RENEWABLE ENERGY SYSTEMS

After Completion of the Course, the student can able to	
C414.1	Students are able to understand the concepts of Renewable and non Renewable energy sources and need of Renewable energy systems. To understand concepts of Solar radiation.
C414.2	Students are able to understand concepts of PV effect and PV technologies and grid connected PV systems
C414.3	To understand basic concepts of wind energy conversion and system , desing considerations, and know about site selection considerations for wind energy conversion systems
C414.4	Students are able to understand the Geothermal energy and its mechanism of production, analyse the concepts of producing Geothermal energies.
C414.5	To distinguish between various alternate sources of energy for different suitable application requirements, and to understand various energy scenarios of ocean, biomass and fuel cells

UNIT-I

SOLAR ENERGY

Introduction:

Energy is the primary source for all human kind. India has a vast supply of renewable energy resources, and it has one of the largest programs in the world for deploying renewable energy products and systems. Specifically, 3,700 MW are currently powered by renewable energy sources (3.5 percent of total installed capacity).

The key drivers for renewable energy are the following:

- The demand-supply gap, especially as population increases
- A large untapped potential
- Concern for the environment
- The need to strengthen India's energy security
- Pressure on high-emission industry sectors from their shareholders
- A viable solution for rural electrification

Solar energy:

Every energy generation and transmission method affects the environment. As it is obvious conventional generating options can damage air, climate, water, land and wildlife, landscape, as well as raise the levels of harmful radiation. Renewable technologies are substantially safer offering a solution to many environmental and social problems associated with fossil and nuclear fuels (EC,1995,1997). Solar energy technologies (SETs) provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities.

The application of solar energy is

1. Heating and cooling residential buildings
2. Solar water heating
3. Solar drying of agricultural and chemical products.
4. Solar distillation of a small community scale
5. Salt production by evaporation of sea water
6. Solar cookers
7. Solar engines for water pumping
8. Food refrigeration
9. Bio conversion and wind energy and which are indirect source of solar energy
10. Solar furnaces
11. Solar electric power generation by
    i) Solar ponds

ii) Steam generators heated by rotating reflectors

iii) reflectors with lenses and pipes for fluid circulation

12. solar photovoltaic cells which can be used for conversion of solar energy directly into electricity (or) for water pumping in rural agriculture purposes.

Solar Radiation

Solar energy, received in the form of radiation, can be converted directly or indirectly in to other forms of energy, such as heat and electricity. The major draw backs of the extensive application of solar energy of

1. the intermittent and variable manner in which it arrives at the earth's surface and
2. the large area require to collect the energy at a useful rate.

Energy is radiated by the sun as electromagnetic waves of which 99% have wave lengths in the range of 0.2 to 4.0 micro meter (1 micro meter = 10^{-6} meter)

Solar energy reaching the top of the earth's atmosphere consists of about

- 8% ultra violet radiation [short wave length >0.39 micrometer]
- 46% visible light [0.39 to 0.78 micrometer]
- 46 % infrared [0.78 micro meter above]

Solar constant:

The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions.Its diameter is 1.39 X 10^6 km while that of earth is 1.27 X 10^4 km. the mean distance between the two is 1.5 X 10^8 km. although the sun is large, its subtends angle of only 32 min. at the earth's surface.

The brightness of the sun varies from its center to its edge. However the calculation purpose the brightness all over the solar disc is uniform. The total radiation from the sun is 5762 degrees K.

This variation in distance produces sinusoidal variation in the intensity of solar radiation I that reaches the earth.

$I_{SC} = 1367$ watts/m^2

$$\frac{I}{I_{SC}} = 1+0.033 \cos \frac{360n}{365}$$

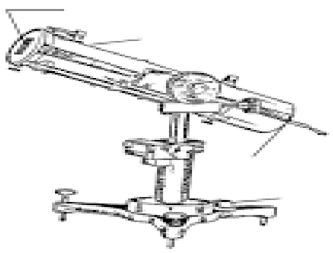
The luminosity of the Sun is about 3.86 x 1026 watts. The power of the sun at the earth, per square metre is called the **solar constant** and is approximately 1370 watts per square metre (W m-2).

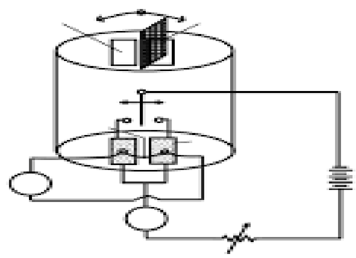
Solar Radiation Measuring Instruments (Radiometers):

A radiometer absorbs solar radiation at its sensor, transforms it into heat and measures the resultingamount of heat to ascertain the level of solar radiation. Methods of measuring heat include taking out heatflux as a temperature change (using a water flow pyrheliometer, a silver-disk pyrheliometer or a bimetallic pyranograph) or as a thermoelectromotive force (using a thermoelectric pyrheliometer or a thermo electric pyranometer). In current operation, types using a thermopile are generally used. The radiometers used for ordinary observation are pyrheliometers and pyranometers that measure directsolar radiation and global solar radiation, respectively.

Pyrheliometers:

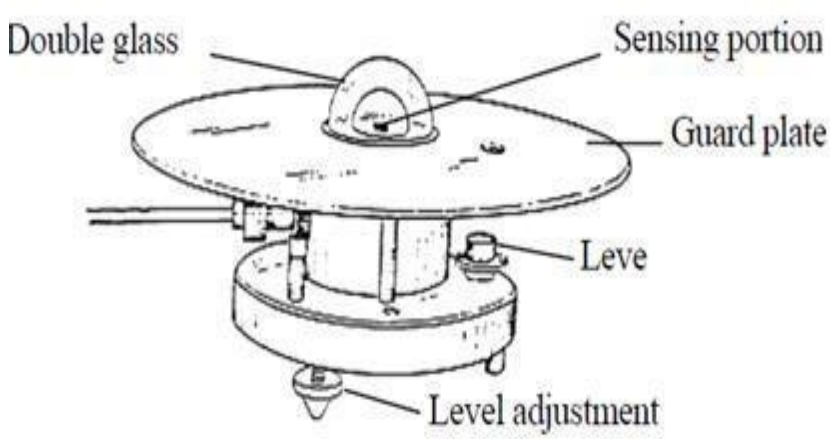
A pyrheliometer is used to measure direct solar radiation from the sun and its marginal periphery. Tomeasure direct solar radiation correctly, its receiving surface must be arranged to be normal to the solardirection. For this reason, the instrument is usually mounted on a sun-tracking device called an equatorialmount.





Pyranometers:

A pyranometer is used to measure global solar radiation falling on a horizontal surface. Its sensor has ahorizontal radiation-sensing surface that absorbs solar radiation energy from the whole sky (i.e. a solid angleof 2π sr) and transforms this energy into heat. Global solar radiation can be ascertained by measuring thisheat energy. Most pyranometers in general use are now the thermopile type, although bimetallic pyranometers are occasionally found.



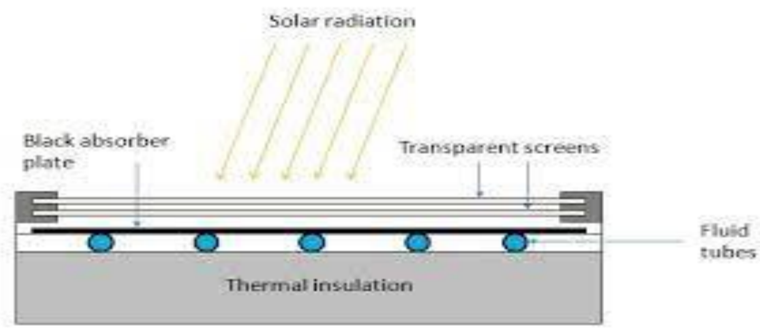
Solar energy and storage:

Solar Collectors:

Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transformits radiation into heat, then transfer thatheat to water, solar fluid, or air. The solar thermal energy can be used in solar waterheating systems, solar pool heaters, andsolar space- heating systems. There areseveral types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors

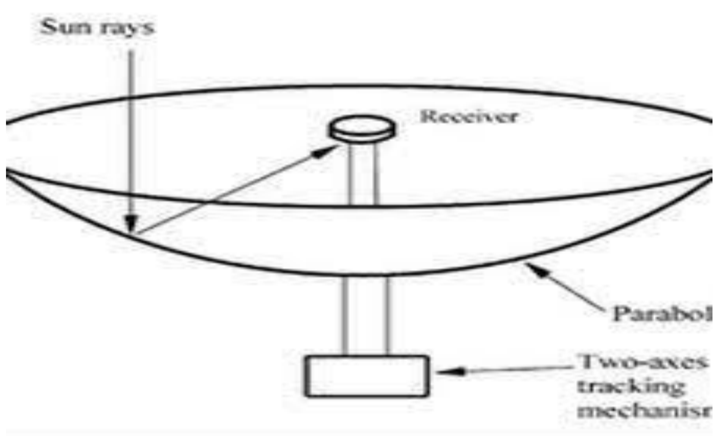
Flat-plate collectors:



Flat-plate collectors are the most common solar collector for solar water-heating systemsin homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 180°F.Flat-plate collectors are used for residential water heating and hydronic space-heating installations.

Concentrating collectors:

Point Focusing :



here in parabola reflector the sun rays falls on to th3e vertex and reflects
these reflected rays falls on the focus where absorber is there, which absorbs radiation and heat is transferred to the transfer fluid.

