Non-Conventional Energy Resources
Unit-V

Bio-mass: Availability of bio-mass and its conversion theory.
Ocean Thermal Energy Conversion (OTEC): Availability, theory and working principle, performance and limitations.
Wave and Tidal Wave: Principle of working, performance and limitations, Waste Recycling plants.

BIG-MASS

5.1 (a) Bio-gas: Biogas typically refers to a mixture of gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from regionally available raw materials such as recycled waste. It is a renewable energy source and in many cases exerts a very small carbon footprint. It is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops.[1] It is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S) and moisture.

Typical composition of biogas		
Compound	**Molecular formula**	**%**
Methane	**CH_4**	50–75
Carbon dioxide	**CO_2**	25–50
Nitrogen	**N_2**	0–10
Hydrogen	**H_2**	0–1
Hydrogen Sulphide	**H_2S**	0–3
Oxygen	**O_2**	0–0

5.1 (b) Bio-gas Conversion Process: There are basically three types of conversion process:

(1) Direct Conversion: Process of burning of oxygen to produce heat, light and byproducts is called combustion. Complete combustion to ashes is called incineration. The process of combustion is applicable to solid, liquid and gaseous fuels. The moisture content of raw biomass is high *i.e.* 8 – 20% for straw, 30 – 60% for wood and upto 95% for water plants. Therefore, the combustion of biomass is more difficult than other fuels.

(2) Thermo-chemical Conversion: Thermo-chemical conversion process converts the biomass and residues to fuels. The basic conversion takes place according to given reactions:

$$\text{Biomass} + O_2 \xrightarrow{Heat} CO + H_2 + \text{Heat}$$
$$\text{Biomass} + H_2O \rightarrow CO + H_2$$

(3) Biochemical Conversion: Biochemical conversion by micro-organism converting biomass to bio-fuels taking enough time at low temperature. This process is called fermentation, which may be explained as the process of decomposition of organic matter by micro-organism. This reaction takes place generally in the absence of oxygen and this type of digestion is called **anaerobic** digestion.

5.1 (c) Biogas Power Plant: Biogas is practically produced as landfill gas (LFG) or digested gas. A *biogas plant* is the name often given to an anaerobic digester that treats farm wastes or energy crops. It can be produced using anaerobic digesters. These plants can be fed with energy crops such as maize silage or biodegradable wastes including sewage sludge and food waste. During the process, an air-tight tank transforms biomass waste into methane, producing renewable energy that can be used for heating, electricity, and many other operations that use an internal combustion engine.

The important biogas plant constructions are as:

(1) Floating Drum Type Biogas Plants:

- In the past, floating-drum plants were mainly built in India.
- Floating-drum plants consist of an underground digester and a moving gas-holder.
- The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own.
- The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored.
- The gas drum is prevented from tilting by a guiding frame.
- The drum in which the biogas collects has an internal and/or external guide frame that provides stability and keeps the drum upright.

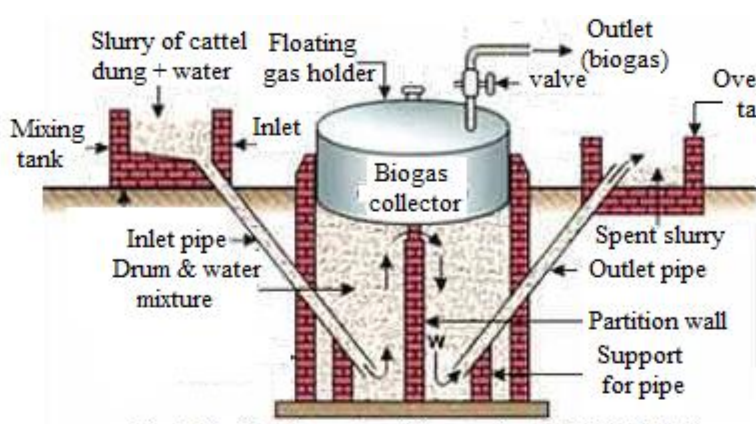

Fig.1. Floating Drum type biogas plant (**KVIC Model**)

- If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back.
- A common Floating drum type biogas power plant in India was suggested by **Khadi and Village Industries Commission (KVIC).**

(2) Fixed Dome Type Plants:

- A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester.
- When gas production starts, the slurry is displaced into the compensation tank.
- Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.
- There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected.
- The plant is constructed underground, protecting it from physical damage and saving space.
- While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester.

