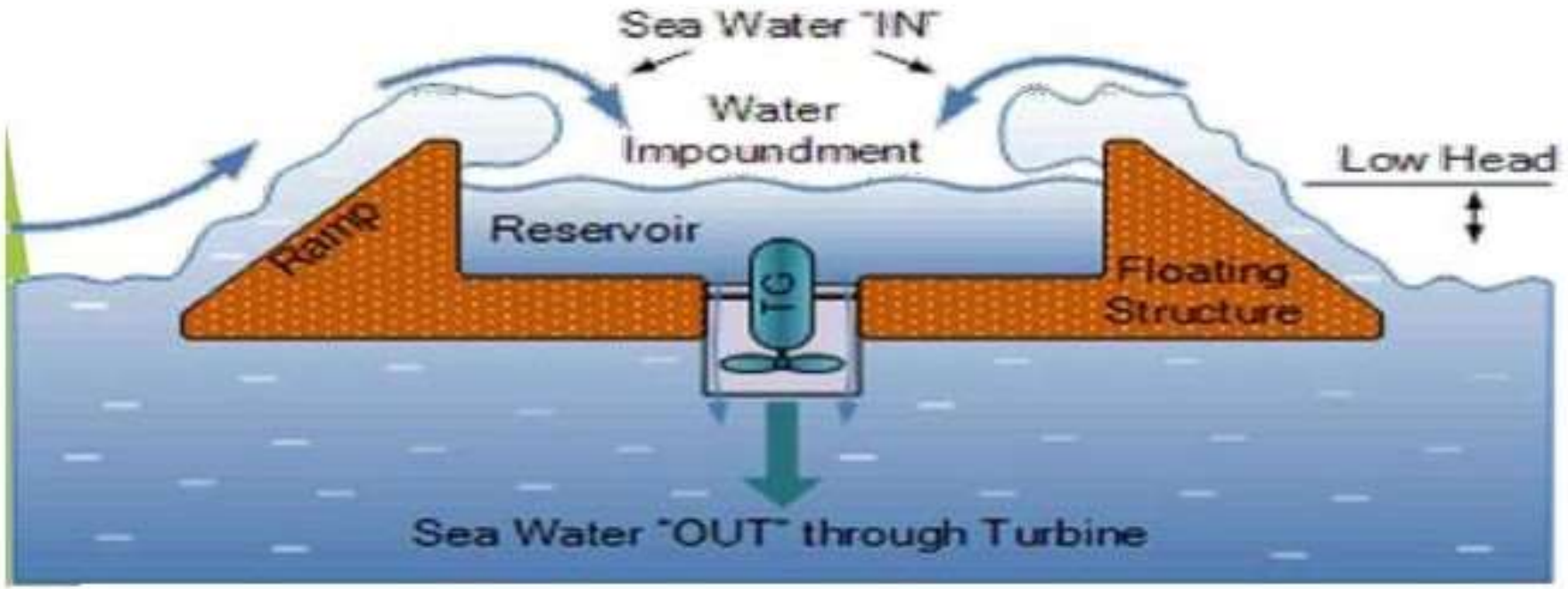
- A Wave Capture Device also known as a Over topping Wave Power Device, is a shoreline to nearshore wave energy device that captures the movements of the tides and waves and converts it into potential energy.
- Wave energy is converted into potential energy by lifting the water up onto a higher level.
- The wave capture device, or more commonly an overtopping device, elevates ocean waves to a holding reservoir above sea level.
- It require sufficient wave power to fill the impoundment reservoir.

Working

- As the waves hit the structure they flow up a ramp and over the top (hence the name "overtopping"), into a raised water impoundment reservoir on the device in order to fill it.

- Once captured, the potential energy of the trapped water in the reservoir is extracted using gravity as the water returns to the sea via a low-head Kaplan turbine generator located at the bottom of the wave capture device.

Wave Capture Device

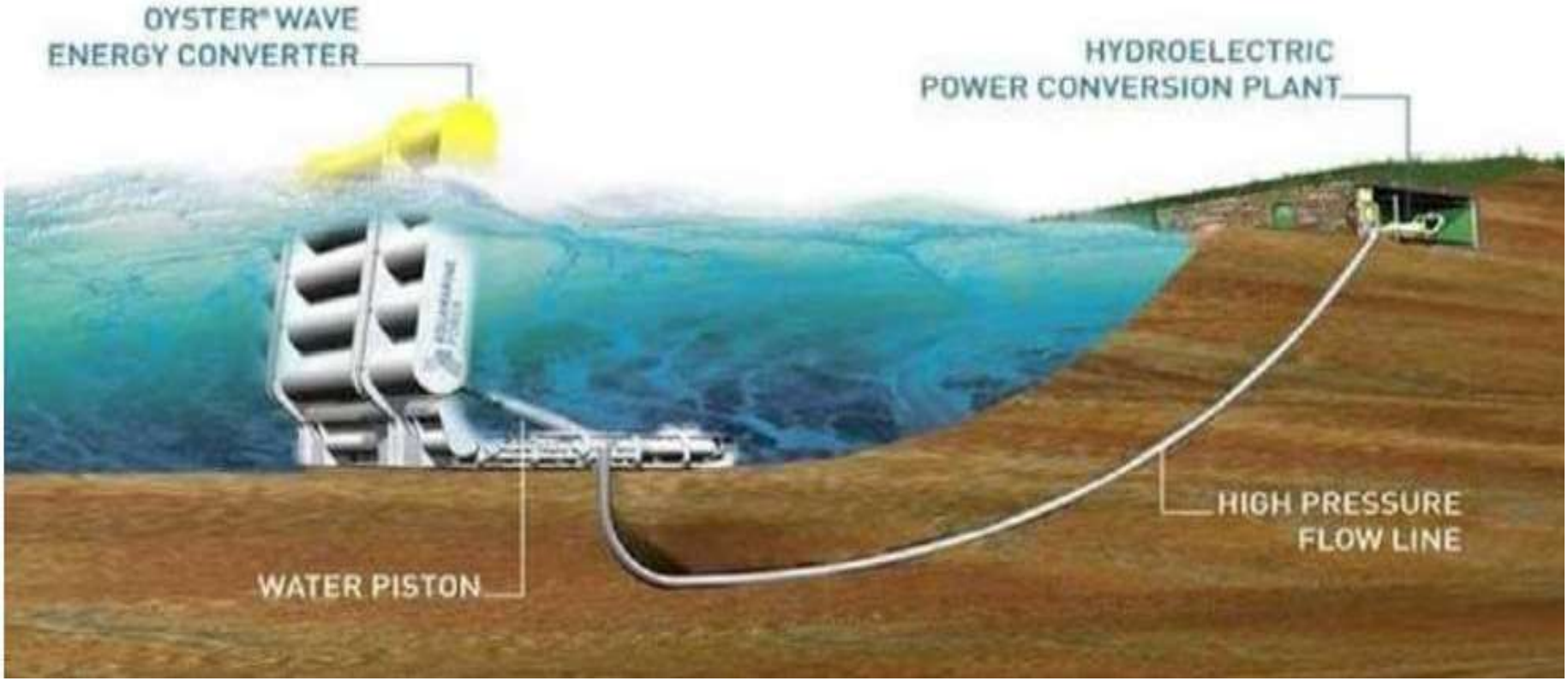


Oscillating Wave Surge Converter

- These devices typically have one end fixed to a structure or the seabed while the other end is free to move. Energy is collected from the relative motion of the body compared to the fixed point.

- These capture systems use the rise and fall motion of waves to capture energy. Once the wave energy is captured at a wave source, power must be carried to the point of use or to a connection to the electrical grid by transmission power cables.

Oscillating Wave Surge Converter



Benefits of Ocean Wave Energy

- **Available 24/7 on 365 days - therefore power produced from them is much steadier and more predictable – waves can be accurately predicted 48** hours in advance and therefore forecast energy output (BUT irregularity in wave ampitude, and direction)
- Good data on waves from wave monitoring bouys
- wave energy contains 1000 times the kinetic energy of wind (can produce the same amount of power in less space).

Introduction to Biomass

- An organic materials (plants, trees and crops) are potential sources of energy and are collectively called as Biomass.
- The plants may be grown on land (terrestrial plants) or may be grown in water (aquatic plants)
- Biomass also includes forest crops and residues, crops grown especially for their energy grown called energy farms, animal manure, wood waste and bagasse.
- Coal, oil and natural gas may take million of years to form, but biomass can be considered renewable energy source because plant life renews and adds to itself every year.

Biomass energy

- Bioenergy consists of solid, liquid, or gaseous fuels.
- Liquid fuels can be used directly in the existing road, railroad, and aviation transportation network stock, as well as in engine and turbine electrical power generators.
- Solid and gaseous fuels can be used for the production of electrical power from purpose-designed direct or indirect turbine-equipped power plants.

RESOURCES OF BIOMASS

Concentrated wastes:

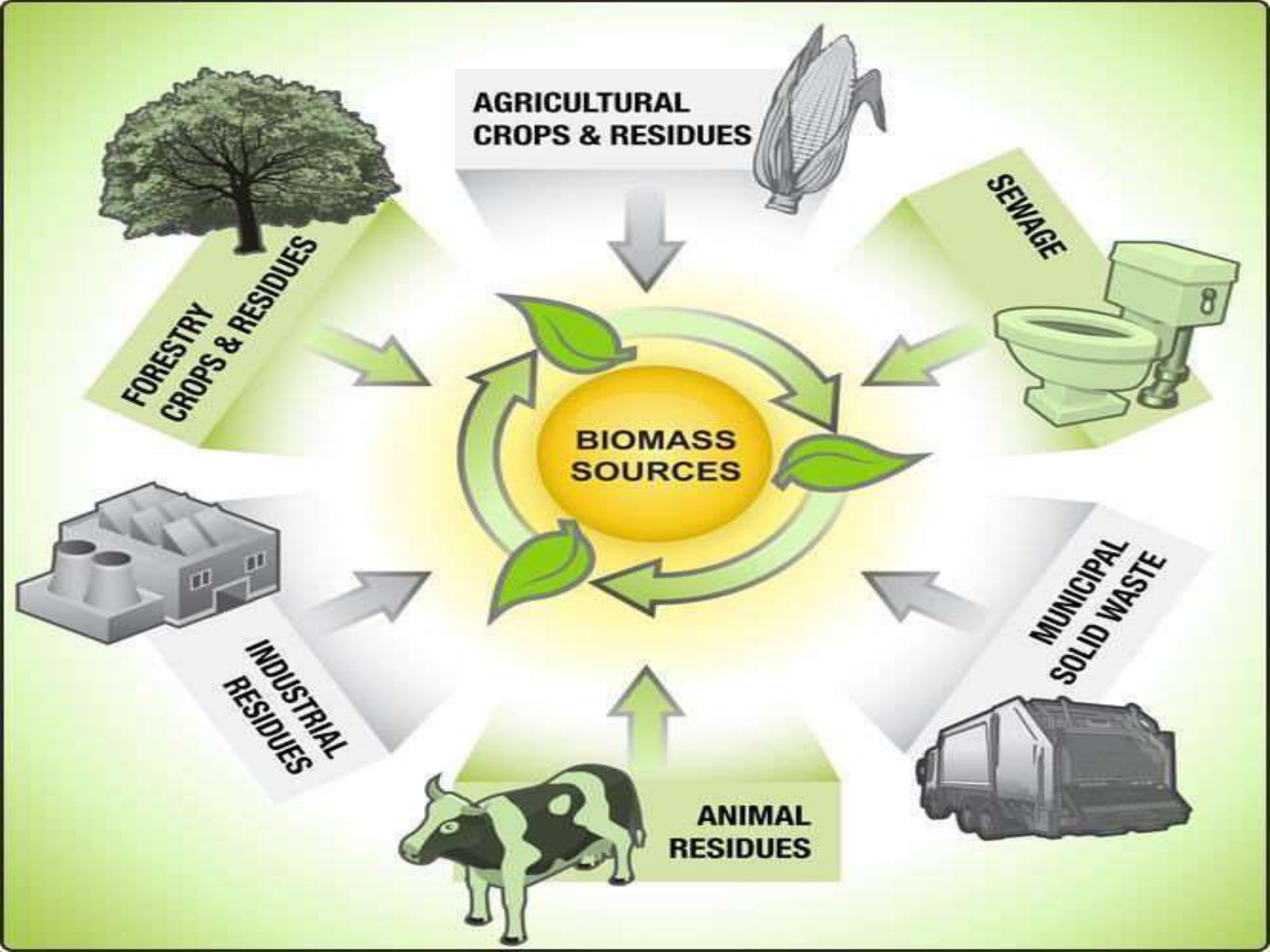
- Municipal solid, Sewage ,food products, Industrial waste, Manure at large lots

Disperse waste residue:

- Crop residue, logging residue, and disposed manure.