Line Focusing:

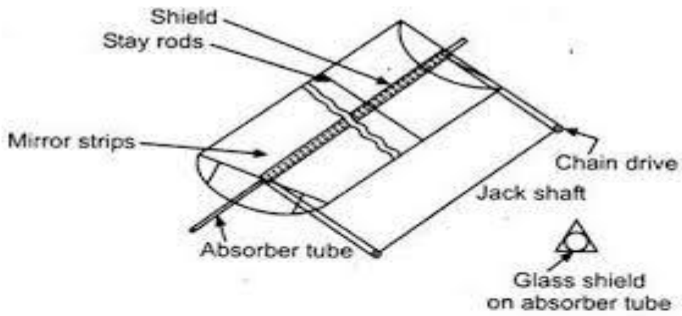
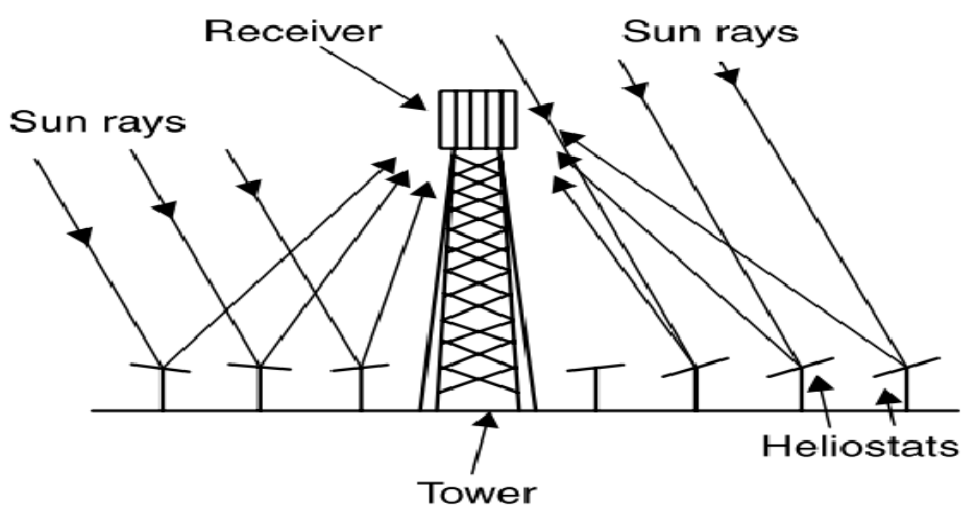


Fig. 3.5. Cylindrical parabolic system.

here sure rays falls on cylindrical shape reflector has mirror strips and rays reflector and falls on the straight which contains absorber tube. The absorber tube contains fluid absorbs heat.

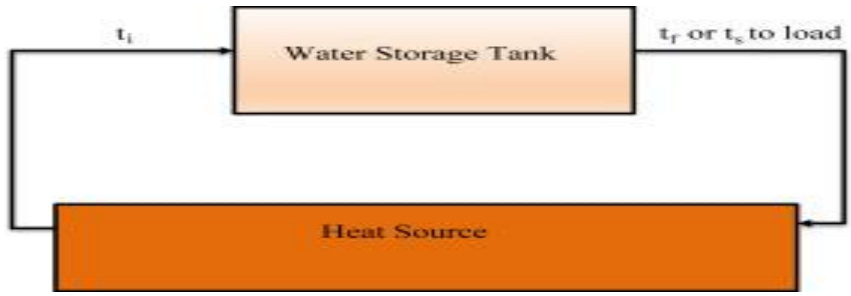
Heliostat:

This type of heiostat point focusing reflector used in large power generation
Here each mirror is called heliostat
There is a central receiver.



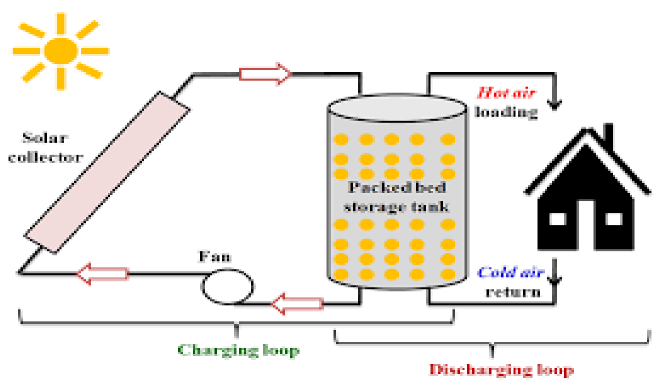
Sensible heat storage:

The use of sensible heat energy storage materials is the easiest method ofstorage. In practice, water, sand, gravel, soil, etc. can be considered asmaterials for energy storage, in which the largest heat capacity of water, sowater is used more often. In the 70's and 80's, the use of water and soil forcross- seasonal storage of solar energy was reported. But the material's sensibleheat is low, and it limits energy storage.



Latent heat-storage:

Latent heat-storage units are storing thermal energy in latent (= hidden, dormant)mode by changing the state of aggregation of the storage medium. Applicablestorage media are called "phase change materials" (PCM).. Commonly saltscrystal is used in low-temperature storage, such as sodium sulfate decahydrate /calcium chloride, sodium hydrogen phosphate 12-water. However, we must
solve the cooling and layering issues in order to ensure the operatingtemperature and service life.



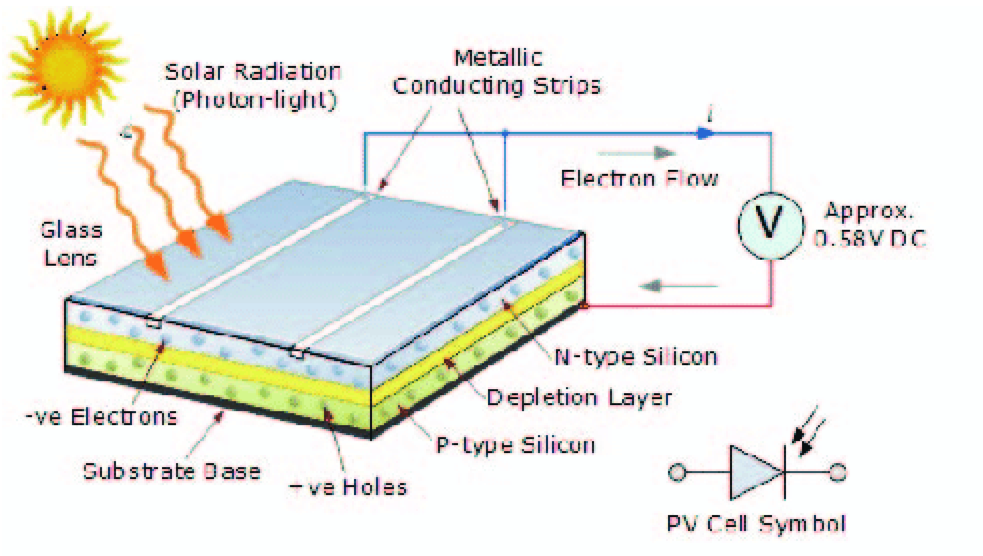
<u>**UNIT II**</u>

<u>**PV ENERGY STEMS**</u>

Photo voltaic cell:

A photovoltaic (PV) system is able to supply electric energy to a given load by directly converting solar energy through the photovoltaic effect.

PV cell:



A photo voltaic cell is a comprised of many layers of materials, each with a specific purpose

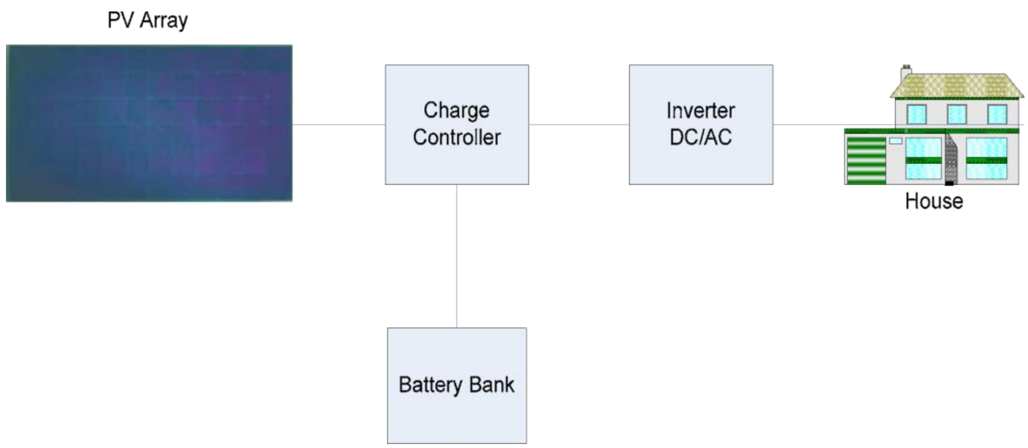
The most important layer of a photo voltaic cell is the specially treated semiconductor layer.

The photovoltaic effect is a process that generates voltage or electric current in a photo voltaic cell when it is exposed to sunlight. The solar cells are composed of two different types of semi conductors a p-type and n-type. There are joined together to create a p-n junction as electrons move to the positive p-side and holes move to negative n-side.