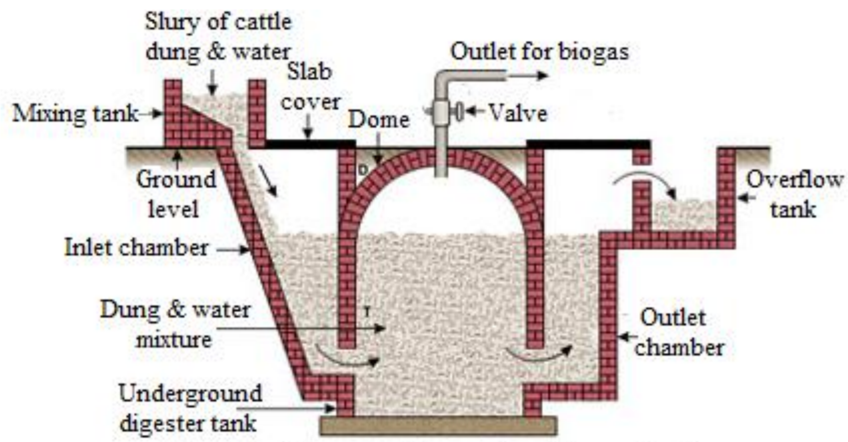

Fig.2. Fixed dome type biogas plant (**Janata Model**)

- No day/night fluctuations of temperature in the digester positively influence the bacteriological processes.
- The Janata model is the basic fixed dome type plant in India, was developed by **Planning Research and Action Division, Lucknow** in 1978.
- It is the first fixed dome plant based on Chinese technology.

(2.2) Deenbandhu Biogas Plant:

- This is a fixed dome plant developed by **Action for Food Production (AFPRO)** in 1984.
- It is suitable for using all types of wastes and minimizes biogas losses from inlet chamber.
- The basic construction is shown in figure 3, which has curved bottom and hemispherical top which are joined at their bases with no cylindrical portion in between.
- Cattle dung slurry prepared in 1:1 ratio with water is fed to the digester by an inlet pipe, upto the level of second step in the outlet tank.
- The anaerobic digestion of biogas slurry produces the biogas which collected in the upper portion of dome.
- The gas pressure causes the digested slurry to move out to the displacement chamber.

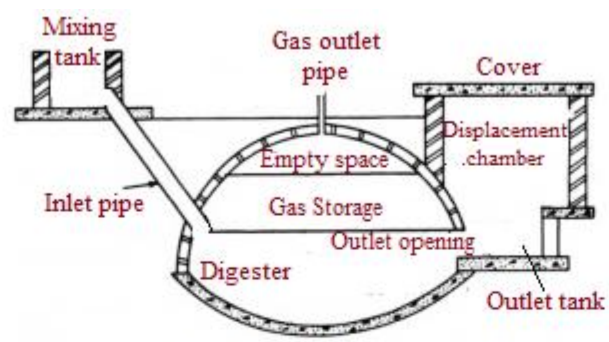

Fig.3. Deenbandhu biogas plant

5.1 (d) Advantages & Disadvantages of Floating Type & Fixed Dome Biogas Plants:

(1) Floating Drum Type Biogas Plants		(2) Fixed Dome Type Plants	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
➢ Constant gas pressure. ➢ Higher gas production. ➢ Less danger of explosion due to separation between biogas and external air. ➢ No problem of gas leakage.	➢ Higher cost. ➢ High maintenance required. ➢ Loss of heat through gas holder.	➢ Less maintenance, due to no moving parts. ➢ Low operating and capital cost. ➢ Heat insulation is better due its underground construction. ➢ Longer working life.	➢ Gas pressure is variable. ➢ Required skilled professionals for construction. ➢ Scum is formed.

5.1 (e) Site Selection for Biogas Plant:

- The site should facilitate easy construction works and should be such that the construction cost is minimized
- The selected site should ensure easy operation and maintenance activities like feeding of plant, use of main gas valve, composing and use of slurry, checking of gas leakage, draining condensed water from pipeline etc.
- To make plant easier to operate and avoid wastage of raw materials, especially the dung/swine manure, plant must be as close as possible to the cattle shed.
- The site should be in slightly higher elevation than the surrounding. This helps in avoiding water logging. This also ensures free flow of slurry from overflow outlet to the composting pit.
- For effective functioning of bio-digesters, right temperature (20-35°C) has to be maintained inside the digester. Therefore it is better

to avoid damp and cool place.

OCEAN THERMAL ENERGY CONVERSION (OTEC)

5.2 (a) Ocean Thermal Energy Conversion (OTEC): Ocean thermal energy conversion (**OTEC**) uses the temperature difference between cooler deep and warmer shallow or surface ocean waters to run a heat engine and produce useful work, usually in the form of electricity. OTEC is a base load electricity generation system, i.e. 24hrs/day all year long. However, the temperature differential is small and this impacts the economic feasibility of ocean thermal energy for electricity generation.