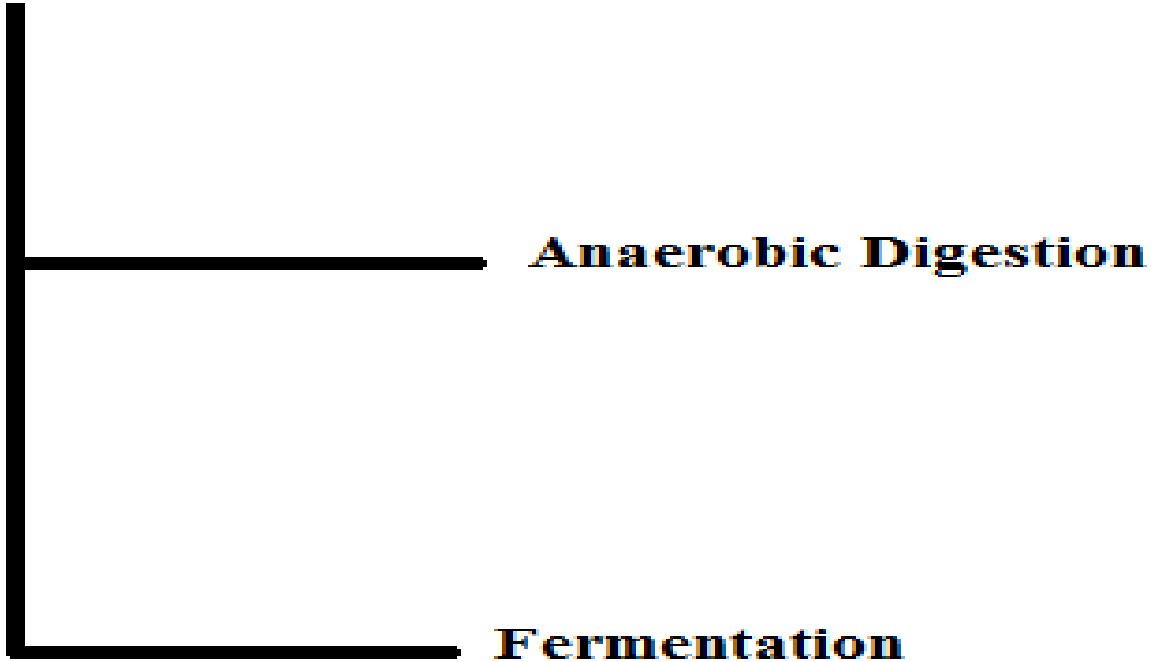
Harvested biomass:

- Standing biomass, biomass energy plantations


AGRICULTURAL
CROPS & RESIDUES
FORESTRY
CROPS & RESIDUES
SEWAGE
BIOMASS
SOURCES
INDUSTRIAL
RESIDUES
MUNICIPAL
SOLID WASTE
ANIMAL
RESIDUES

Biomass conversion Principles or Technologies

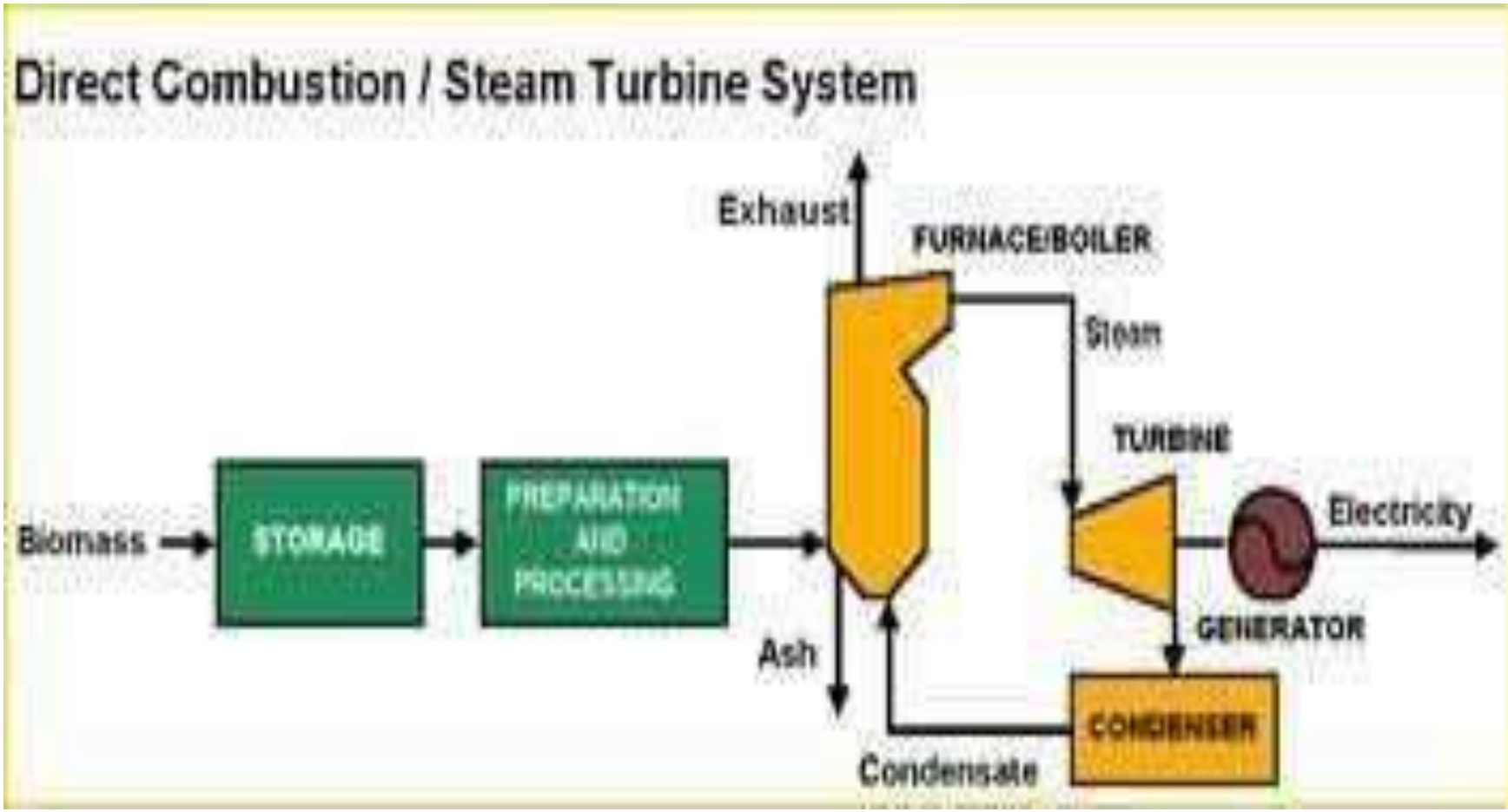
- Direct combustion
- Thermo chemical conversion
- Biochemical Conversion



COMBUSTION OF BIOMASS

- At present, the primary approach for generating electricity from biomass is combustion direct-firing.
- The biomass fuel is burned in a boiler to produce high-pressure steam.
- This steam is introduced into a steam turbine, where it flows over a series of turbine blades, causing the turbine to rotate.
- The turbine is connected to an electric generator.
- The steam flows over and turns the turbine. The electric generator rotates, producing electricity. This is a widely available, commercial technology.
- This technology is used for the efficient combustion of forestry and agricultural waste materials such as saw dust, wood chips, rice husk etc.

Combustion of Biomass



Thermochemical Conversion

- There are two forms of thermochemical conversion

  -- Gasification

  -- Liquefaction

- Gasification is a process in which biomass is heated in an environment (with limited oxygen) where the solid biomass breaks down to form a flammable gas(low calorific value gas) or by reacting it with steam and oxygen at high pressure and temperature to produce high heating value gas. The biogas can be cleaned and filtered to remove problem chemical compounds. The gas can be used in more efficient power generation systems called combined cycles, which combine gas turbines and steam turbines to produce electricity.