PV systems can be broadly classified in two major groups:

1) **Stand-Alone**
2) **Grid-Tied:**

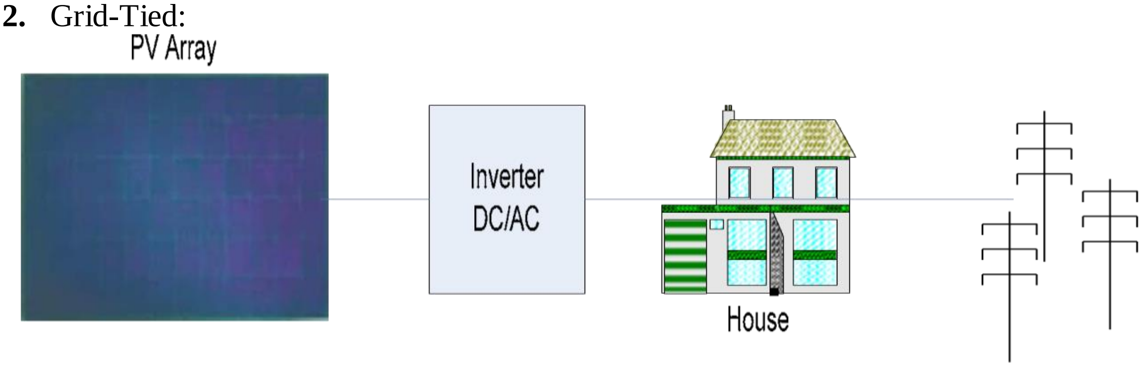
1. **Stand-Alone:**



It includes all the elements necessary to serve AC appliances in a common household or commercial application. The inverter could be eliminated or replaced by a DC to DC converter if only DC loads are to be fed by the PV modules.

Ex: water pumping applications were a PV module is directly coupled to a DC pump, water is stored in a tank through the day whenever energy is available.

2. Grid-Tied:



These systems are directly coupled to the electric distribution network and do not require battery storage. Electric energy is either sold or bought from the local electric utility depending on the local energy load patterns and the solar resource variation during the day,

This operation mode requires an inverter to convert DC currents to AC currents. There are many benefits that could be obtained from using grid-tied PV systems instead of the traditional stand-alone schemes

Benefits of grid type:

1) Smaller PV arrays can supply the same load reliably.
   Less balance of system components are needed.

2) Eliminates the need for energy storage and the costs associated to substituting and

recycling batteries for individual clients.

3) Efficient use of available energy. Contributes to the required electrical grid generation while the client's demand is below PV output.

There are three types of cell technologies:

1) **Monocrystalline**:

- These are cells that are grown from a single crystal.
- The production methods are difficult and expensive. These tend to be more efficient (more power in less area) and more expensive.

2) **Multicrystalline:**

- The production process allows multiple crystalline structures to develop within the cell.
- It is relatively cheaper than mono- crystalline at the expense of lower efficiency.

Thin-film:

- Uses less silicon to develop the cell) allowing for cheaper production costs (silicon is in high demand).
    - It tends to be less expensive but has also lower efficiency.

PV Module:

Def:

A photovoltaic module is an array of photovoltaic cells pre-arranged in a single mounting mold.

or

A number of solar cells electrically connected to each other and mounted in a support structure are called a photovoltaic module

- The basic building block of a photovoltaic module is the photovoltaic cell; these convert solar energy into electricity.
- The power output will depend on the amount of energy incident on the surface of the cell and the operating temperature of the photovoltaic cell.

The power output of a single cell can supply small loads like calculators or watches, but in order to be useful for high energy demand projects these cells must be arranged in series and parallel connections.

Characteristics of various PV cell technologies:

- Polarity of output terminals or leads
- Maximum series fuse for module protection
- Rated open-circuit voltage
- Rated operating voltage
- Rated operating current
- Rated short-circuit current
- Rated maximum power

Maximum permissible system voltage

Types of silicon cell technologies:

1) Single Crystal Silicon

2) Polycrystalline Silicon

3) Ribbon Silicon

4) Amorphous Silicon

1) Single Crystal Silicon:

It is a silicon material in which the crystal lattice of the entire sample is continuous and unbroken to the edges of the sample, with no grain boundaries.

Advantages:

- Well established and tested technology
- Stable
- Relatively efficient

Disadvantages:

- Uses a lot of expensive material
- Lots of waste in slicing wafers
- Costly to manufacture

Round cells can't be spaced in modules efficiently

2.Polycrystalline Silicon:

Made up by polycrystalline having small crystals

Advantages

- Well established and tested technology
- Stable
- Relatively efficient
- Less expensive than single Crystalline Si
- Square cells for more efficient spacing

Disadvantages:

- Uses a lot of expensive material
- Lots of waste in slicing wafers
- Fairly costly to manufacture
- Slightly less efficient than Single Crystalline Si

3) Ribbon Silicon:

Is a thin sheet type made up of silica

Advantages:

- Does not require slicing
- Less material waste than single and polycrystalline
- Potential for high speed manufacturing
- Relatively efficient

Disadvantages:

- Has not been scaled up to large-volume production
- Complex manufacturing process

4) Amorphous Silicon:

Amorphous silicon solar cells are **the most well-developed thin-film solar cell**. The structure usually has the p-i-n (or n-i-p) type of duality, where p-layer and n-layer are mainly used for establishing an internal electric field (i-layer) comprising amorphous silicon. It is alloy of silicon and carbon

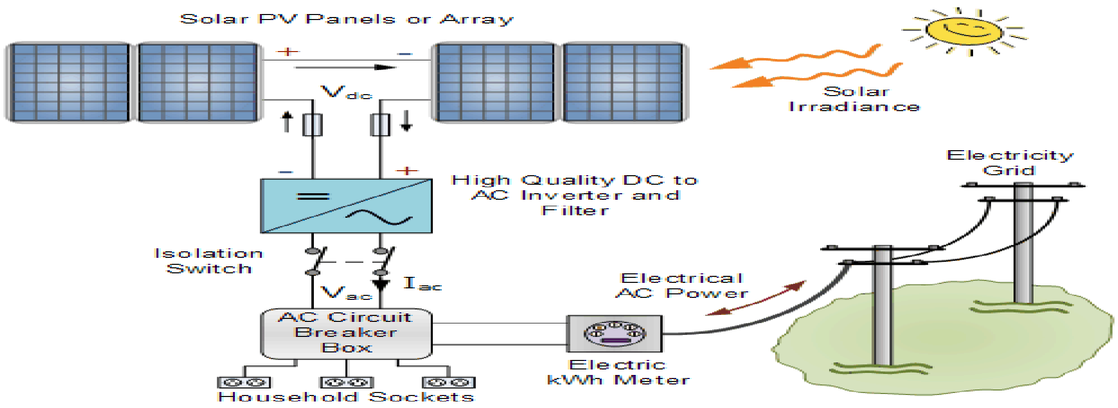
Advantages:

- Very low material use
- Potential for highly automated and very rapid production
- Potential for very low cost

Disadvantages:

- Pronounced degradation in power output
- Low efficiency

Grid connected PV systems



Inverter:

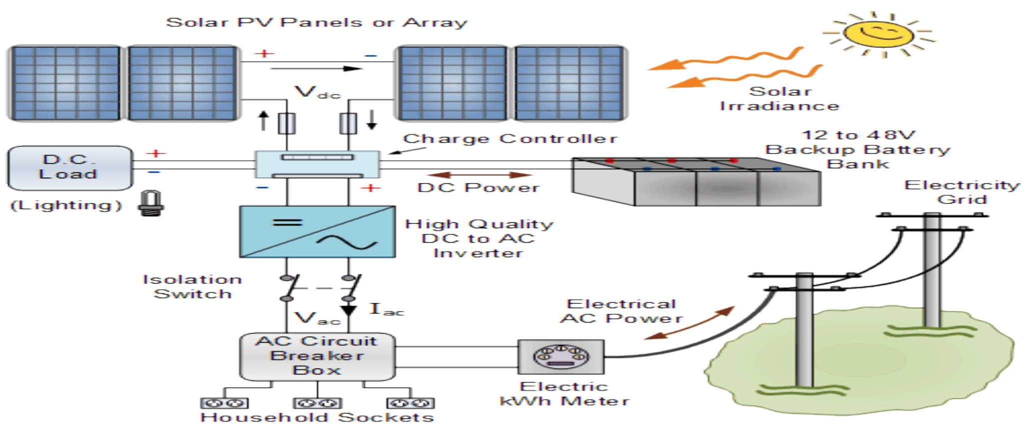
-The inverter is the most important part of any grid connected system.

- The inverter extracts as much DC (direct current) electricity as possible from the PV array and converts it into clean mains AC (alternating current) electricity at the right voltage and frequency for feeding into the grid or for supplying domestic loads.

Electricity Meter:

- The electricity meter also called a Kilowatt hour (kWh) meter is used to record the flow of electricity to and from the grid.

Grid connected system with battery:



- The battery charge controller, determines whether the power generated by the solar panels is needed for home use,

UNIT III

WIND ENERGY

Introduction:

Wind power or wind energy is the use of wind to provide the mechanical power through windturbines to operate electric generators. Wind power is a sustainable and renewable energy. Wind possessesenergy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail orpropeller, can extract part of the energy and convert it into useful work. The spinning blades, attached to ahub and a low-speed shaft, turn alongwiththe blades.The rotating low-speed shaft isconnected toagearbox that connects to a high-speed shaft on the opposite side of the gearbox. This high-speed shaftconnects to an electrical generator that converts the mechanical energy from the rotation of the blades intoelectrical energy.

