Program : **Diploma in Electrical and Electronics Engineering**	
Course Code : **5033A**	Course Title: **Renewable Energy Power Plants**
Semester : **5**	Credits: **4**
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Periods per week: **4 (L:3 T:1 P:0)**	Periods per semester: **60**

Contents:

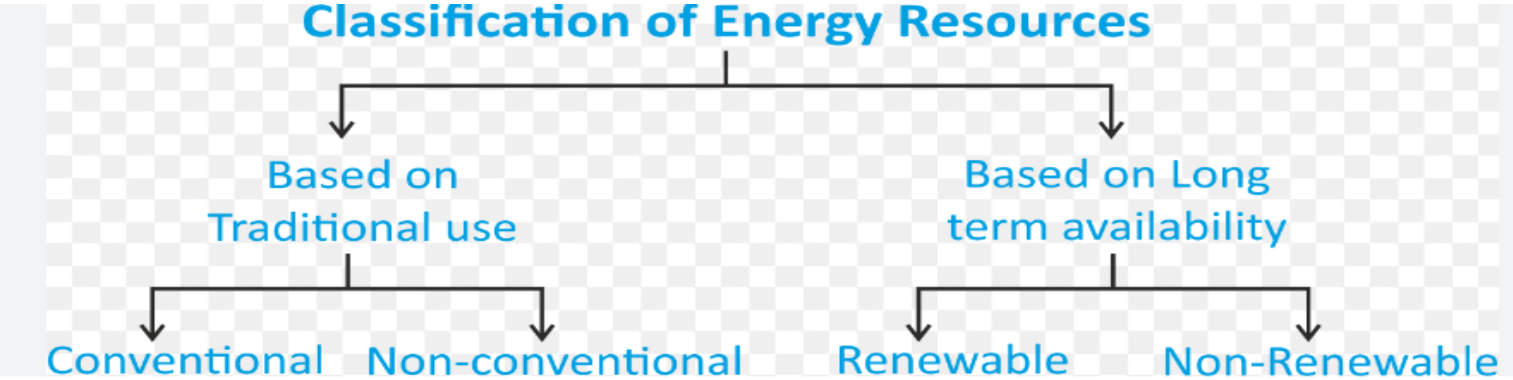
Energy sources -Classification of energy sources with examples- -conventional -non conventional-need of renewable energy -advantages

Small Hydel Power Plants-overview of hydro power plants- classifications - based on head - based on capacity - small hydro power plants- schematic diagram-- turbines-types(explanation with diagram)- advantages -disadvantages-applications-criterion for selection of sites

Geothermal Energy-introduction- resources-advantages- disadvantages- methods of generation-schematic diagrams -Flash stream-Binary cycle-Vapour dominated

Bio Energy -Biomass-Definition- resources -examples - different processes -Pyrolysis-Gasification

Bio gas- Definition-list the constituents -applications - process-Anaerobic digestion - biogas plants-types -construction - working-dome type - drum type.



Sources of energy can be classified into:

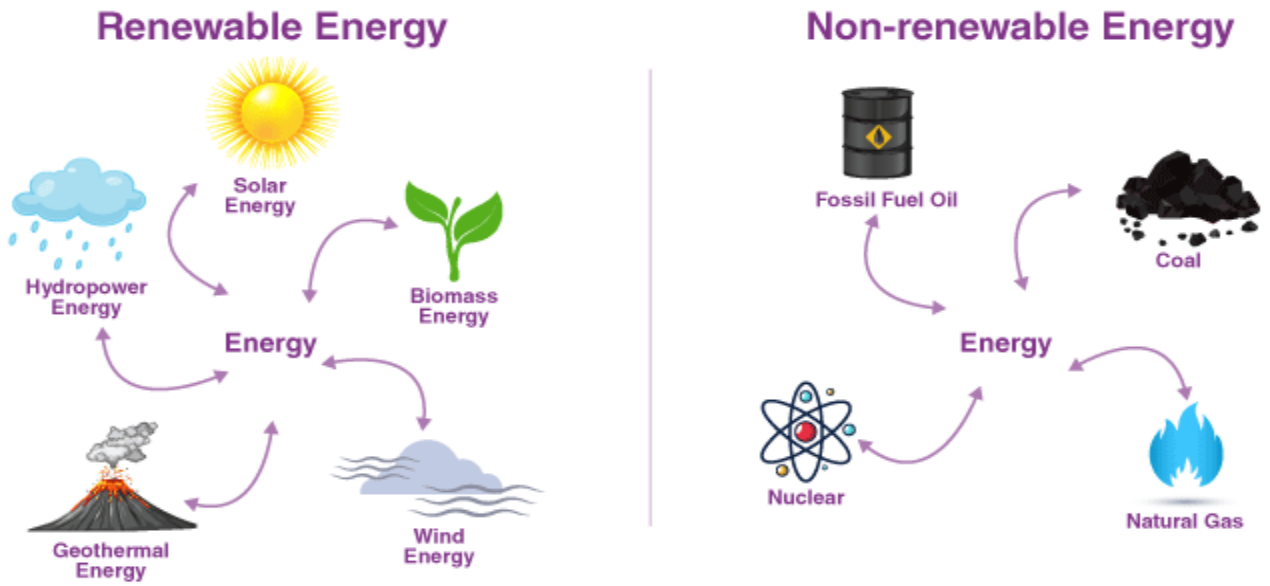
Renewable Sources
Non-renewable Sources

Renewable sources of energy are available plentiful in nature and are sustainable. These resources of energy can be naturally replenished and are safe for the environment.

Examples of renewable sources of energy are: Solar energy, geothermal energy, wind energy, biomass, hydropower and tidal energy.

A non-renewable resource is a natural resource that is found underneath the earth. These type of energy resources do not replenish at the same speed at which it is used. They take millions of years to replenish. The main examples of non-renewable resources are coal, oil and natural gas.

Examples of non-renewable sources of energy are: Natural gas, coal, petroleum, nuclear energy and hydrocarbon gas liquids.



DIFFERENCE BETWEEN RENEWABLE AND NON-RENEWABLE SOURCES OF ENERGY

Renewable	Non-renewable
The resources that can be renewed once they are consumed are called renewable sources of energy.	The resources that cannot be renewed once they are consumed are called non-renewable sources of energy.
These resources do not cause any environmental pollution.	These resources cause environmental pollution..
Renewable resources are inexhaustible.	Non- Renewable resources are exhaustible.
Renewable resources are not affected by human activities.	Non- Renewable resources are affected by human activities.
Examples of Renewable resources- Air, water and solar energy.	Examples of Non-renewable resources- natural gas, coal and nuclear energy.

Types of Natural Sources of Energy
There are two types of natural sources of energy classified by their popularity and use,

CONVENTIONAL SOURCES OF ENERGY
NON-CONVENTIONAL SOURCES OF ENERGY

Conventional	Non-conventional
These resources are exhaustible.	These resources are inexhaustible.
These resources cause pollution as they emit smoke and ash.	These resources are usually pollution-free.
These resources are very expensive to be maintained, stored and transmitted.	These resources are less expensive for local use and can easily be maintained.
Examples- coal, natural gas, petroleum, and water power.	Examples- solar, biomass, wind, biogas, and tidal, geothermal.

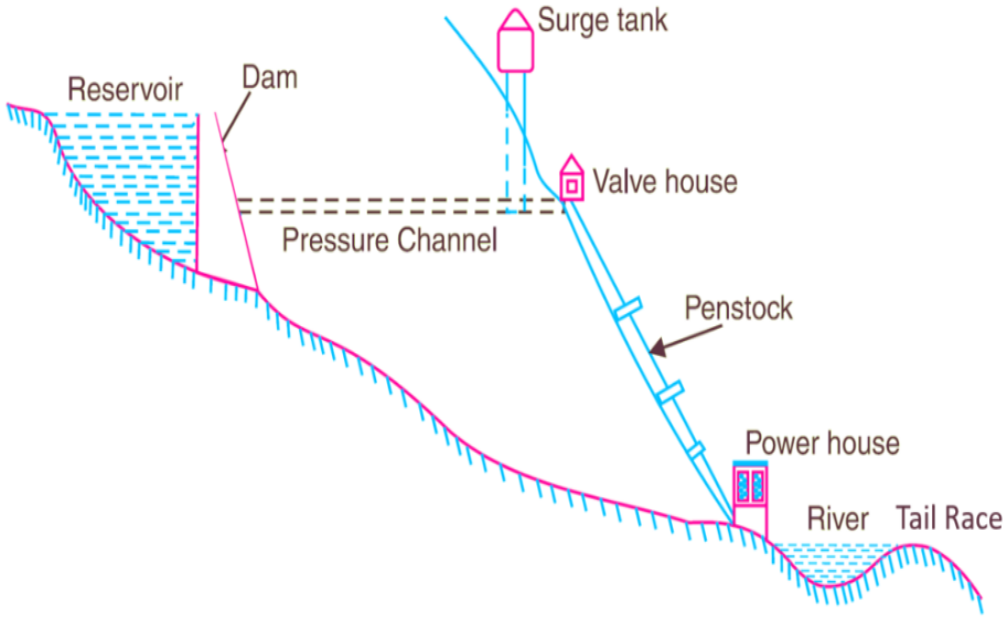
HYDEL POWER PLANTS (HYDRO POWER PLANTS)

SMALL HYDRO POWER PLANT

Small hydro is the development of hydroelectric power on a scale suitable for local community and industry, or to contribute to distributed generation in a regional electricity grid.[1] Exact definitions vary, but a "small hydro" project is less than 50 megawatts (MW), and can be further subdivide by scale into "mini" (<1MW), "micro" (<100 kW), "pico" (<10 kW).