Thermochemical Conversion

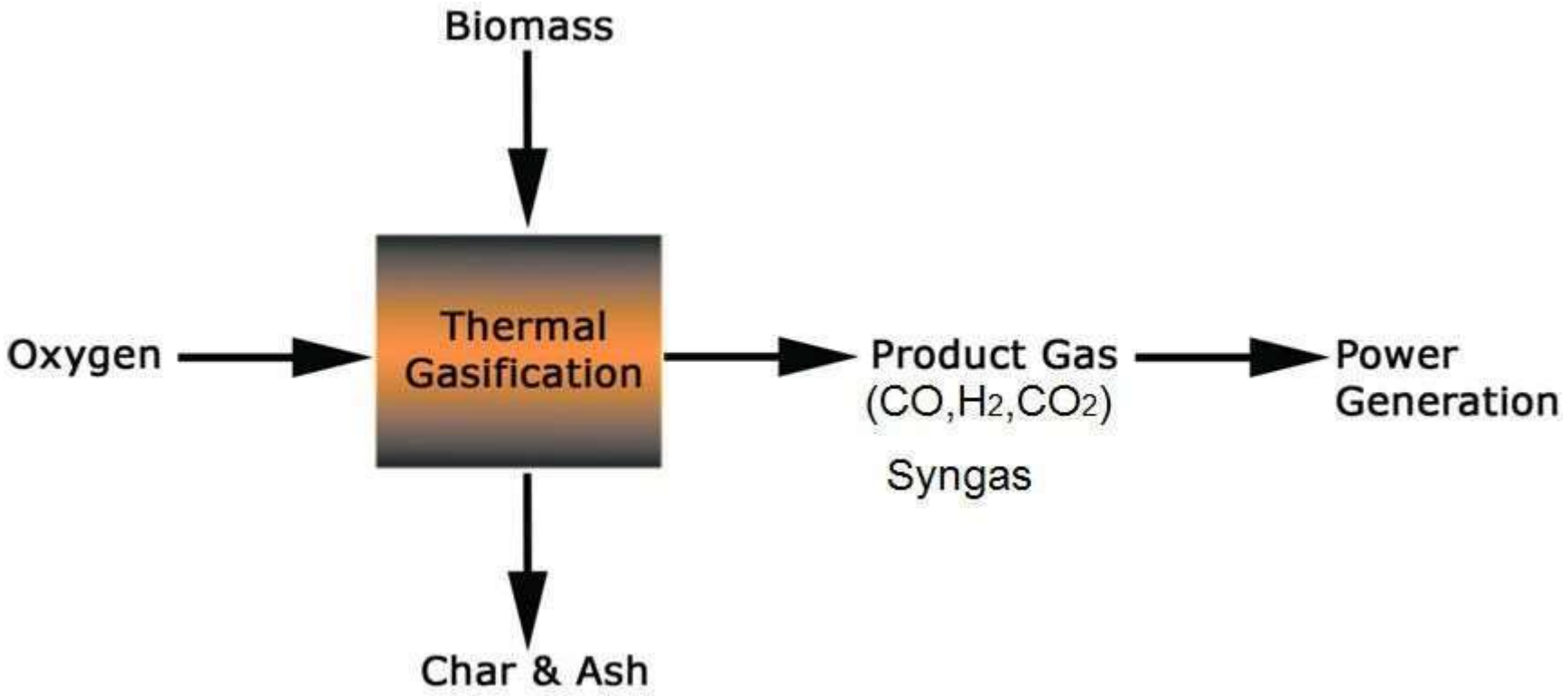


Fig: Gasification

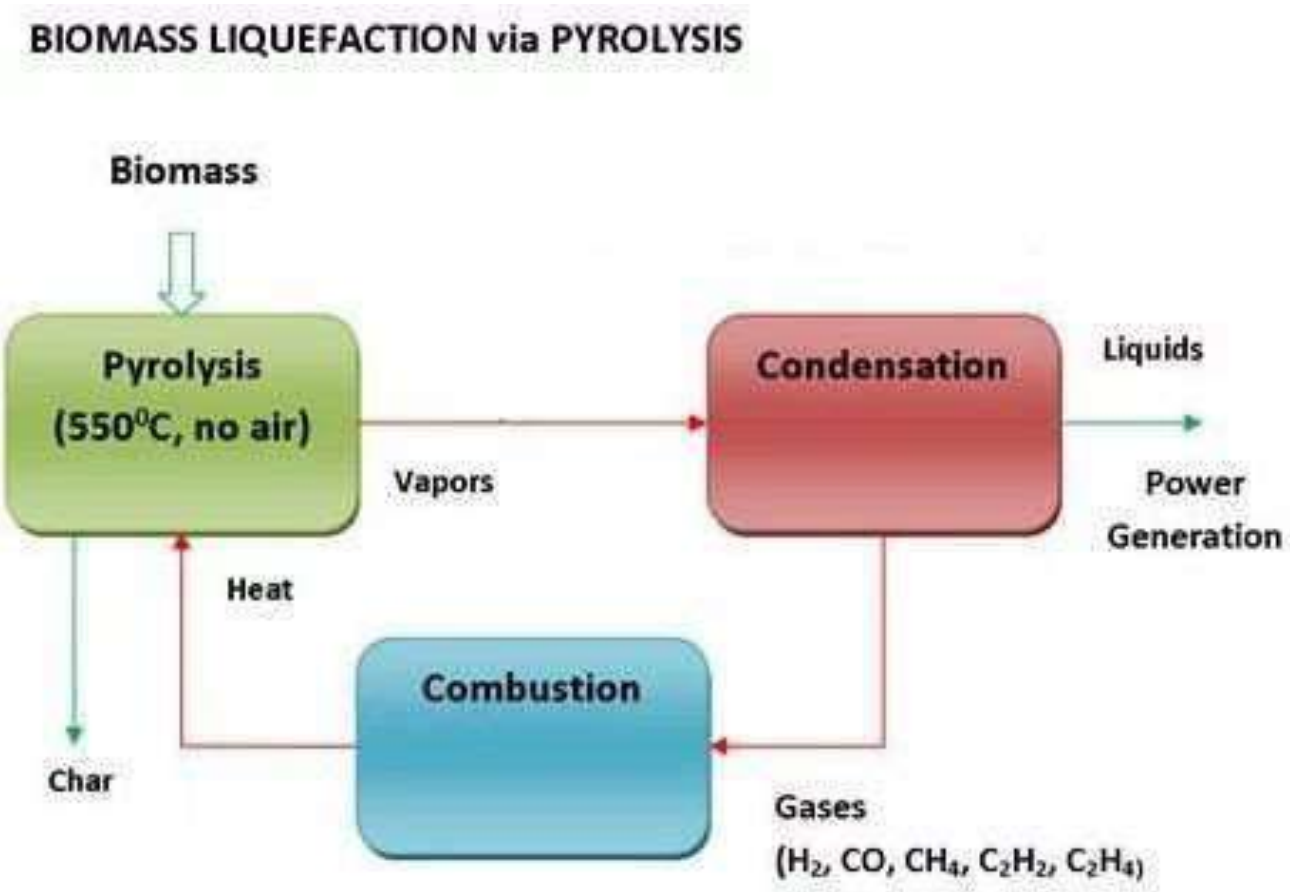
Thermochemical Conversion

- Liquefaction is a process in which biomass is heated in the absence of air. Then the solid biomass breaks down to form a vapour under certain temperature. This vapour is condensed at certain temperatures to form liquids which are used for power generation.
- The fluids like Methonol, ethonol etc are produced by liquefaction.

Note:

Pyrolysis is the process of heating of biomass in a closed vessel at temperatures in the range 500^{o}C-900^{o}C in absence of O2/air. Decomposition of organic material at elevated temperatures in the absence of oxygen takes place. It produces solid, liquid and gases.

Thermochemical conversion



Biochemical Conversion

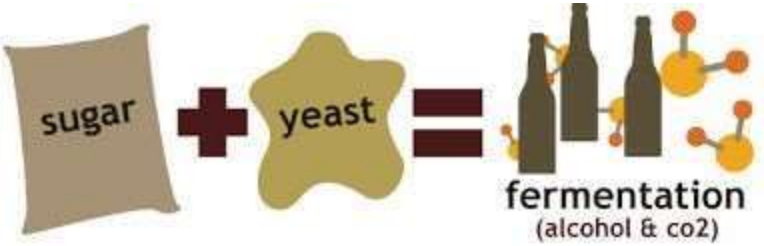
In biochemical processes the bacteria and micro organisms are used to transform the raw biomass into useful energy like methane and ethane gas. Following organic treatments are given to the biomass:

1) Fermentation of biomass (Aerobic digestion)
2) Anaerobic digestion of biomass

Fermentation

Fermentation is a process of decomposition of complex molecules of organic compound under the influence of micro-organism(ferment) such as yeast, bacteria, enzymes etc.

The example of fermentation process is the conversion of grains and sugar crops into ethanol and CO_2 in presence of yeast.



$$C_6H_{12}O_6 \xrightarrow{\text{Yeast}} 2\,CH_3CH_2OH + 2\,CO_2$$

glucose — ethanol — carbon dioxide

Anaerobic digestion

- The anaerobic digestion or anaerobic fermentation process involves the conversion of decaying wet biomass and animal waste into biogas through decomposition process by the action of anaerobic bacteria.
- The most useful biomass for production of biogas are animal and human waste, plant residue and other organic waste material with high moisture content.

Biogas Generation

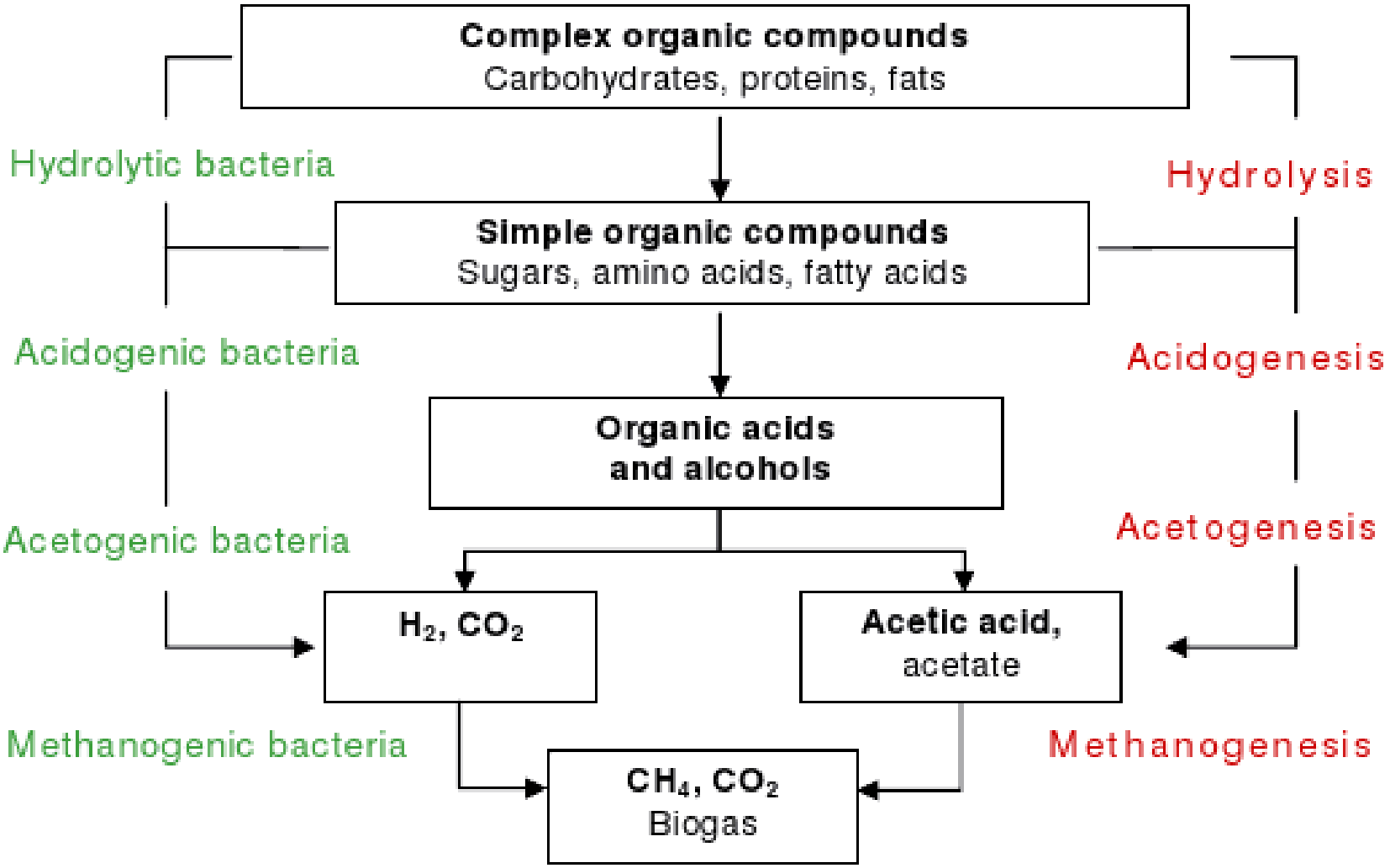
- Biogas contains 55-65% methane, 30-40% CO_2, and the remainders are impurities like H_2S, H_2, N_2 gases.
- Cattle dung can produce 0.037 m^3 of biogas per kg of cow dung. The calorific value of gas is 21000 to 23000 kJ/kg or about 38000 kJ/m^3 of gas. The material from which biogas is produced retains its value as fertilizer.

Biogas Generation

- Biogas can be produced by digestion pyrolysis or hydro gasification. Digestion is a biological process that occurs in absence of O_2 and in presence of anaerobic organisms at atmospheric pressure and temperatures of 35^{o}C-70^{o}C. The container in which the digestion takes place is called digester.

- When organic matter undergoes fermentation, the anaerobic bacteria extracts oxygen by decomposing the biomass at low temperatures up to 65^{o}C in the presence of moisture. The gas so produced is called biogas.

Steps in Biogas generation



Steps in Biogas generation

The conversion of biomass to biogas in the tank with the help of microorganisms is called anaerobic fermentation. End product of this process is biogas - the mixture of methane, carbon dioxide and other components. It runs in four consecutive stages, referred to as:

1. Hydrolysis: It is carried out in an environment containing oxygen in the air. Organic polymers (polysaccharides, lipids, proteins) with the help of anaerobic bacteria decompose into monomers (alcohol and a fatty acid) to release the hydrogen and carbon dioxide.
2. Acid formation: In this process, the residual oxygen in the air creating an anaerobic environment and formation of the higher organic acids, ammonia, hydrogen by acidogenic bacteria. Later organic acids and alcohols converted into the acetic acid, hydrogen and carbon dioxide by acetogenic bacteria.
3. Methane formation: Methanogenesis is the last stage of decomposition process, where methanogenic bacteria decompose acetic acid to methane, carbon dioxide..

Factors affecting biogas production

The rate of production of biogas depends on the following factors:

1) Temperature & Pressure
2) Solid concentration & Loading rate
3) Retention period
4) pH value
5) Nutrients composition
6) Toxic substances
7) Digester size & shape
8) Stirring agitation of the content of digestion

Classification of Biogas Plants:

Biogas plants are mainly classified as:

1. Continuous and batch type(as per the process)
    a) Single stage process
    b) Double stage process
2. The dome and drum type
3. Different variation in the drum type

Classification of Biogas Plants:

Biogas plants are mainly classified as:

1. Fixed dome type biogas plant
2. Floating drum type biogas plant

Raw material used

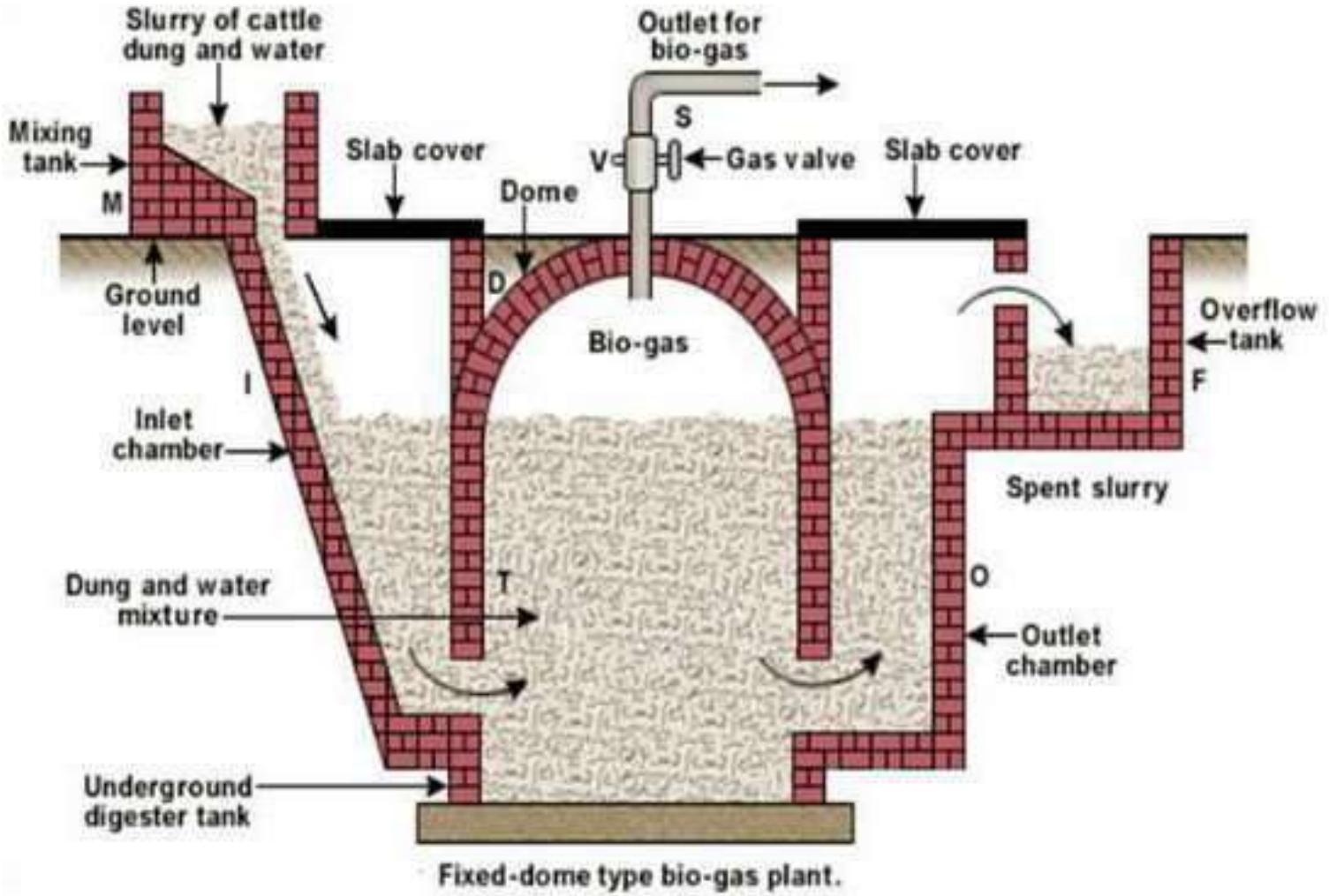
- Animal dung
- Poultry waste
- Plant wastes(Husk, grass, weeds etc)
- Human excreta
- Industrial waste (waste food processing industries, saw dust etc)
- Domestic waste (food and vegetable waste)

Construction of fixed dome biogas digester

The biogas plant is a brick and cement structure having the following five sections:

- **Mixing tank** present above the ground level.
- **Inlet tank**: The mixing tank opens underground into a sloping inlet chamber.
- **Digester:** The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling. The ceiling of the digester has an outlet with a valve for the supply of biogas.
- **Outlet tank**: The digester opens from below into an outlet chamber.
- **Overflow tank**: The outlet chamber opens from the top into a small over flow tank.

Fixed dome Biogas digester



Fixed dome type biogas plant

(Janta biogas plant)

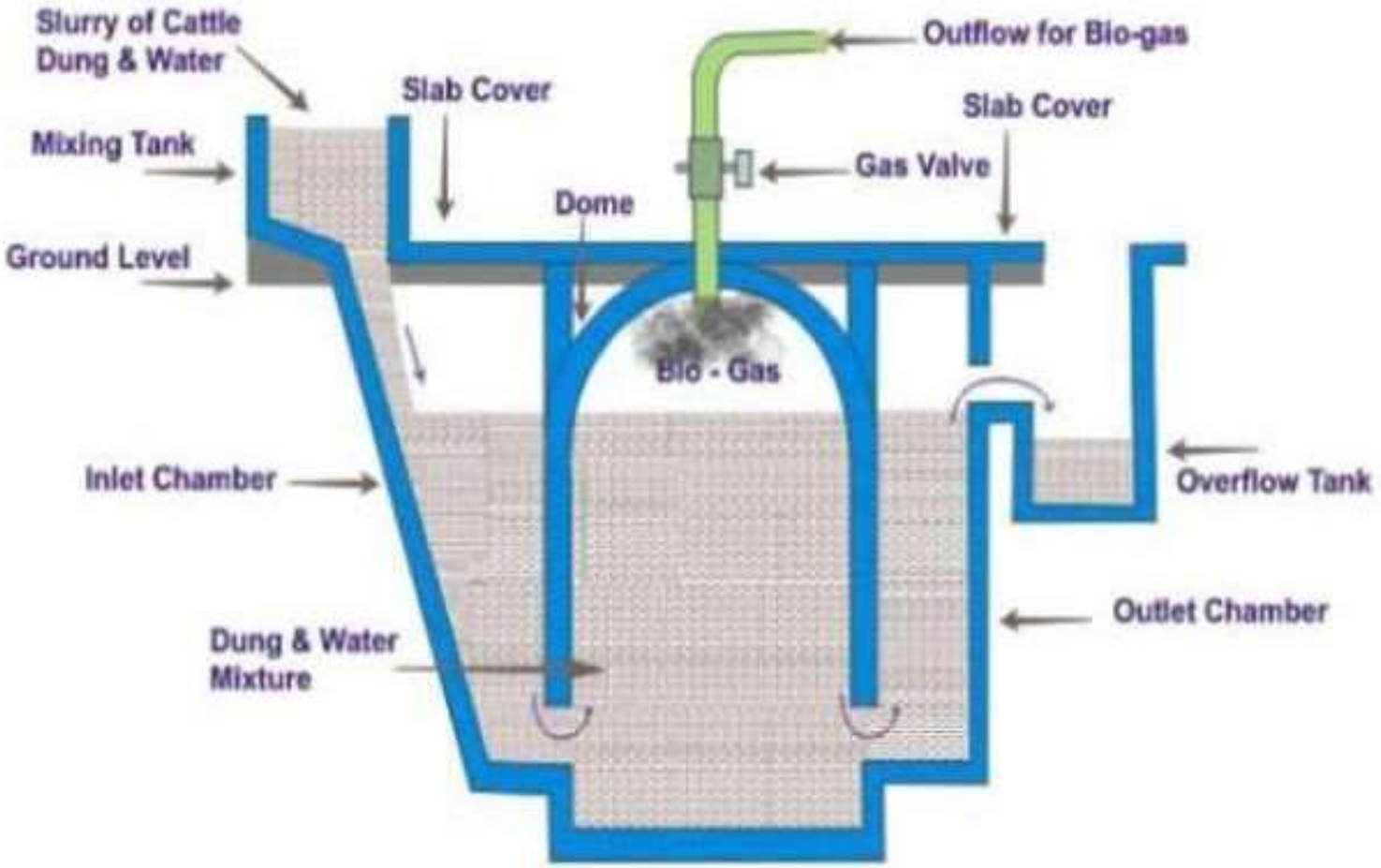
Working of fixed dome biogas digester

- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the **slurry**.
- The slurry is fed into the digester through the inlet chamber.
- When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about two months.
- During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.
- As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.

Working of fixed dome biogas digester

- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
- From the outlet chamber, the spent slurry overflows into the overflow tank.
- The spent slurry is manually removed from the overflow tank and used as manure for plants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas is required.
- To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry.

Fixed dome biogas plant



Fixed Dome type Bio-gas Plant

Fixed dome biogas plant

Advantages:

- Cost of plant is less compare to floating drum type plant.
- Loss of heat is negligible since these are constructed underground.
- No corrosion problems
- It is maintenance free.

Disadvantages:

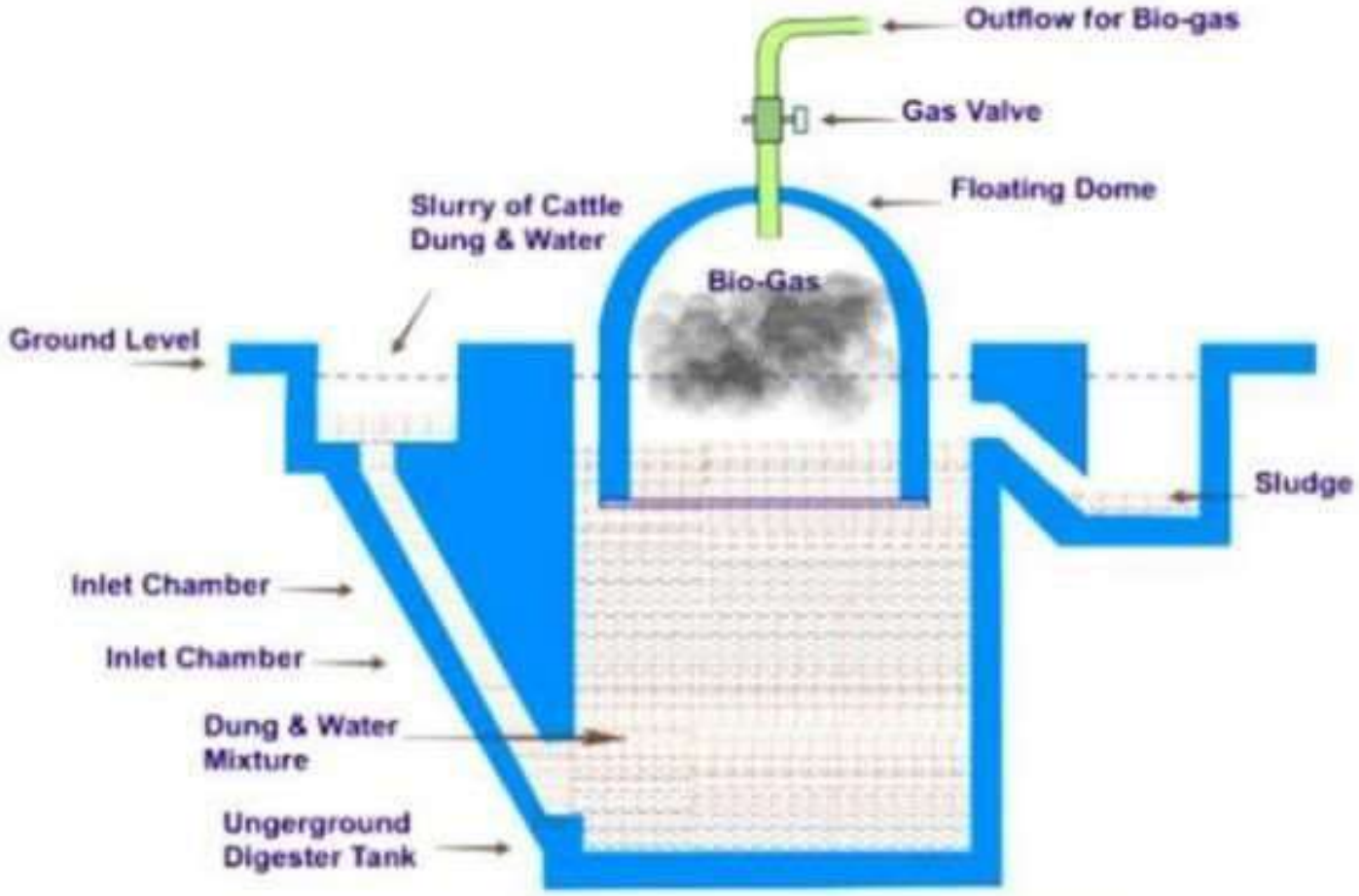
- Needs skilled labour to operate.
- Gas production per m^3 of digester volume is less.
- Gas is produced at variable pressure.