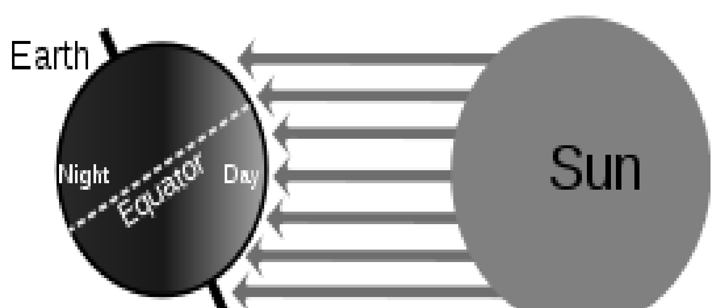
Wind energy is a form of solar energy. Wind is caused by the uneven heating of the atmosphere bythe sun, variations in the earth's surface, and rotation of the earth. Mountains, bodies of water and vegetationinfluence wind flow patterns. Wind speeds vary based on geography, topography and season. As a result,therearesomelocations better suited forwindenergygeneration.

Wind power is the conversion of wind energy into electricity or mechanical energy using windturbines. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator canconvert mechanical power into electricity. Mechanical power can also be utilized directly for specific taskssuchas pumping water.

Windmills:Peoplehavebeenusingwindmillsforcenturiestogrindgrain,pumpwater,anddootherwork. Windmillsgenerate mechanical energy,but theydo notgenerateelectricity.

WindTurbines:Incontrasttowindmills,modernwindturbinesarehighlyevolvedmachineswithmorethan8,000 parts that harnesswind's kineticenergyand convertit into electricity.

Un even solar heating:



First, the earth is a sphere revolving around the sun in the same plane as its equator. Because thesurface of the earth is perpendicular to the path of the sunrays at the equator but parallel to the sunrays at thepoles, the equator receives the greatest amount of energy per unit area, with energy dropping off toward thepoles. Due to the spatial uneven heating on the earth, it forms a temperature gradient from the equator to thepolesandapressuregradientfromthepolestotheequator.Thus,hotairwithlowerairdensityattheequator rises up to the high atmosphere and moves towards the poles and cold air with higher density flowsfrom the poles towards the equator along the earth‘s surface.

The earth‘s self-rotation is another important factor to affect wind direction and speed. The Coriolisforce, which is generated from the earth's self-rotation, deflects the direction of atmospheric movements.

Classification of Wind Energy Conversion Systems

(1) Based on axis

  (a) Horizontal axis machines

  (b) Vertical axis machines

(2) According to size

  (a) Small size machines (upto 2k W)

  (b) Medium size machines (2 to 100k W)

  (c) Large size machines (100kW andabove)

    i. Single generator at single site

    ii. Multiple generators

(3) Types of output

  (a) DC output

    i. DC generator

    ii. Alternator rectifier

  (b) AC output

  i. Variable frequency,variable or constant voltage AC.

  ii. Constant frequency, variable or constantvoltageAC

(4) According to the rotational speed of the area turbines

(1) Constant speed and variable pitch blades

(2) Nearly constant speed with fixed pitch blades

(3) Variable speed with fixed pitch blades

(a) Field modulated system

(b) Double output indication generator

(c) AC-DC-A Clink

(d) AC commentator generator

(4) Variable speed constant frequency generating system.

(5) As per utilization of output

(a) Battery storage

(b) Direct conversion to an electro magnetic energy converter

(c) Thermal potential

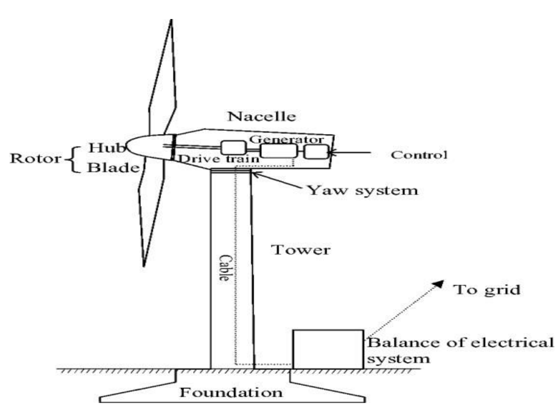
(d) Inter convention with conventional electric utility guides

Types of wind turbines:

Wind turbines can be separated into two basic types determined by which way the turbine spins.Wind turbines that rotate around a horizontal axis are more common (like a wind mill), while vertical axis wind turbines are less frequently used (Savonius and Darrieus are themost common in the group).

1. HorizontalAxisWindTurbines(HAWT)

Horizontal axis wind turbines (HAWT) are the common style that most of us think of a wind turbine.A HAWT has a similar design to a windmill, it has blades that look like a propeller that spin on the horizontal axis.



Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower,and they must be pointed into the wind. Small turbine are pointed by a simple wind vane placed square withthe rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn theturbine into the wind. Most large wind turbines have a gearbox, which turns the slow rotation of the rotorintoafasterrotation that is moresuitabletodrivean electrical generator.

Important point to remember recording HAWT are

- Lift is the main force
- Much lower cyclic stress
- 95% of the existing turbines are HAWTs
- Nacelle is placed at the top of the tower
- Yaw mechanism is required

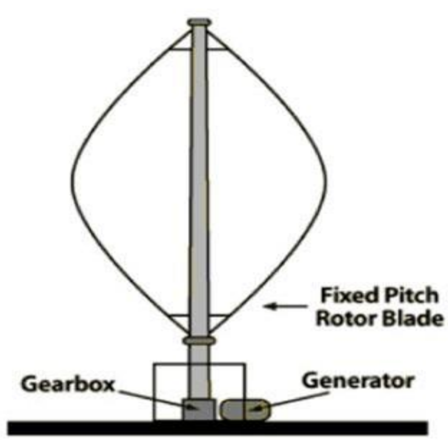
Advantages:

1) The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites,everyten meters upthewind speed can increaseby20%and the power output by34%.
2) High efficiency, since the blades always move perpendicular to the wind, receiving power throughthewhole rotation.

Disadvantages:

- Massivetowerconstructionisrequired tosupporttheheavyblades,gearbox,andgenerator.
- Components of horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being liftedinto position.
- Their height makes them obtrusively visible across large areas, disrupting the appearance of thelandscape and sometimes creating local opposition.
- Download variants suffer from fatigue and structural failure caused by turbulence when a bladepasses through the tower‘s wind shadow (for this reason, the majority of HAWTs use an upwinddesign,with therotor facing thewind in front of thetower).
- HAWTsrequireanadditionalyawcontrolmechanismtoturnthebladestowardthewind. HAWTs generally require a braking or yawing device in high winds to stop the turbine

2. VerticalAxisWindTurbines(VAWT)



Vertical axis

Vertical wind turbines (VAWTs), have the main rotor shaft arranged vertically .The main advantageof this arrangement is that the wind turbine does not need to be pointed into the wind. This makes themsuitable in places where the wind direction is highly variable or has turbulent winds. With a vertical axis, thegenerator and other primary components can be placed near the ground, so the tower does not need tosupport it, also makes maintenance easier. The main drawback of a VAWT is that, it generally creates dragwhenrotating into the wind.

Important points to remember for VAWT:

- Nacelle is placed at the bottom.
- Drag is the main force
- Yaw mechanism is not required
- Lower starting torque
- Difficulty in mounting the turbine
- Unwanted fluctuations in the power output

VAWT Advantages

- No yaw mechanisms is needed
- AVAWT can be located nearer the ground, making it easier to maintain the moving parts.
- VAWTshave lower wind start up speeds than the typical HAWTs.
- VAWTs may be built at locations where taller structures are prohibited.
- VAWTs situated close to the ground can take advantage of locations where rooftops, means hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

VAWT Disadvantages

- In contrast to HAWT, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to the wind leads to inherently lower efficiency.

<u>**UNIT IV**</u>

<u>**GEOTHERMAL ENERGY**</u>

Introduction:

The word geothermal comes from greek words geo means earth, and thermal means heat.Geothermal energy is heat from with in the earth. We can use the steam and hot water produced inside the earth to heat buildings or generate electricity.

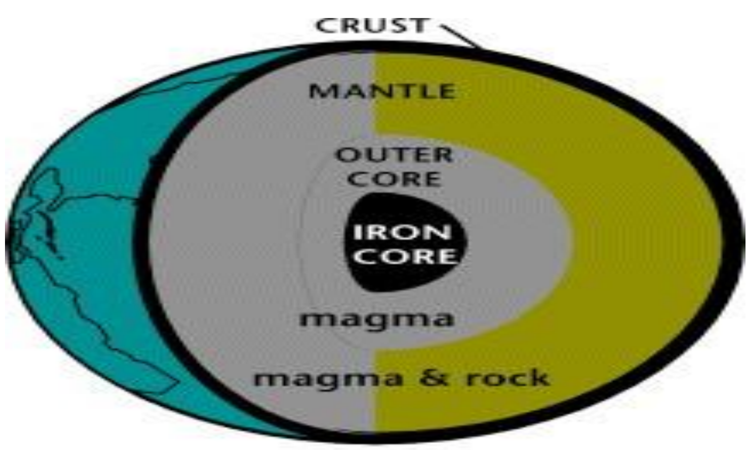
Energy inside the earth:

-Geothermal energy is generated in the earth's core, about 4,000 miles below the surface.