WORKING AND CONSTRUCTION OF HYDRO ELECTRIC POWER PLANT

1. Catchment Area
2. Water Reservoir
3. Dam
4. Valve house
5. Penstock
6. Water Turbine
7. Surge Tank
8. Pressure channel
9. Alternator
10. Tail Race
11. Spillway



Catchment Area: It is the area over which rainfall is collected and led to the reservoir

Water Reservoir: A dam is constructed across a river at a suitable place and water is stored in the catchment area from where it is led to the water reservoir. The main sources of water are rainfall and melting of ice in the mountains.

Dam: It is generally a masonry structure and its functions are to cre- ate a water head and to store water in the catchment area. The dam should be able to resist failure against sliding, overturning and rup- turing. The water from the reservoir is brought to the surge tank through the pressure channel.

Valve House: At the start of the penstock there is a valve house which contains main sluice Valves for controlling the water flow. In addition to this there are also provided automatic isolating valves which come into operation when the penstock bursts, which cuts off further supply of water

Penstock: The huge steel or concrete pipe that conveys the water from valve house to water turbine.

Water Turbine: From the penstock water is taken to the turbine. The turbine converts the water energy into mechanical energy.

Surge Tank: It is an open tank built just before the valve house. It acts as the storage of water which is sufficient for one day or for a specific period of time. Surge tank is also helpful in reducing the thrust of water on penstock in case of sudden closing fixed gates of a water turbine.

Pressure Channel: A pressure channel is constructed between reservoir and valve house to carry water from reservoir to valve house.

Alternator: To the turbine is coupled the alternator which converts the mechanical energy into electrical energy.

Tall Race: After the water has done its useful work in the turbine, it is discharged to the tail race which may lead it to the same stream.

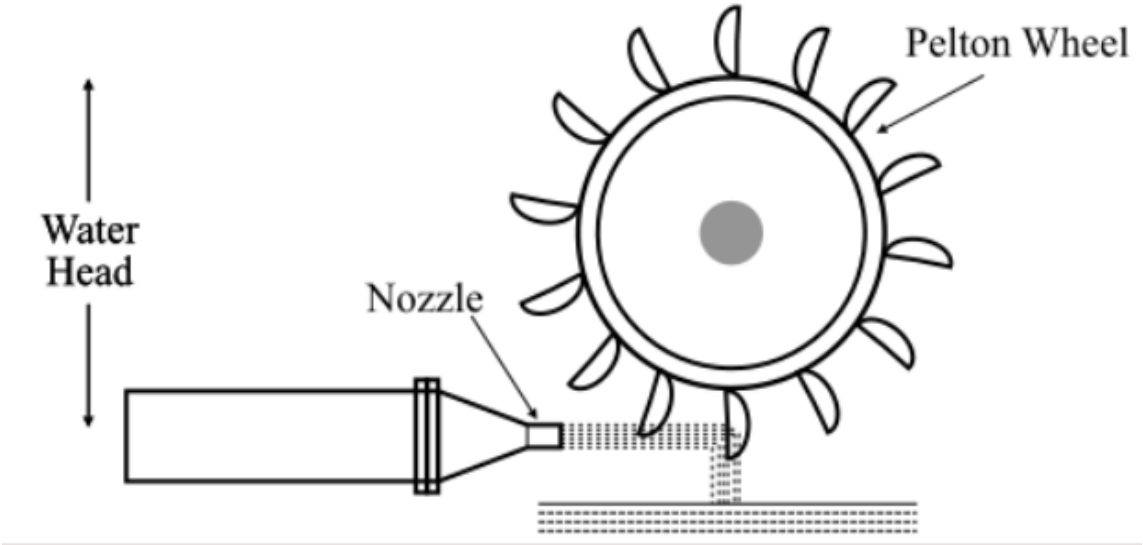
Spillway: It is normally constructed at the top of the dam acting as a safety valve by discharging the overflow of water to the down- stream when the reservoir is full during the rainy season. This is generally constructed of concrete and provided with water discharge openings shut off by metal control gates. By changing the de- gree to which the gates are opened the discharge of water head can be accomplished in order to maintain the water level in the reservoir

DIFFERENT TYPES OF WATER TURBINE

Water Turbine
In a hydroelectric power plant, a device which is used to convert the energy of falling water into mechanical energy is known as water turbine. There are two types of water turbines used in a hydroelectric power plant viz. −

Impulse Turbine
Reaction Turbine

IMPULSE TURBINE
In an impulse turbine, the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the water jet drives the turbine wheel. Impulse turbines are used for high heads. The pelton wheel is an example of the impulse turbine. It consists of a wheel fitted with elliptical buckets along its periphery. The force of water jet striking the buckets on the wheel drives the turbine. The quantity of water jet falling on the turbine is controlled by a needle placed in the tip of the nozzle and the movement of the needle is controlled by the governor.