Construction of floating dome biogas digester

The floating gas holder type of biogas plant has the following chambers/ sections:

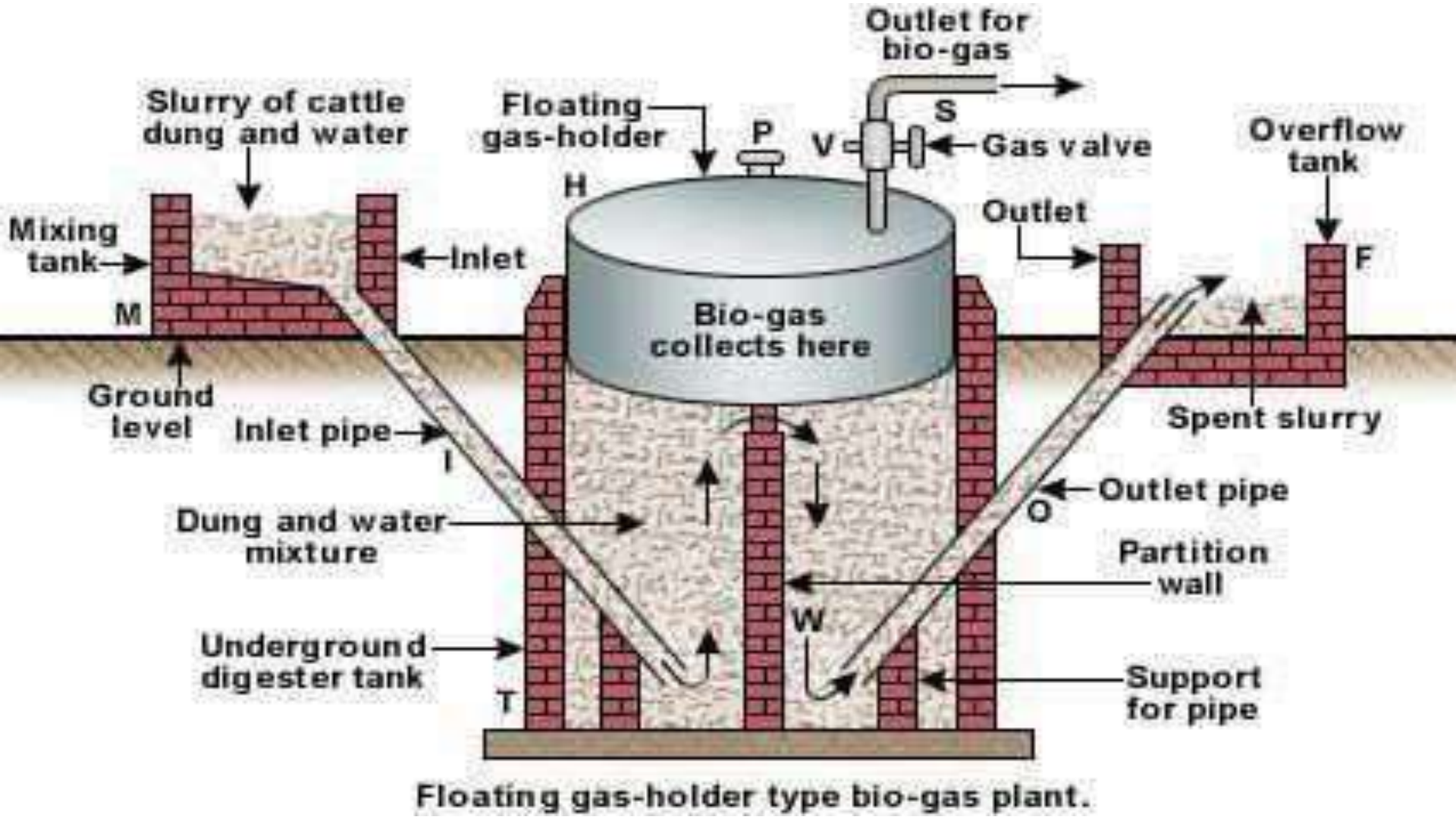
- **Mixing Tank** - present above the ground level.
- **Digester tank** - Deep underground well-like structure. It is divided into two chambers by a partition wall in between.
- It has two **long cement pipes**
  - i) **Inlet pipe opening** into the inlet chamber for introduction of slurry.
  - ii) **Outlet pipe opening** into the overflow tank for removal of spent slurry.
- **Gas holder** - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.
- **Over flow tank** - Present above the ground level.

Floating drum type biogas plant



Floating Dome type Bio-gas Plant

Floating drum type biogas plant



Floating gas-holder type bio-gas plant.

Working of Floating drum type biogas plant

- Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank.
- The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe.
- The plant is left unused for about two months and introduction of more slurry is stopped.
- During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester.
- Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts moving up.

Working of Floating drum type biogas plant

- The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry.
- The spent slurry is now forced into the outlet chamber from the top of the inlet chamber.
- When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure for plants.
- The gas valve of the gas outlet is opened to get a supply of biogas.
- Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

Floating drum type biogas plant

Advantages:

- High gas yield.
- No problem of gas leakage.
- Works under constant pressure naturally.
- No problem of mixing of biogas with external air, thus no danger of explosion.

Disadvantages:

- It has higher cost.
- Heat is lost through metal gas holder.
- Requires painting of drums to avoid corrosion at least twice a year.
- Requires maintenance of pipes and joints.

Advantages of Biogas

- Cost of equipments used for making biogas is less and equipments used are very simple.
- Biogas can be used for lighting, running the engines, farm's machine and cooking gas in the kitchen.
- Biogas is the best medium for cooking food.
- Organic feed stocks used in the plants are easily available at all places.
- Biogas plant gives efficiency as much as 60%.
- Distribution of gas has no problems of any gas leakage and fire.
- Waste product obtained from digester is best quality of fertilizer and gives best yields.

Disadvantages of biogas

- Biogas produced from biogas plant has to be used at near by places only. It can't be transported over long distances.
- Biogas can't be filled in the bottles.
- Biogas plant requires more area.
- It can be established in urban area where availability of land is limited.

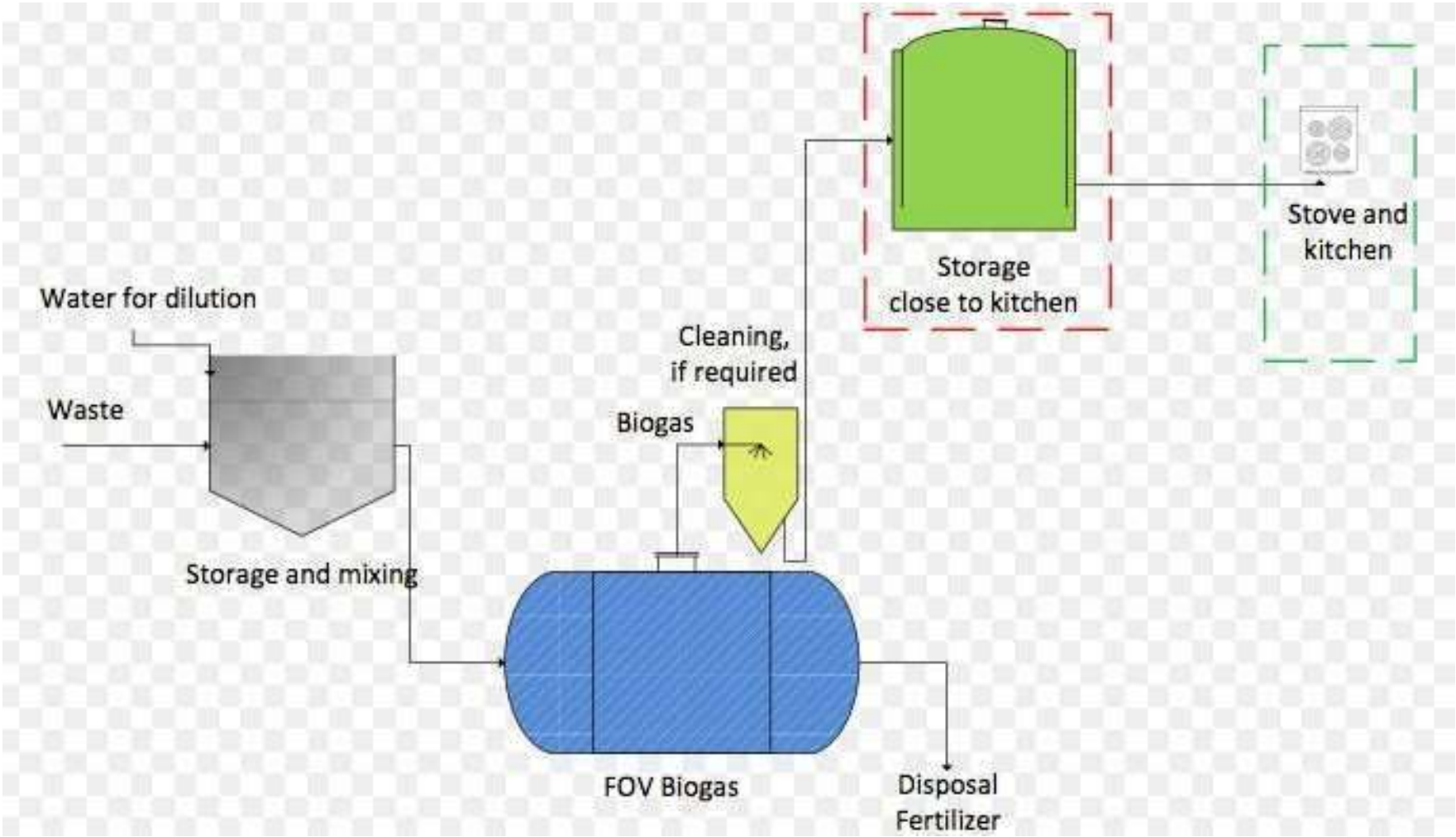
Application of biogas

- Biogas is used as cooking fuel.
- Biogas is used for lighting purpose.
- Biogas is used for water heating.
- It is used as fuel in I.C. Engine.
- It is used as fuel to run agricultural machineries.
- It is used to run diesel engine generator set to produce electricity.
- Heat of biogas is utilized in the dryer for drying the agricultural products.
- Heat of biogas is used to heat ammonia of refrigerating plant.
- It is used for running pumps for irrigation purpose.
- Methane and carbon dioxide are used as raw chemical feed stock to manufacture various chemicals.

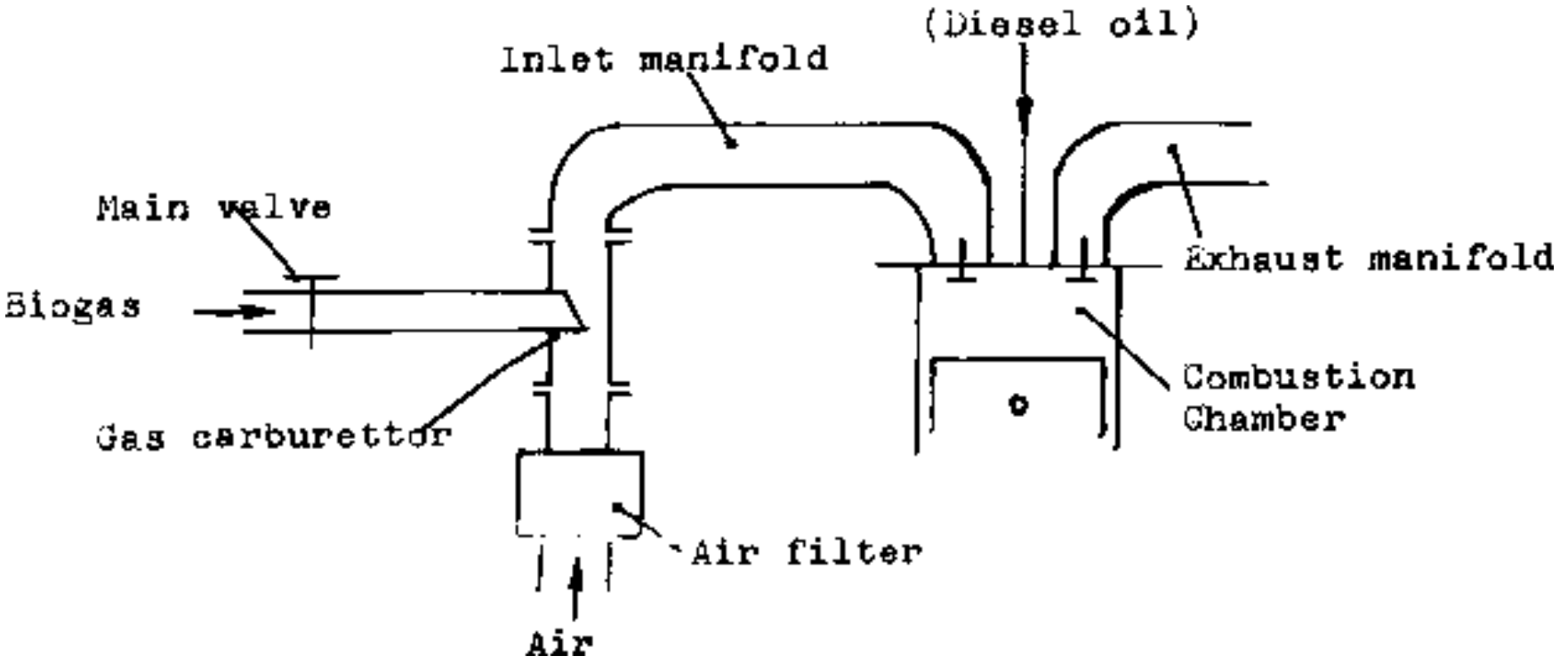
Biogas applications

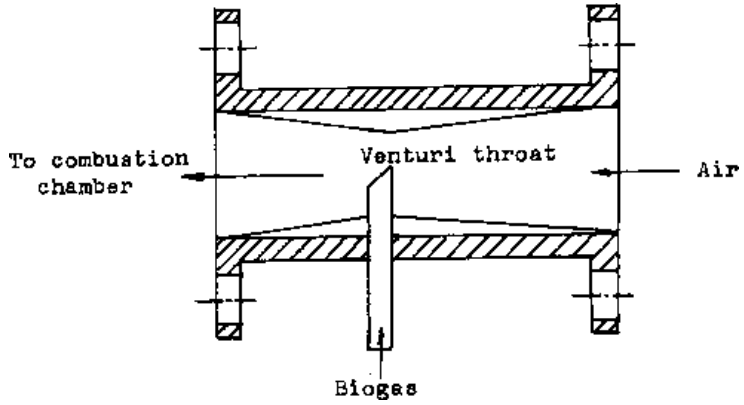
- Biogas for cooking
- Biogas for IC engine
- Biogas for power generation