The earth has a number of different layers:

- The core itself has two layers: a **solid iron core** and an outer core made of very hot melted rock, called **magma**.

- The **mantle** which surrounds the core and is about 1,800 miles thick. It is made up of magma and rock.



THE EARTH'S INTERIOR

The crust is the outermost layer of the earth, the land that forms the continents and ocean floors. It can be three to five miles thick under the oceans and 15 to 35 miles thick on the continents. The earth's crust is broken into pieces called plates. Magma comes close to the earth's surface near the edges of these plates. This is where volcanoes occur. Deep underground, the rocks and water absorb the heat from this magma.

People around the world use geothermal energy to heat their homes and to produce electricity by digging deep wells and pumping the heated underground water or steam to the surface.

Classification of Geothermal fields:

Based on the classifying earth's surface divided into three broad groups.

- Non thermal area- having temperature of 10° C to 40° C per km depth

- Semi thermal area- having temperature of 70° C per km depth

- Hyper thermal area- temperature more than non thermal

Geothermal sources:

General kinds of geothermal sources are

1) Hydrothermal Convective system
   - Vapour dominated or dry steam fields

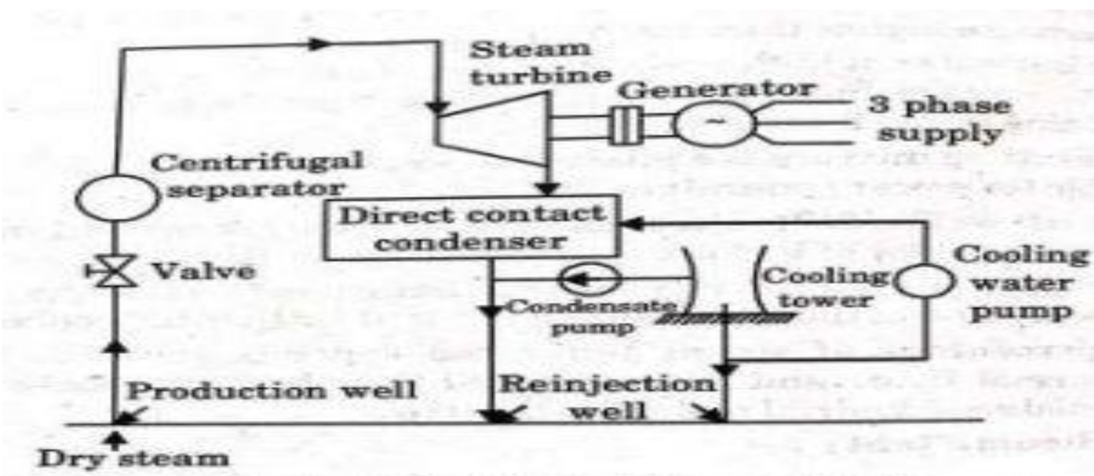
   - Liquid dominated system or wet steam

2) Geo pressure resources

3) Magma resources

4) valconoes

Vapour dominated system (dry steam):



Vapour Dominated Power Plant

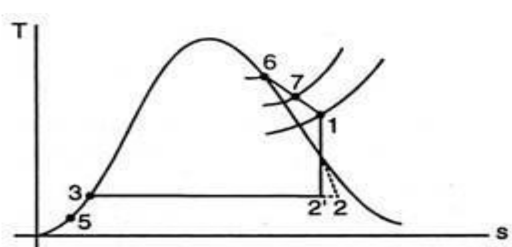
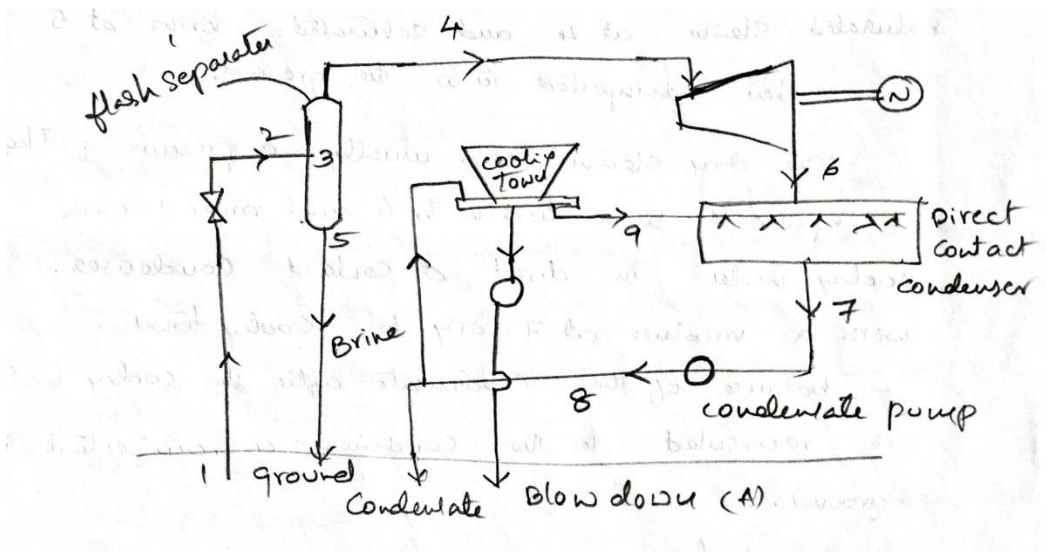


Fig. 7.2. T-s diagram

The energy conversion in geothermal power plants is based on the Rankine cycle. Dry steam at 35 bar and 200°C is available at the bottom of the well gets superheated due to pressure drop to 7 bar. The particulate matter is separated in a centrifugal separator. The process 6-7 and 7-1 are throttling processes so that enthalpy of steam remains constant. After passing through steam turbine and condenser, it is re-injected back to earth.

Liquid dominated system: (wet steam fields):

Flashed steam system:



Hot water is available above 150°C to 315°C underground. When tapped, the water can flow naturally under its own pressure or be pumped to the surface of the earth. The drop in pressure causes it to partially flash into steam and a liquid-dominated, low-quality, two-phase mixture of water and stream is avail-able at the well head. The water contains dissolved solids. The flow diagram and T-s diagram of a flash-steam system are shown

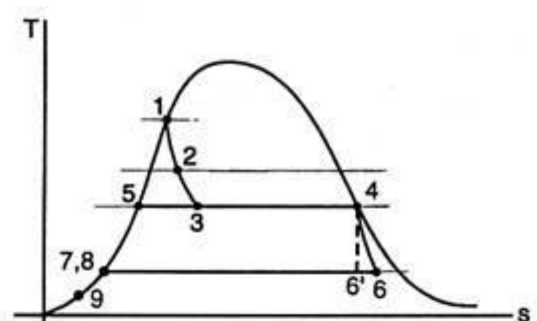
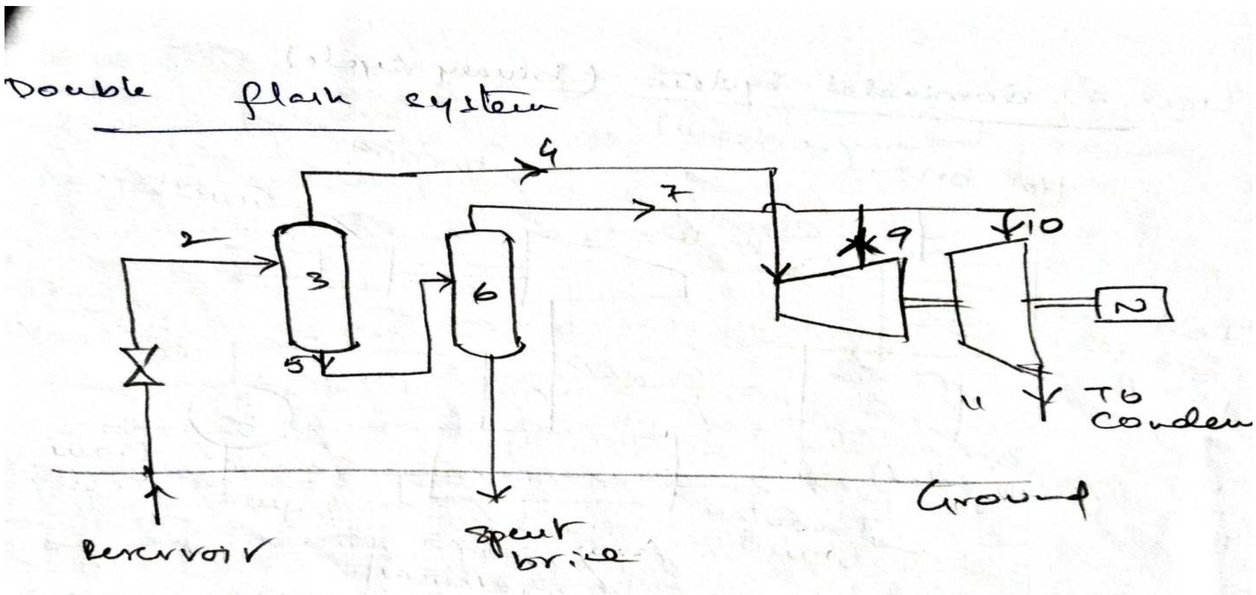


Fig. 7.4. T-s diagram of single-flash steam cycle

Hot water from reservoir (1) reaches the well head (2) Pressure p2 is lower than P1 and process 1-2 is a constant enthalpy throttling process. The two-phase mixture of low quality (2) is passed through a flash separator (3) the quality of steam is higher at point 3. The dry saturated steam (4) at pressure of about 8 bars is expanded in the steam turbine. The separated brine (5) is re-injected into the ground. The exhaust steam from turbine is mixed with cooling water in a direct- contact condenser. The mixture is cooled in a cooling tower.