5.3 (b) Availability: The oceans cover more than 70% of Earth's surface and capture about 80% of the sun's radiation incident on the earth, making them the world's largest solar collectors and energy storage system. It stores an annual energy flux of 0.85×10^{18} kWh. Utilizing just a small portion of this energy, can cover the global energy need. The energy source of OTEC is free, available abundantly and is continually being replenished as long as the sun shines and the natural ocean currents exist. The solar radiation absorbed in the surface layer of the ocean water in the equatorial zone heat the water upto 27-30^{0}C depending on the season. The surface temperature varies both with latitude and season.

5.3(c) Types of OTEC Systems:

(1) Open or Claude Cycle OTEC System:

- Open-cycle OTEC uses warm surface water directly to make electricity.
- The warm seawater is "flashed evaporated" into a low-pressure container, which causes it to boil.
- In some schemes, the expanding steam drives a low-pressure turbine attached to an electrical generator.
- The steam, which has left its salt and other contaminants in the low-pressure container, is pure fresh water.
- It is condensed into a liquid by exposure to cold temperatures from deep-ocean water.

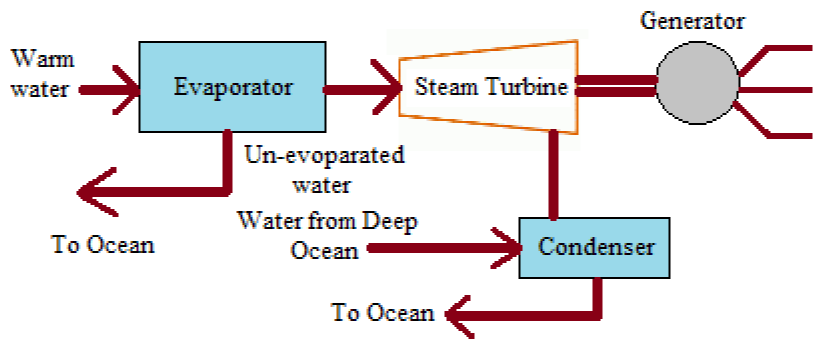

Fig.4 Open or Claude cycle OTEC system

- This method produces desalinized fresh water, suitable for drinking water, irrigation or aquaculture.
- A heat exchanger is not required and direct-contact with between the exhaust steam and cold water spray makes a heat exchanger.
- In such scheme, the generated steam is at very low pressure, this requires a large volume of steam.

(2) Closed or Anderson Cycle OTEC System:

- Closed-cycle systems use fluid with a low boiling point, such as ammonia, Freon-12, butane to power a turbine to generate electricity.
- Warm surface seawater is pumped through a heat exchanger which acts as boiler to vaporize the fluid at high pressure.
- The expanding vapor turns the turbo-generator. Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.
- The overall efficiency of such plant is very low in the range of 2 – 3% only.

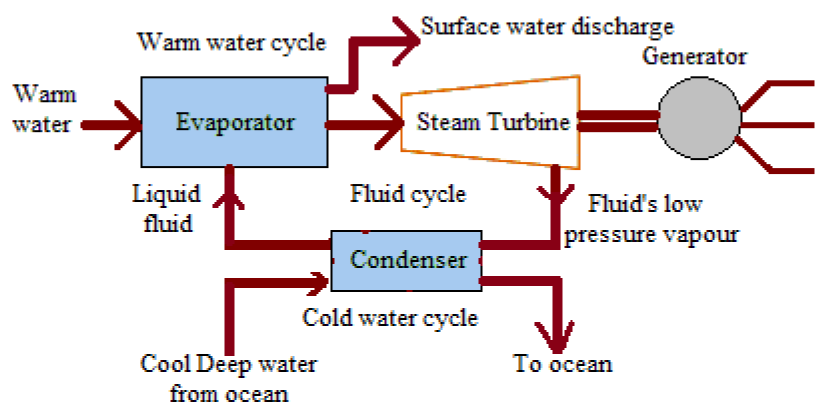

Fig.5. Closed or Anderson Cycle OTEC System

5.3 (d) Advantages & Disadvantages of OTEC Systems:

Advantages	Disadvantages
➢ Power developed is almost constant and independent of weather.	➢ High capital cost.
➢ There is small variation in power output from season to season.	➢ Low efficiency.
➢ Small changes are required to use as conventional power plant.	➢ Expensive working fluids in case of closed cycle.
➢ Useful to produce desalinated water and nutrients.	➢ High generation cost of power per kWh.

TIDAL ENERGY

5.4 (a) Tidal Energy: Tidal energy is a form of hydropower that converts the energy of tides into useful forms of power, mainly electricity. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability.