Biogas for cooking

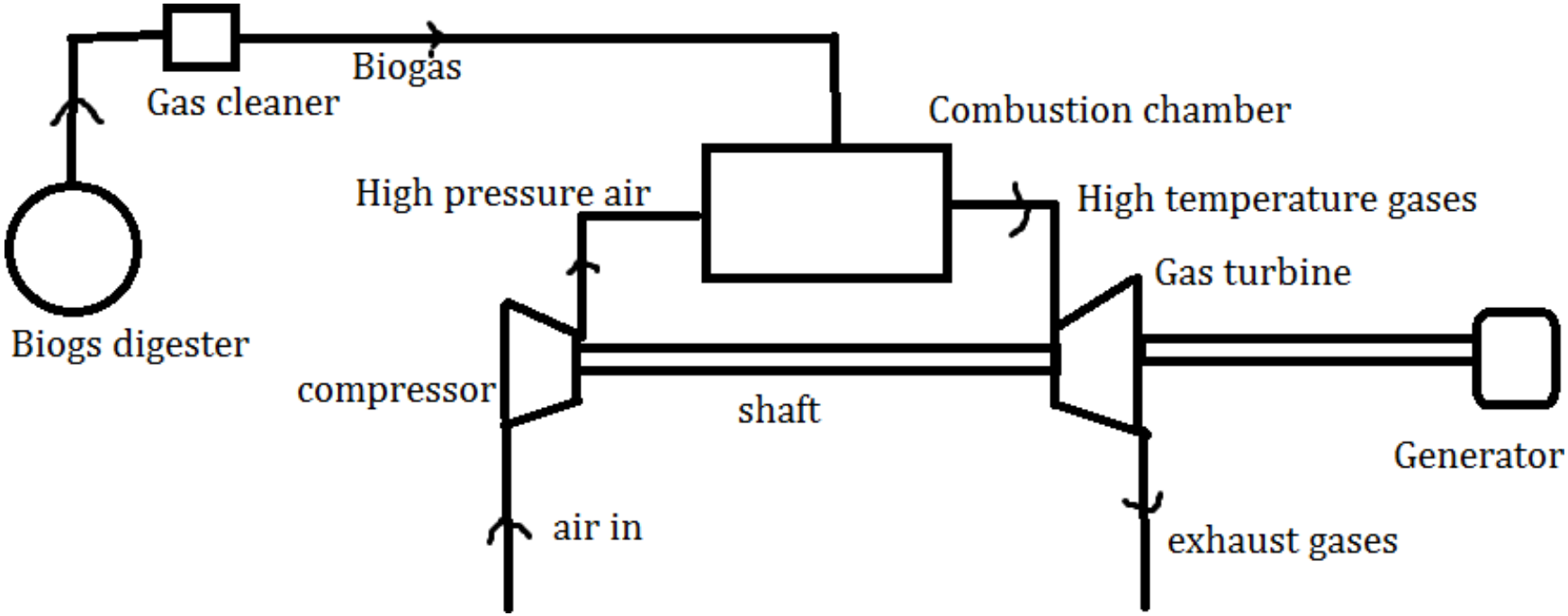


Biogas for IC engine

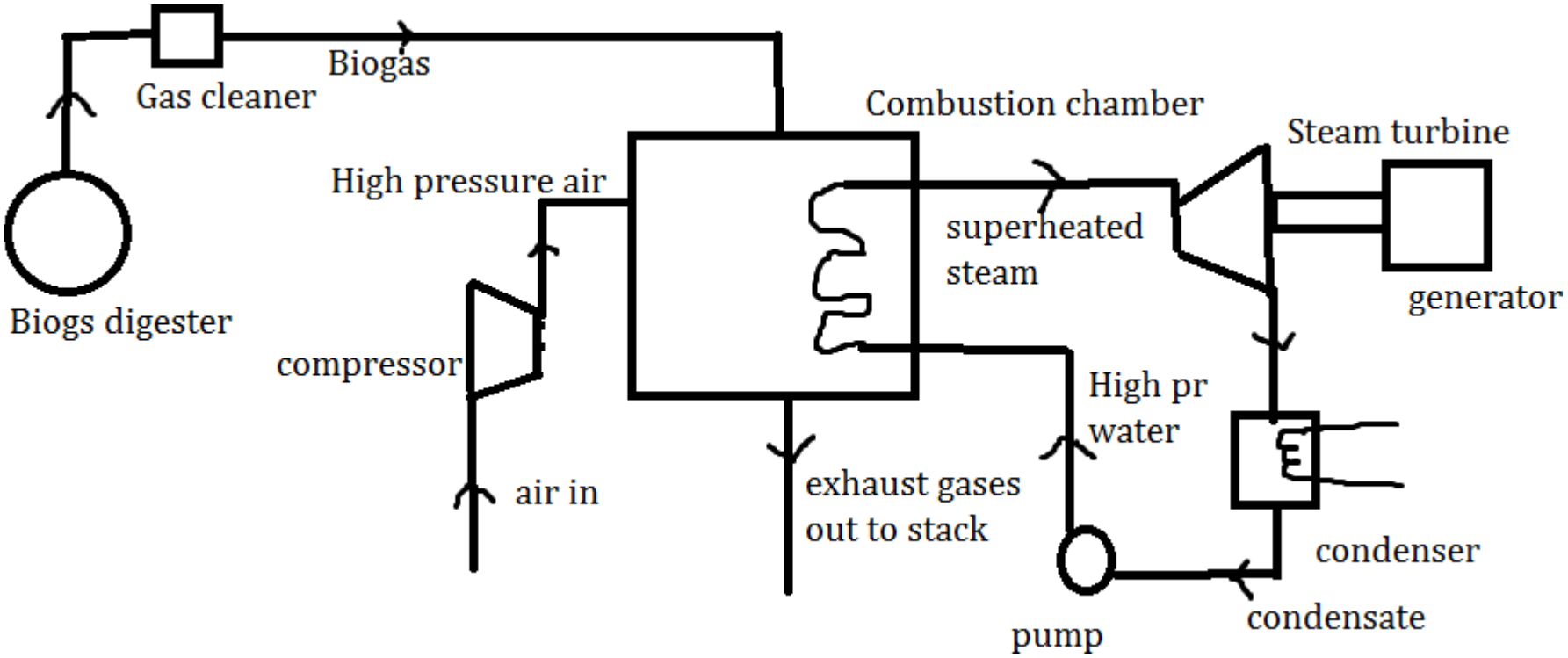




Biogas for power generation



Biogas for power generation



Combustion characteristics of biogas

Type	Bilk density(kg/m^3)	Proximate Analysis				
		Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	CV(MJ/kg)
Rice husk	150	12	11	72	17	18
Corn cobs	190	8	<1	85	15	18
Baggasse	80	50	<1	80	20	19
Wood saw dust chips	160	20	<1	80	20	20

Content of Methane in Bio-gas produced from different feed stocks

S.No.	Feed Stock	Content of Methane in Bio gas in Percentage
1.	Cattle Manure	54-56
2.	Pig Manure	57
3.	Poultry Manure	55
4.	Farm yard Manure	55
5.	Straw	55
6.	Grass	60
7.	Leaves	58
8.	Kitchen Waste	50-52
9.	Human excreta	60

Selection of site for biogas plant

(1) The distance between the plant and site of gas consumption or kitchen should be less to Minimize cost on gas pipe line and gas leakage.

(2) It should be near the cattle-shed to minimize the distance for carrying cattle dung and transportation cost.

(3) There should be enough space for storage of digested slurry or construction of compost pit.

(4) It is should be 10 to 15 meters away from any drinking water well to prevent contamination of water.

(5) The area should be free from roots of trees which are likely to creep into the digester and cause damage.

(6) It should be open to receive the Sun's rays for most part of the day and to keep the plant in warm. The sunlight should fall on the plant as temperature between $20^{o}C$ to $30^{o}C$ is essential for gas generation at good rate.

(7) It should be on an elevated area so that the plant does not get submerged during normal rains.

(8) Sufficient space must be available for day to day Operation and Maintenance. As a guide line 10 to 12 m^2 area is needed per m^3 of the gas.

(9) Plenty of water must be available as the Cow dung slurry with a solid concentration of 7% to 10% is used.

Economical benefits of bio gas utilization

(1) Bio gas technology, which is based on recycling of readily available resources in rural areas, gives comparatively cheaper and better fuel for cooking lighting and power generation.

(2) An individual can reduce the consumption of commercial energy sources such as fire wood, coal, kerosene, etc. by adopting waste recycling technology which vigorously help in reducing the family fuel budget.

(3) The problem of uncertainly of availability of commercial energy can be resolved by use of bio gas technology.

(4) The rural population of the country uses fire wood for meeting their cooking requirements. This reduces the national forest wealth. Our forest area can be conserved by using bio gas.

(5) The dependency on chemical fertilizer for better-agricultural production has increased to a great extent after independence in India. Bio gas slurry can be proved a best organic fertilizer which helps in improving soil fertility and crop production.

(6) Presently country is facing the problem of foreign exchange and balance of payment. Bio gas technology reduces the import of chemical fertilizers by using home made organic fertilizer and also petro products.

(7) Bio gas technology utilizes effectively the man power and resources, resulting in self-sufficiency and self reliance in the society.

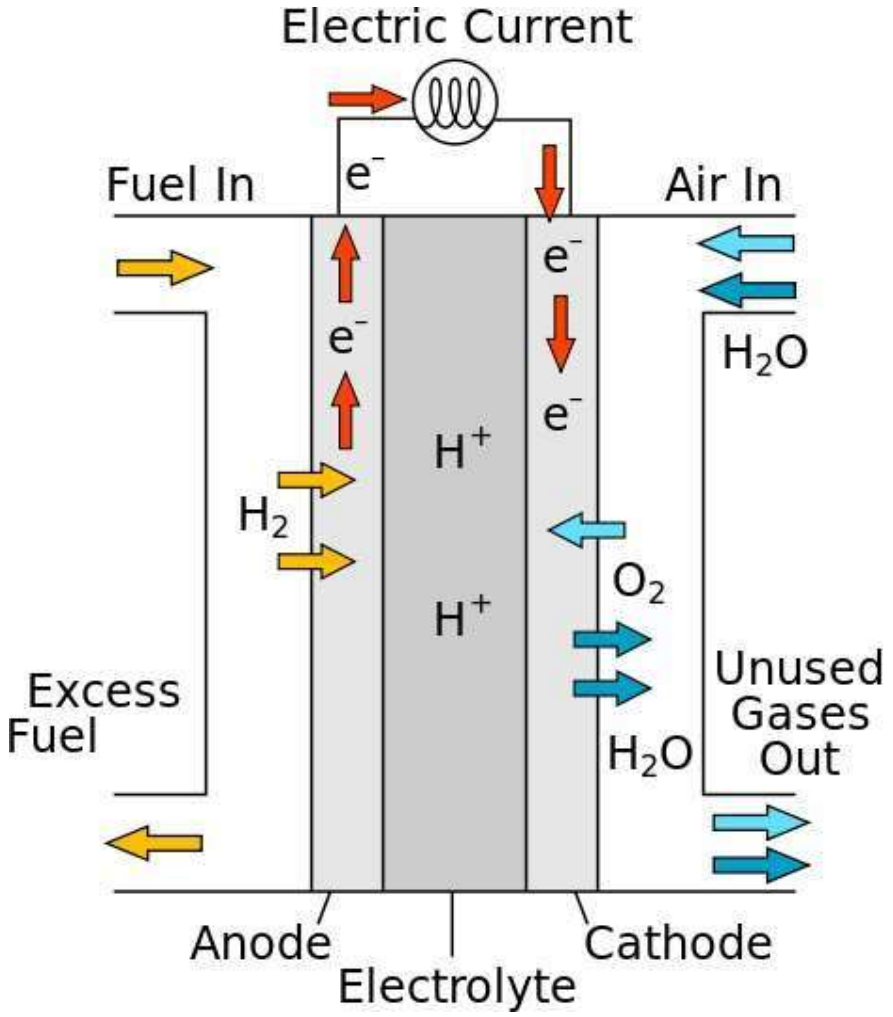
What is a fuel cell

- Creates electricity through electrochemical process
- Operates like a battery
- Emits heat and water only

Parts of fuel cells

There are 4 main parts

- Anode
- Cathode
- Catalyst
- Proton exchange membrane (Electrolyte)



Parts of fuel cell

The Anode:

- The anode is the negative post of the fuel cell.
- It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit.
- It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst

The Cathode:

- The cathode is the positive post of the fuel cell.
- It has channels etched into it that distribute the oxygen to the surface of the catalyst.
- It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

Parts of fuel cell

The Catalyst:

- The catalyst is a special material that facilitates the reaction of oxygen and hydrogen.
- It is usually made of platinum powder very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen.
- The platinum-coated side of the catalyst faces the PEM.