Double flash system:



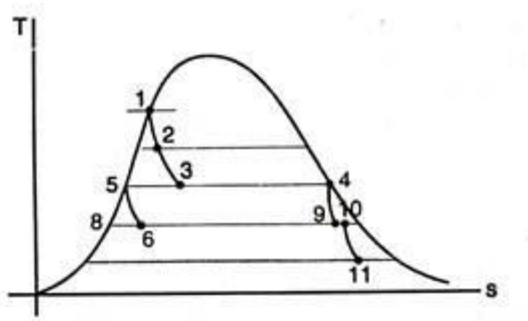
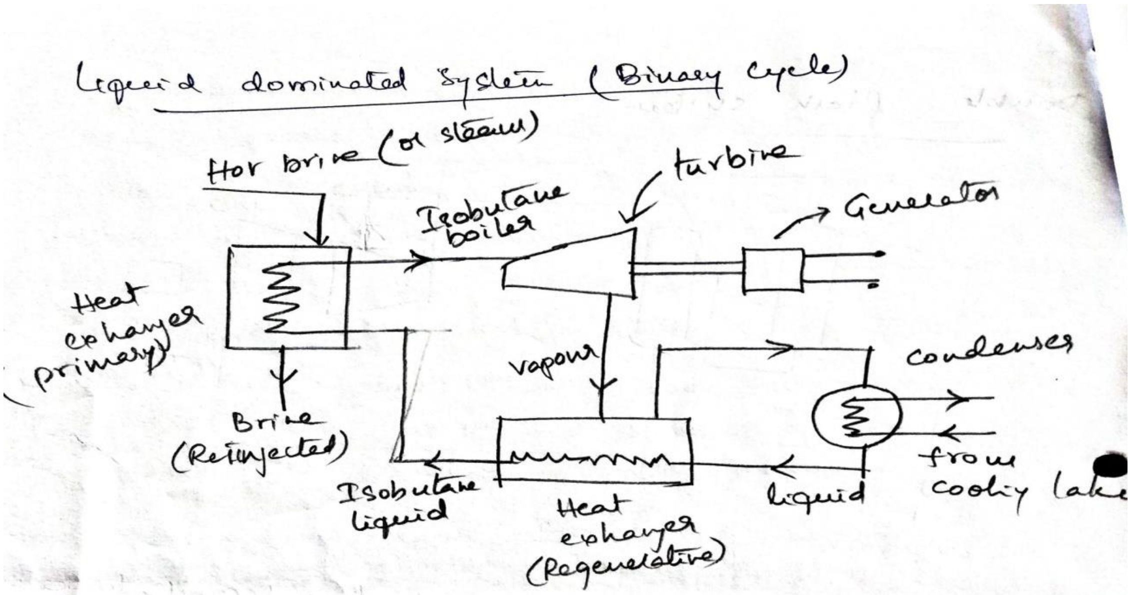


Fig. 7.6. T-s diagram of Double Flash Steam Cycle

Depending upon the original water conditions, the brine at point 5 is ad-mitted to a second, lower-pressure separator, where it flashes to a lower pressure steam. This steam is admitted to a low-pressure stage in the turbine as shown .

The new low-pressure brine contains less energy and therefore cycle energy loss is reduced. It uses an innovative steam condenser and gas extraction system and a dual – admission steam turbine.

Liquid dominated binary cycle:



Water in lower temperature ranges is unsuitable for power production. It can be used directly for domestic and industrial process heating. Hot water can also be used in heating an organic fluid with low boiling point and can be used to run a Rankine Cycle. The working fluids can be isobutene, Freon-12, ammo-nia or propane.

Hot brine from underground reservoir circulates through a heat exchanger (HX) and is pumped back to ground. The organic fluid is heated to superheated vapour and is used in a standard closed Rankine cycle. The vapour drives the turbine and is condensed in a surface condenser. The condenser is cooled by water from a natural source or a cooling tower circulation system. There is no problem of corrosion and scaling in the working cycle components.

Kamchatka binary cycle plant in Russia is 680 kW plant using hot water at 80°C. The working fluid is Freon-12.

UNIT V

OCEAN ENERGY

Introduction:

The sources of energy from ocean are Ocean Thermal Energy Conversion(OTEC). The conversion of solar energy stored as heat in the ocean in to electrical energy by making use of the temperature difference between warm surface water and the colder deep water.

Ocean thermal energy conversion is an electricity generation system. Ocean Thermal Energy, also called Ocean Thermal Energy Conversion (OTEC), refers to using the temperature difference between the deep parts of the sea, which are cold and the shallow parts of the sea, which are cold, to run a heat engine and produce useful work.

The deeper parts of the ocean are cooler because the heat of sunlight cannot penetrate very deep into the water. Here the efficiency of the system depends on the temperature difference. Greater the temperature difference, the greater the efficiency.

The temperature difference in the oceans between the deep and shallow parts is maximum in the tropics, 20o C to 25o C. Tropics receive a lot of sunlight which warms the surface of the oceans, increasing the temperature gradient.

Types of Ocean thermal electric conversion (OTEC).

- Open cycle OTEC system or Claude cycle

- The closed or Anderson OTEC cycle

Open cycle OTEC cycle:

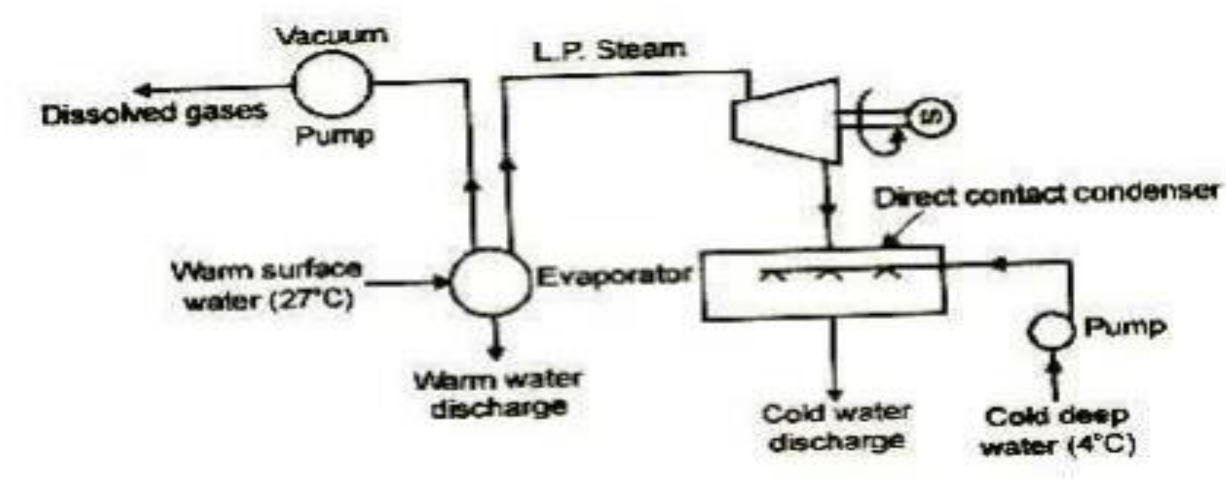


Figure: OTEC – open cycle.

Open cycle OTEC directly uses the warm water from the surface to make electricity. The warm seawater is first pumped into a low-pressure chamber, where it undergoes a drop in boiling point due to the pressure drop. This causes the water to boil. This steam drives a low-pressure turbine which is attached to an electrical generator.

The advantage this system has over a closed system is that, in the open cycle, desalinated water is obtained in the form of steam. Since it is steam, it is free from all impurities.

This water can be used for domestic, industrial, or agricultural purposes.Ocean Thermal Energy (OTEC) is a real candidate as one of the future sources of energy. Its environmental impact is negligible. The mixing of deep and shallow seawater brings up nutrients from the seafloor. The deepwater is rich in nitrates, which can also be used in agriculture.