5.4 (b) Tidal Power Plants:

Tidal power plant can be classified on the basis of basin used for power generation. There are two types of basin systems:

(1) Single Basin System:

- This is the simplest system to generate tidal power. This scheme has only one basin which is separated from the sea by a dam.
- The sluiceway is opened during high tide to fill the basin, and used to empty the basin during the low tides.
- The water during high tides is first trapped in basin and then allowed to escape during the period of low tides.
- The water while escaping to run a hydraulic turbine coupled to a generator.
- In such systems the power house is situated at the mouth of basin. The hydraulic turbine in the power house only operates during the discharge of water from the basin during ebb tide.
- We also have **double cycle system** in which the power generation is affected during the ebb as well as flood tides.
- The direction of flow through the turbine during the ebb and flood tides alternates and generation of power is accomplished, both during the filling and emptying of basin.

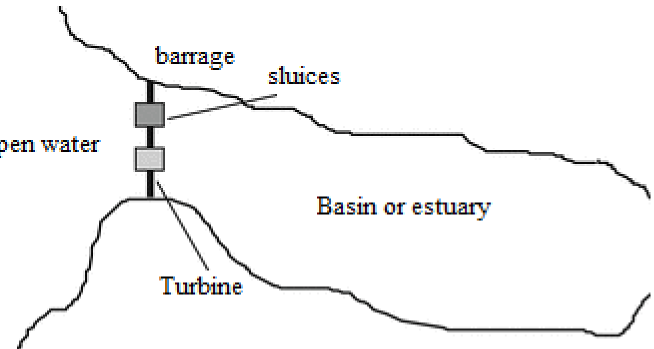

Fig.6. Single basin one way system of Tidal power plant

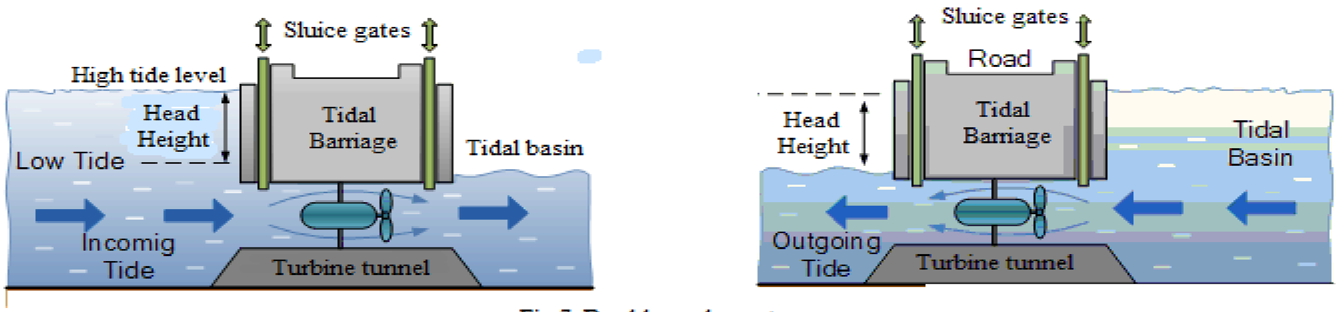

Fig.7. Double cycle system

(2) Double Basin System:

- This system has two basins at different levels and a dam is provided in between these basins as shown in figure 8.
- One basin 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.
- When the water level in upper basin is maximum during high tide the inlet sluice is closed and the level of water in lower basin keeps on rising due to discharge of water by the turbine.

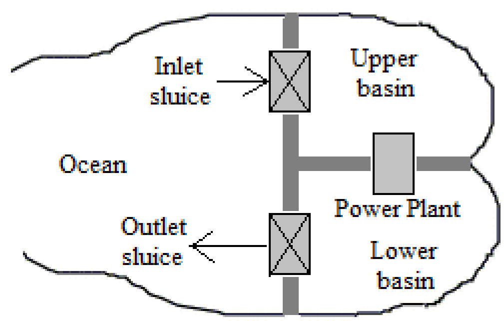

Fig.8. Double basin Tidal Power plant

- When the level of water in lower basin equals during the ebb tide, the outlet sluice is opened and it is closed when the water level reaches to its minimum level. This cycle is repeated, which is responsible for rotation of turbine.
- Two-basin schemes are very expensive to construct due to the cost of the extra length of barrage.

5.4 (c) Advantages, Disadvantages & Environmental Impact of Tidal Power Plants:

Advantages	Disadvantages	Environmental Impacts
➢ Freely available and inexhaustible. ➢ Pollution free. ➢ Monsoon independent. ➢ No extra submerging of land is involved.	➢ High initial cost. ➢ Difficult to install due to less location. ➢ Sea water is corrosive. ➢ Uneven operation. ➢ Because of variable tidal range, the efficiency of plant is affected. ➢ Sedimentation of basins is a problem.	➢ Changes the hydrology and salinity. ➢ Marine life is affected. ➢ Changes environmental climate. ➢ Responsible for lost of some spices.