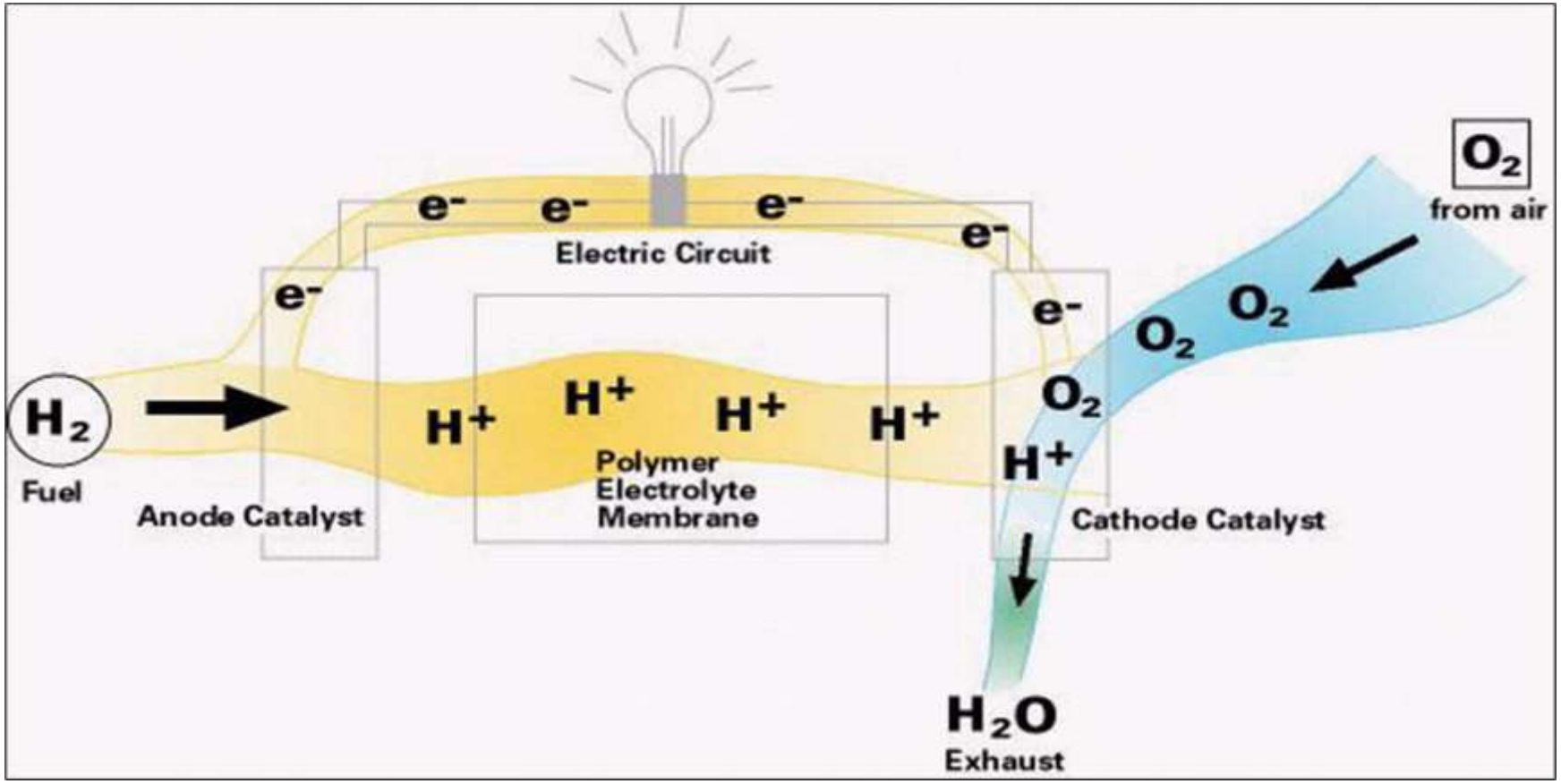
The Proton Exchange Membrane:

- The electrolyte is the proton exchange membrane.
- This is a specially treated material that only conducts positively charged ions.
- The membrane blocks electrons.

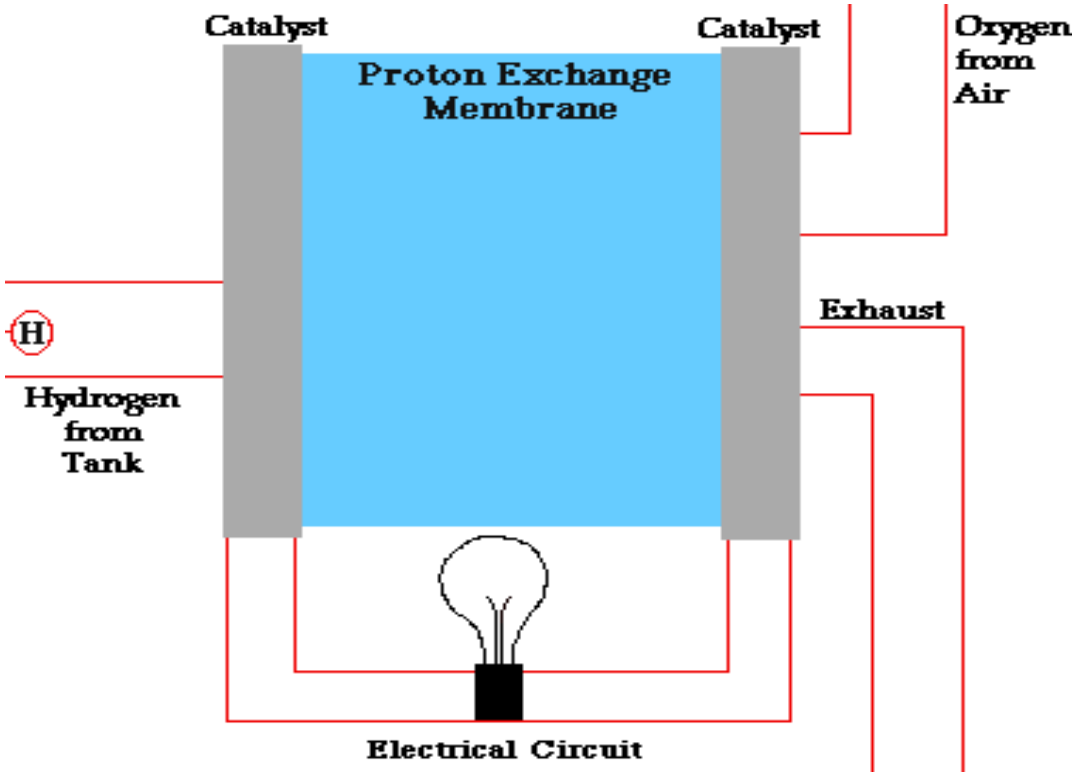
Fuel Cell Theory

- A fuel cell consists of two electrodes - Anode and Cathode.
- Hydrogen and Oxygen are fed into the cell.
- Catalyst at Anode causes hydrogen atoms to give up electrons leaving positively charged protons.
- Oxygen ions at Cathode side attract the hydrogen protons.
- Protons pass through electrolyte membrane.
- Electrons are redirected to Cathode through external circuit.
- Thus producing the current - power

Working of Fuel cell



Graphic showing working of Fuel Cell



http://americanhistory.si.edu/fuelcells/basics.htm

The Chemistry of a Fuel cell

Anode side:

$2H_2 \Rightarrow 4H^+ + 4e^-$

Cathode side:

$O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$

Net reaction:

$2H_2 + O_2 \Rightarrow 2H_2O$

- Pressurized hydrogen gas (H2), enters the fuel cell on the anode side
- Oxygen gas (O2) is forced through the catalyst on the Cathode side
- This reaction in a single fuel cell produces about 0.7 volts

Types of fuel cells

Type	Temperature(°C)	Application
• Alkaline (AFC)	70-90	Space
• Phosphoric Acid (PAFC)	150-210	Commercially available
• Solid Polymer (PEMFC)	70-90	Automotive application
• Moltan Carbonate (MCFC)	550-650	Power generation
• Solid Oxide (SOFC)	1000-1100	Power generation
• Direct Methanol (DMFC)	70-90	Under development

Alkaline Fuel Cell

- Used in spacecraft to provide drinking water and electricity
- Electrolyte: Aqueous solution of alkaline potassium Hydroxide
- Output of 300W -5kW
- Power generation efficiency of about 70%
- Too expensive for commercial applications
- Platinum and other precious materials used as electrodes.

Alkaline Fuel Cell

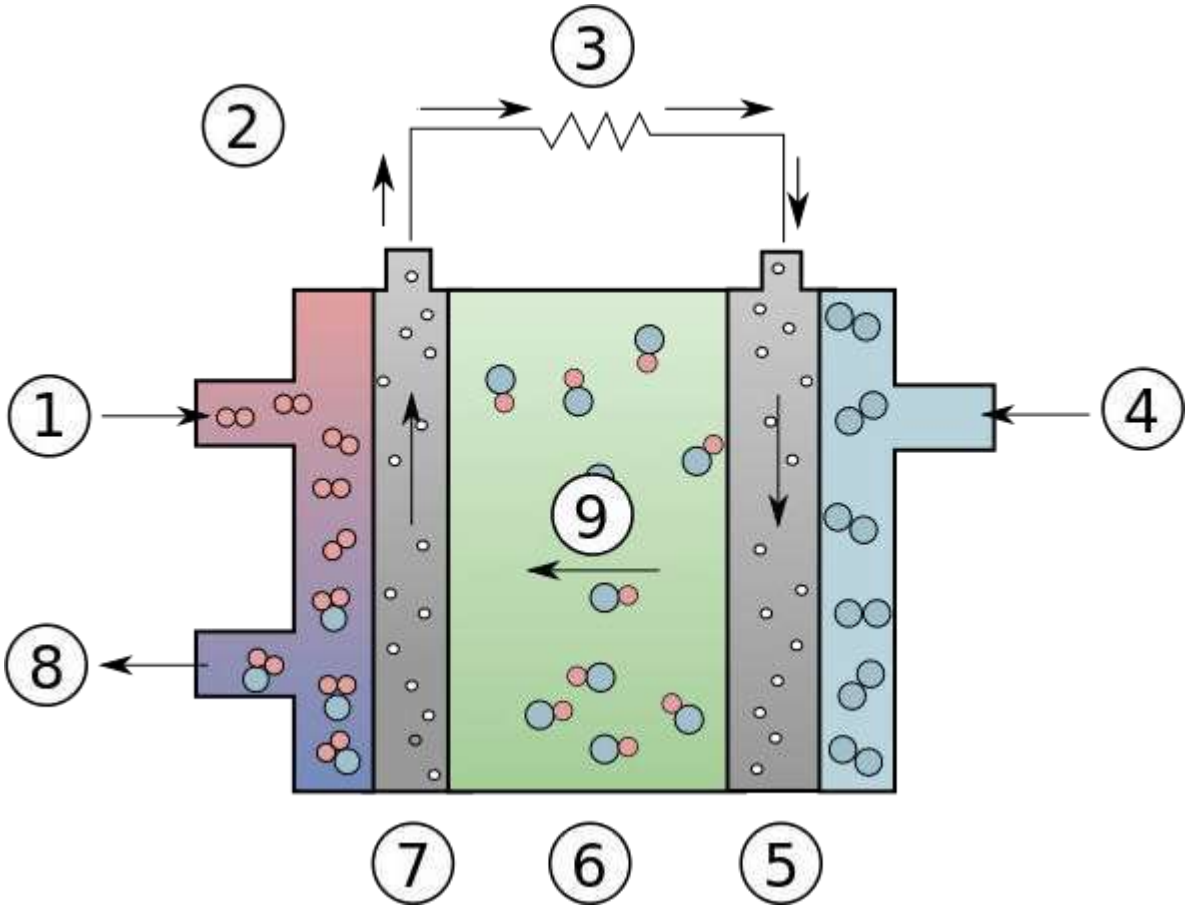


Diagram of an Alkaline Fuel Cell. 1: Hydrogen, 2:Electron flow, 3:Load, 4:Oxygen, 5:Cathode, 6:Electrolyte, 7:Anode, 8:Water, 9:Hydroxyl Ions.