Closed cycle OTEC system:

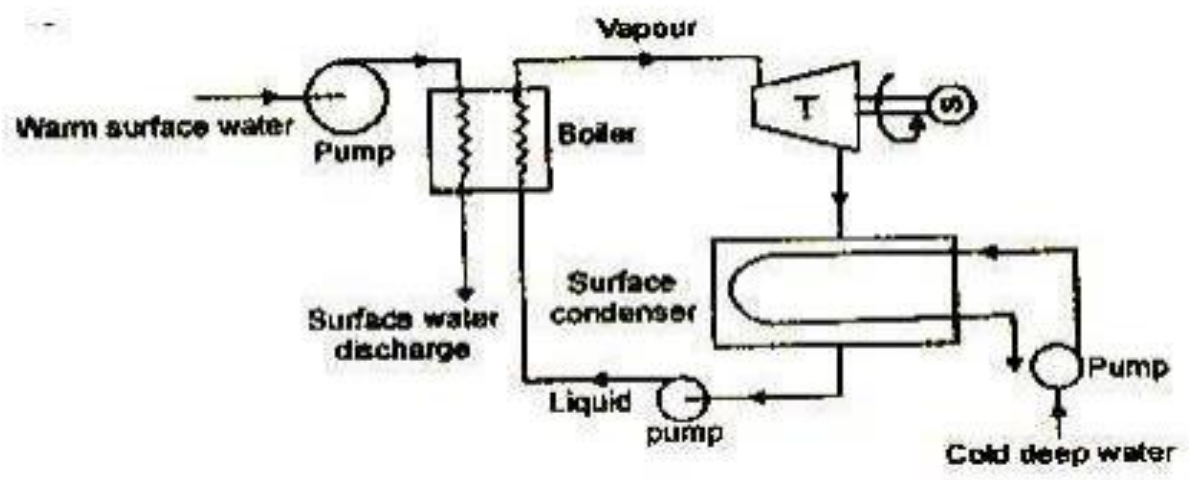


Figure: OTEC – closed cycle

Closed cycle Ocean Thermal Energy Conversion systems use a working fluid with a low boiling point, Ammonia, for example, and use it to power a turbine to generate electricity. Warm seawater is taken in from the surface of the oceans and cold water from the deep at 5o. The warm seawater vaporises the fluid in the heat exchanger, turning the generator’s turbines.

The fluid now in the vapour state is brought in contact with cold water, which turns it back into a liquid. The fluid is recycled in the system, which is why it is called a closed system.

BIO MASS ENERGY

Introduction:

- Biomass energy is organic matter produced by plants which growth both on land and in water. The source of all energy in biomass is the sun, the biomass acting as a kind of chemical energy store. Biomass is constantly undergoing a complex series of physical and chemical transformations and being regenerated while giving off energy in the form of heat to the atmosphere.

- Solar energy--> photo synthesis--> Biomas--> energy generation

- **Solid biomass** - the use of trees, crop residues, animal and human waste (all though not strictly a solid biomass source, it is often included in this category for the sake of convenience), household or industrial residues for direct combustion to provide heat. Often the solid biomass will undergo physical processing such as cutting, chipping, briquetting, etc. but retains its solid form.

  Biogas - biogas is obtained by anaerobically (in an air free environment) digesting organic material to produce a combustible gas known as methane. Animal waste and municipal waste are two common feed stocks for anaerobic digestion.

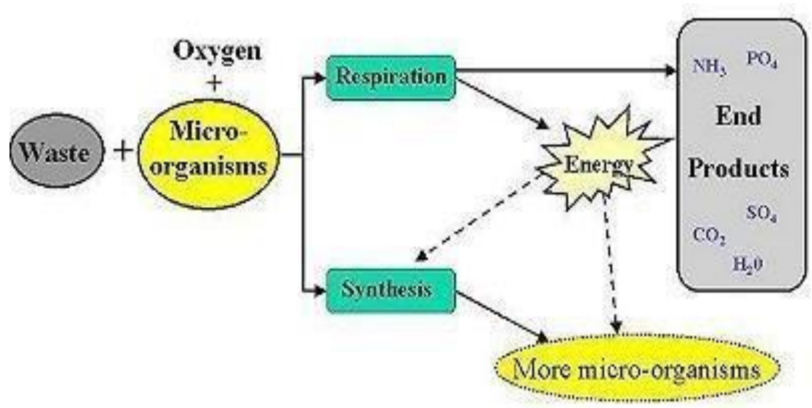
Aerobic Digestion:

Aerobic digestion of waste is the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste.

During oxidation process, pollutants are broken down into carbon dioxide (CO_2), water (H_2O), nitrates, sulphates and biomass (microorganisms). By operating the oxygen supply with aerators, the process can be significantly accelerated. Of all the biological treatment methods, aerobic digestion is the most widespread process that is used throughout the world.

Advantages :

Aerobic bacteria are very efficient in breaking down waste products. The result of this is; aerobic treatment usually yields better effluent quality that that obtained in anaerobic processes. The aerobic pathway also releases a substantial amount of energy. A portion is used by the microorganisms for synthesis and growth of new microorganisms.



Aerobic Decomposition:

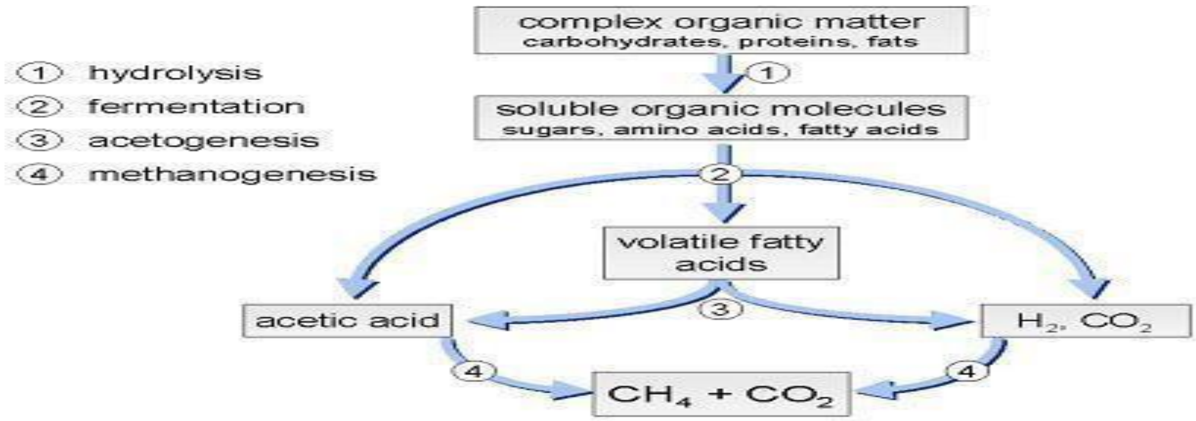
A biological process, in which, organisms use available organic matter to support biological activity. The process uses organic matter, nutrients, and dissolved oxygen, and produces stable solids, carbondioxide, and more organisms. The microorganisms which can only survive in aerobic conditions are known as aerobic organisms. In sewer lines the sewage becomes anoxic if left for a few hours and becomes anaerobic if left for more than 1 1/2 days. Anoxic organisms work well with aerobic and anaerobic organisms. Facultative and anoxic are basically the same concept.

Anaerobic Digestion:

Anaerobic digestion is a complex biochemical reaction carried out in a number of steps by several types of microorganisms that require little or no oxygen to live. During this process, a gas that is mainly composed of methane and carbon dioxide, also referred to as biogas, is produced. The amount of gas produced varies with the amount of organic waste fed to the digester and temperature influences the rate of decomposition and gas production.

Anaerobic digestion occurs in four steps:

- Hydrolysis : Complex organic matter is decomposed into simple soluble organic molecules using water to split the chemical bonds between the substances.
- Fermentation or Acidogenesis: The chemical decomposition of carbohydrates by enzymes, bacteria, yeasts, or molds in the absence of oxygen.
- Acetogenesis: The fermentation products are converted into acetate, hydrogen and carbon dioxide by what are known as acetogenic bacteria.
- Methanogenesis: Is formed from acetate and hydrogen/carbon dioxide by methanogenic bacteria.



Advantages of Anaerobic Digestion:

Wastewater pollutants are transformed into methane, carbon dioxide and smaller amount of bio-solids. The biomass growth is much lower compared to those in the aerobic processes. They are also much more compact than the aerobic bio-solids.

Biomass two types

- Traditional solid mass (wood and agriculture residue)
- Non Traditional form (liquid fuels)

Based on Category – 3 types

1) Is to burn the biomass directly & get the energy
2) Is converted in to ethanol(ethyl alcohol) and methonol (methyl alcohol) , liquid form
3) Fermentation of biomass to obtain a gaseous fuel called biogas

Bio mass conversion :

Bio conversion taken in different forms

- Direct combustion of wood
- Thermo chemical conversion

Bio chemical conversion

Classification of biogas plants:

1) Continuous and batch type

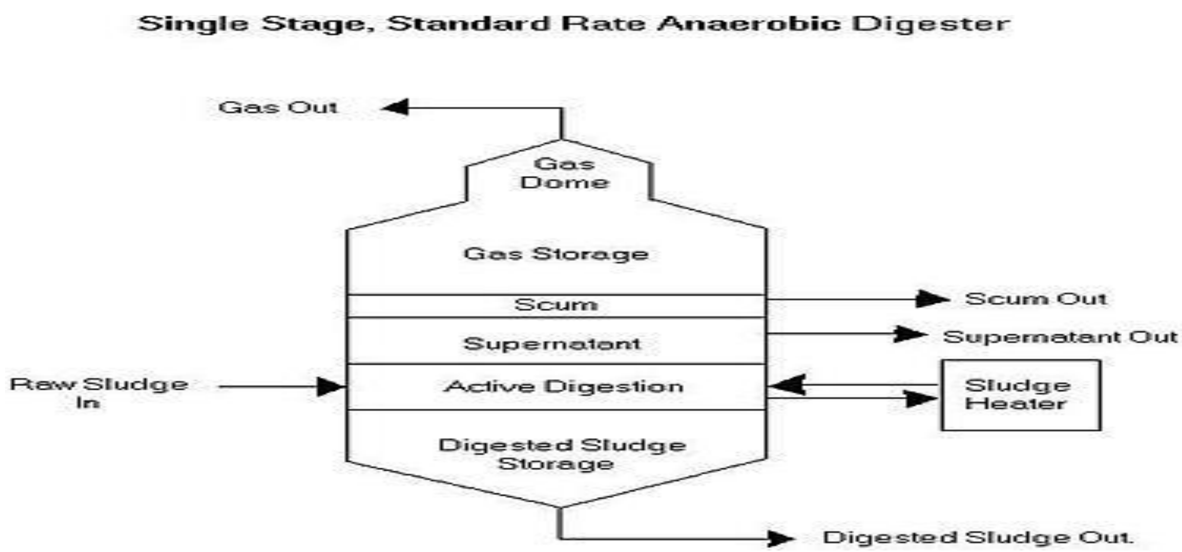
- Single stage

- Double stage

2) Dome and drum type

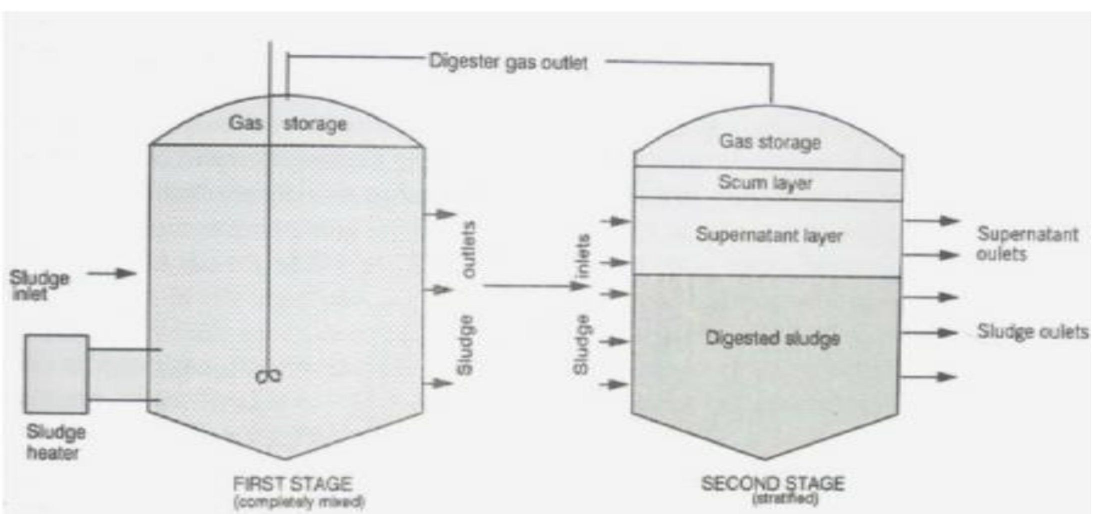
- The floating gas holder digester
- Fixed dome digester

Single stage:



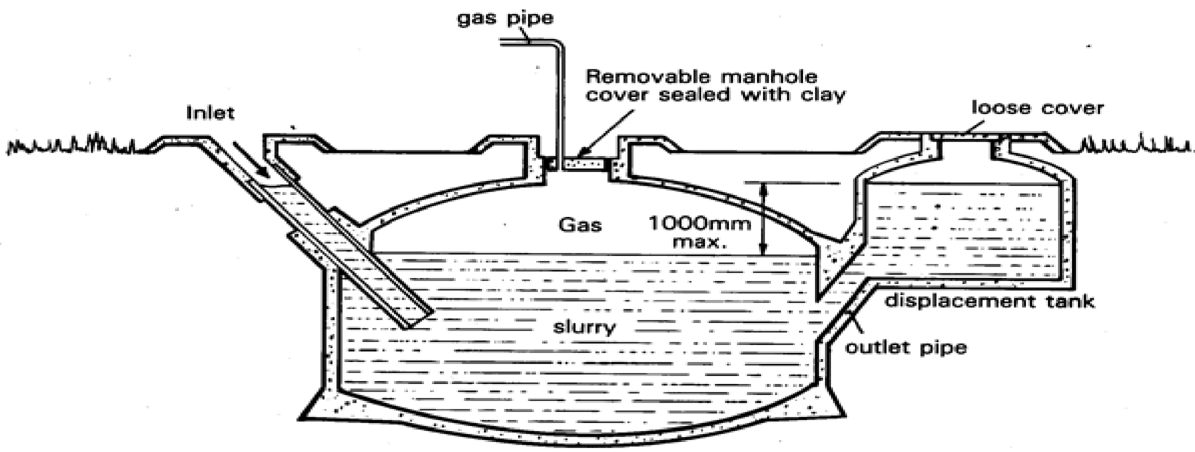
This refers to mixed fermentation with only one biogas digester (or fermentation device), and its fermentation process is only carried out in one fermentation digester. The equipment for single-stage fermentation is simple, but its condition control is difficult.

Double stage:



In order to improve the digestibility and removal rate of organic matter, a two-stage or multistage biogas fermentation process has been developed. This type of fermentation is characterized by fermentation in two or more connected fermentation ponds. The raw materials are decomposed and gas is produced in the first fermentation pool over a certain period of time, then the feed liquid is transferred from the first fermentation pool to the second or other fermentation pools for further fermentation. The fermentation process has a long detention period and decomposes organic matter completely, but the investment cost is higher.

Fixed dome type:



A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas- holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gasholder, the gas pressure is low.

Digester:

The digesters of fixed-dome plants are usually masonry structures, structures of cement and ferro-cement exist. Main parameters for the choice of material are:

Technical suitability (stability, gas- and liquid tightness);

.cost-effectiveness;

- availability in the region and transport costs;
- availability of local skills for working with the particular building material.

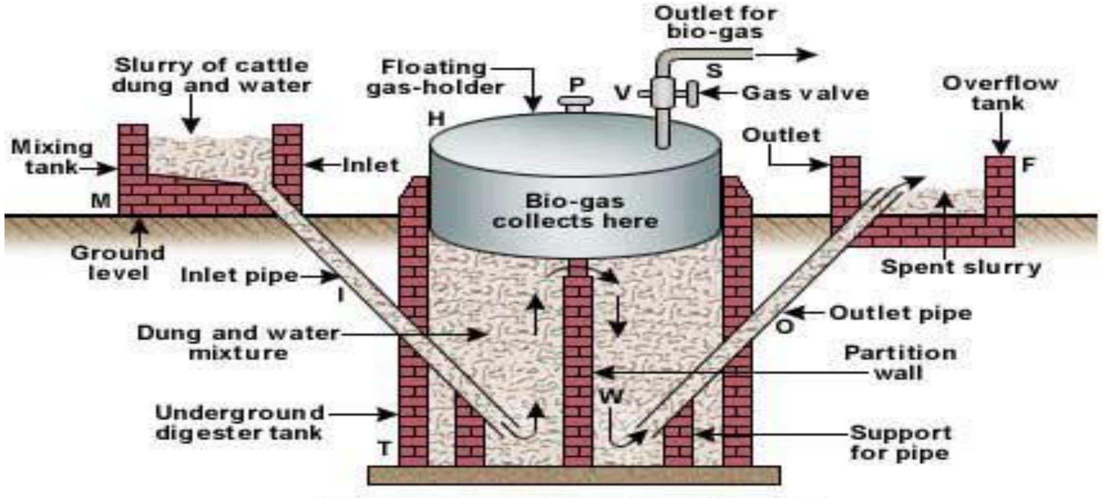
Fixed dome plants produce just as much gas as floating-drum plants, if they are gas-tight. However, utilization of the gas is less effective as the gas pressure fluctuates substantially. Burners and other simple appliances cannot be set in an optimal way. If the gas is required at constant pressure (e.g., for engines), a gas pressure regulator or a floating gas-holder is necessary.

Advantages: Low initial costs and long useful life-span; no moving or rusting parts involved; basic design is compact, saves space and is well insulated; construction creates local employment.

Disadvantages: Masonry gas-holders require special sealants and high technical skills for gas-tight construction; gas leaks occur quite frequently; fluctuating gas pressure complicates gas utilization; amount of gas produced is not immediately visible, plant operation not readily understandable; fixed dome plants need exact planning of levels; excavation can be difficult and expensive in bedrock.

Fixed dome plants can be recommended only where construction can be supervised by experienced biogas technicians.

Floating gas holder type:



Floating gas-holder type bio-gas plant.

In the past, floating-drum plants were mainly built in India. A floating-drum plant consists of a cylindrical or dome shaped digester and a moving, floating gas-holder, or drum. The gas-holder floats either directly in the fermenting slurry or in a separate water jacket. The drum in which the biogas collects has an internal and/or external guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas holder sinks back.

Floating-drum plants are used chiefly for digesting animal and human feces on a continuous feed mode of operation, i.e. with daily input. They are used most frequently by small- to middle-sized farms (digester size: 5-15m3) or in institutions and larger agro-industrial estates(digester size: 20-100m3).

Advantages: Floating-drum plants are easy to understand and operate. They provide gas at a constant pressure, and the stored gas-volume is immediately recognizable by the position of the drum. Gas- tightness is no problem, provided the gasholder is de-rusted and painted regularly.

Disadvantages: The steel drum is relatively expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substrates are used, the gas-holder shows a tendency to get "stuck" in the resultant floating scum.