Alkaline Fuel Cell

- The fuel cell produces power through a redox reaction between hydrogen and oxygen. At the anode, hydrogen is oxidized according to the reaction.

$$2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$$

- Water produces and electrons release. The electrons flow through an external circuit and return to the cathode, reducing oxygen in the reaction

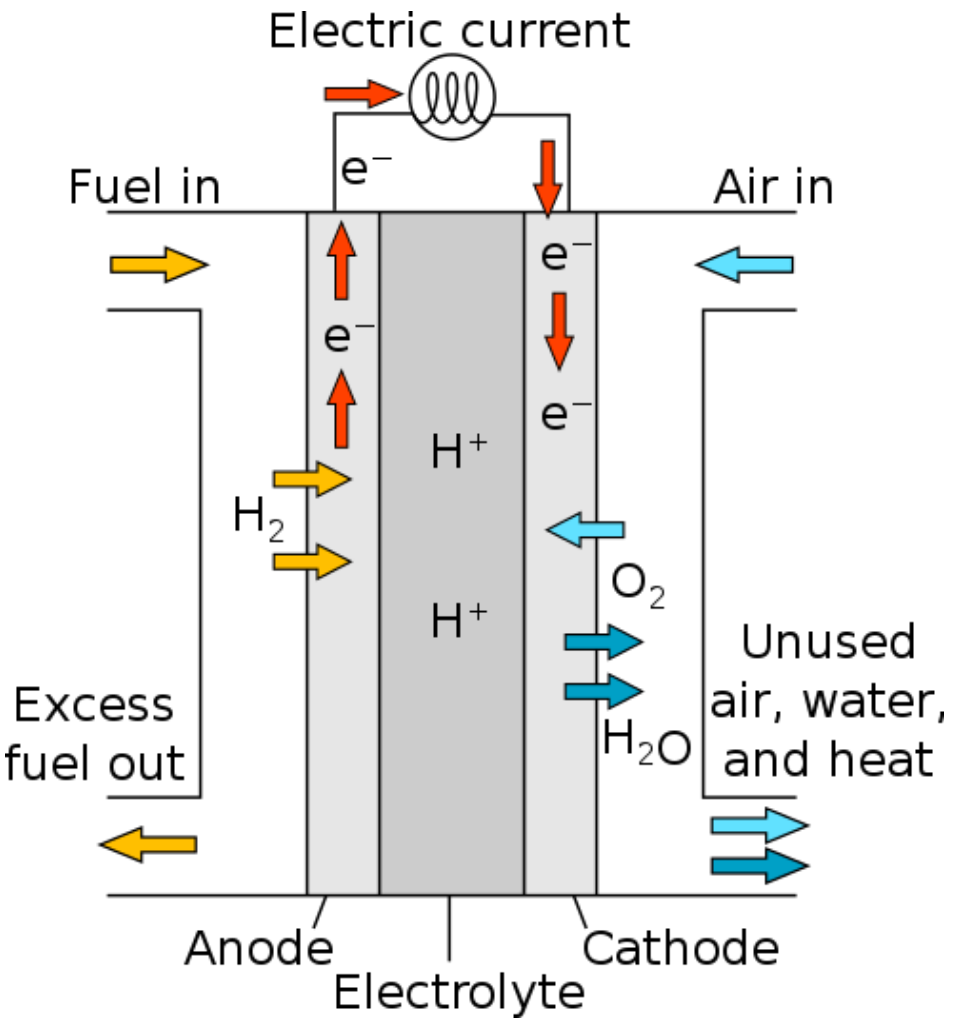
$$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$$

- The above reaction produces hydroxide ions. The net reaction consumes one oxygen molecule and two hydrogen molecules in the production of two water molecules. Electricity and heat are formed as by-products of this reaction

Phosphoric Acid Fuel cell

- Used in hospitals, nursing homes and for all commercial purposes
- Electrolyte: Liquid Phosphoric acid
- Catalyst: platinum
- Electrical efficiency of 40%
- Advantages : using impure hydrogen as fuel and 85% of the steam can be used for cogeneration
- Disadvantages: uses expensive platinum as catalyst, Large size and weight, Low power and current
- PAFC have been used for stationary power generators with output in the 100 kW to 400 kW range and are also finding application in large vehicles such as buses

Phosphoric Acid Fuel cell



Phosphoric Acid Fuel cell

- Electrolyte is highly concentrated or pure liquid phosphoric acid (H_3PO_4) saturated in a silicon carbide matrix (SiC). Operating range is about 150 to 210 °C. The electrodes are made of carbon paper coated with a finely dispersed platinum catalyst.
- The chemical reactions are

Anode reaction: $2H_2(g) \rightarrow 4H^+ + 4e^-$

Cathode reaction: $O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$

Overall cell reaction: $2\ H_2 + O_2 \rightarrow 2H_2O$

Proton Exchange Membrane Cells

- Also called as Solid Polymers and used for quick startup in automobiles, light duty vehicles and potentially to replace rechargeable batteries
- Electrolyte :Solid organic polymer poly-per flouro sulfonic acid.
- Catalyst: Metals (usually platinum) coated on both sides of membrane act as catalyst
- Advantages: Use of solid electrolyte reduces corrosion and management problems
- Disadvantages: Sensitive to fuel impurities
- Cell outputs generally range from 50 to 250 kW.

Molten Carbonate Fuel cell

- Majorly used for electric utility applications
- Electrolyte: Liquid solution of lithium, sodium and/or potassium carbonates.
- Catalyst: Inexpensive metals can be used as catalyst other than Platinum
- Advantages: High operating temperature allow for inexpensive catalysts . Higher efficiency and flexibility to use more type of fuels.
- Disadvantage: Higher temperature enhances corrosion and breakage of cell components

Molten Carbonate Fuel cell

Anode:

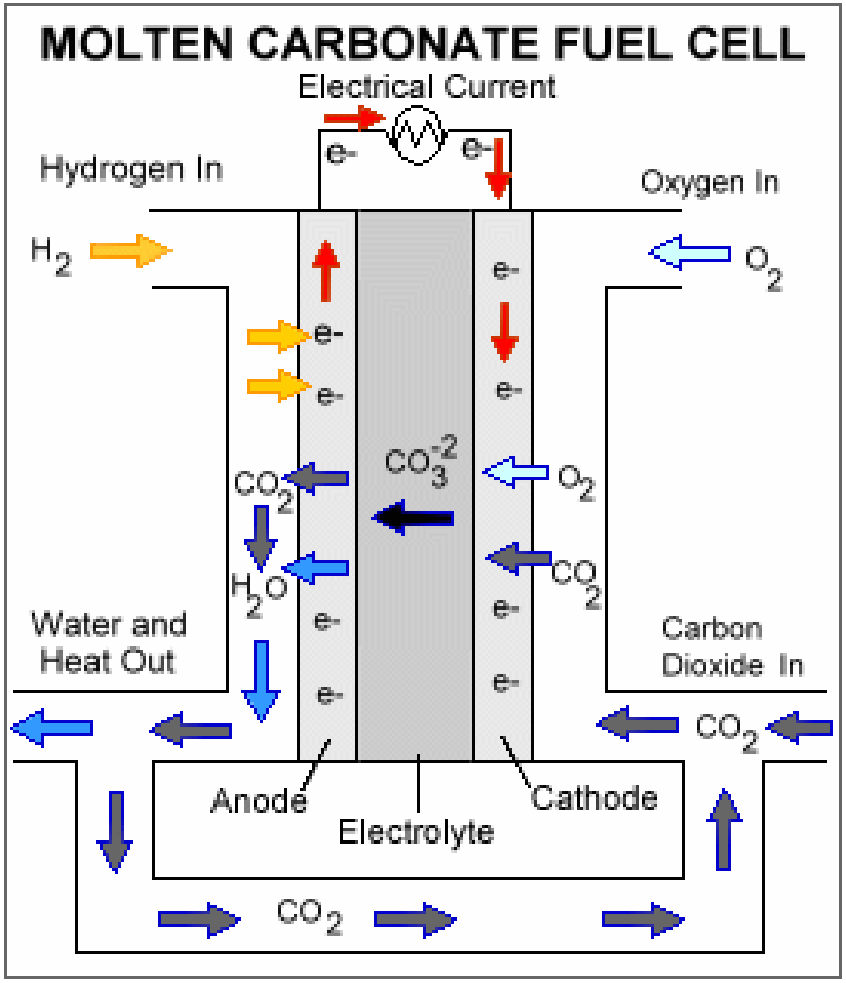
$$H_2 + CO_3^{=} = H_2O + CO_2 + 2e^-$$

Cathode:

$$\frac{1}{2}O_2 + CO_2 + 2e^- = CO_3^{=}$$

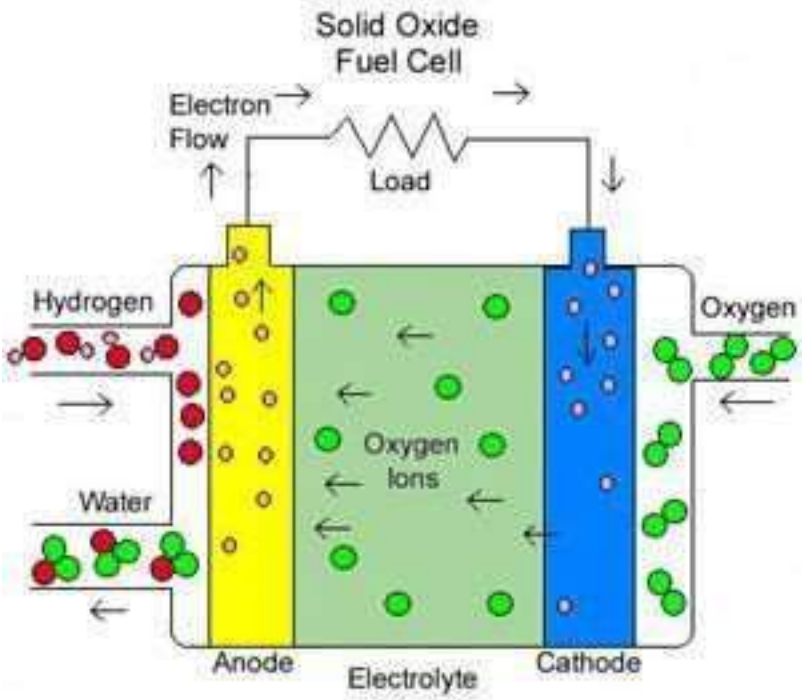
Cell:

$$H_2 + \frac{1}{2}O_2 + CO_2 = H_2O + CO_2$$



Solid Oxide Fuel Cell

- Highly promising fuel cell
- Used in big, high-power applications including industrial and large-scale central electricity generating stations
- Some developers also see SOFC use in motor vehicles
- Power generating efficiencies could reach 60% and 85%



Solid Oxide Fuel Cell

- Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O_2) as electrolyte.
- Operating temperatures are about 1,000 °C (about 1,800 °F).
- Cells output is up to 100 kW. However, the high temperature limits applications of SOFC units and they tend to be rather large. While solid electrolytes cannot leak, they can crack.

Advantages of fuel cells

1) The fuel cell converts its fuel directly to electric power. There is no pollution.
2) No cooling water is needed so it can be located at any desired place.
3) As it does not make noise. It can be readily accepted in residential areas.
4) The fuel cell takes little time to go into operation.
5) It would be an ideal reserve power source with in large conventional power plants to handle peak or emergency loads.
6) Efficiency remains constant from 100% to 25 % of rated load.
7) There is no maximum or minimum size for a fuel cell power plant.
8) The land requirement is considerably less compared with conventional power plants.
9) The maintenance charges are low as there are no moving parts and outages are also less.
10) The weight and volume of the fuel cell is considerably low compared to other energy sources.