When the load on the turbine decreases, the governor pushes the needle into the nozzle and hence decreasing the quantity of water striking the buckets. On the other hand, when the load is increased, the governor pulled out the needle from the nozzle, thereby increasing the quantity of water striking the buckets.

REACTION TURBINE

In a reaction turbine, water enters the runner partly with velocity head and partly with pressure energy. Reaction water turbines are mainly used for medium and low heads.

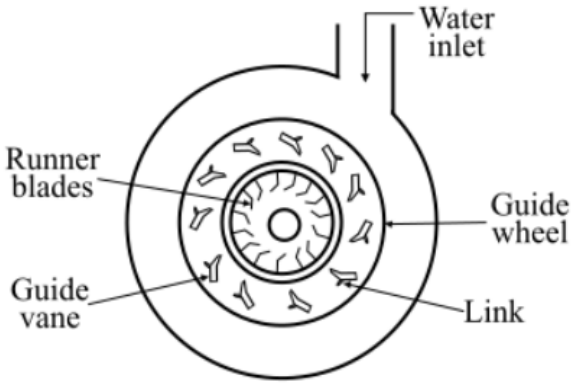
Reaction turbines are also classified into two types viz. −

Francis Turbine

Kaplan Turbine

Francis Turbine

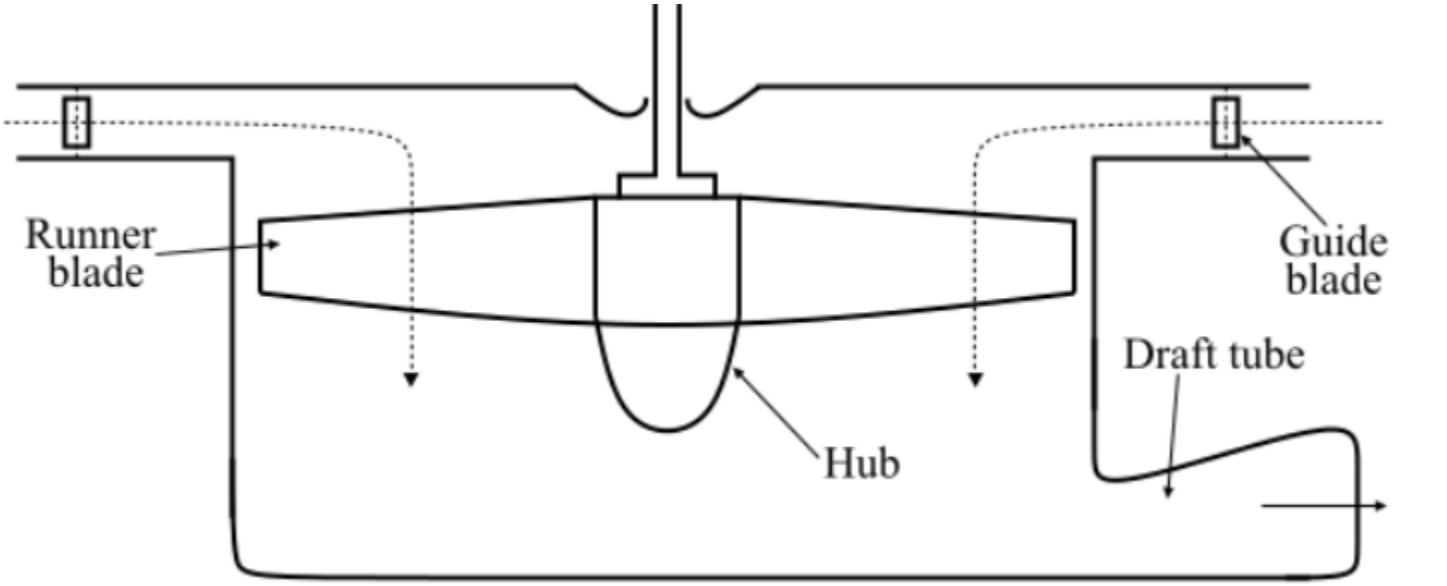
The Francis turbine is used for low to medium water heads. The Francis turbine consists of an outer ring of stationary guide blades which are fixed to the turbine casing and an inner ring of moving blades forming the runner. The guide blades are used to control the flow of water to the turbine.



In the Francis turbine, the water flows radially inwards and changes to a downward direction while passing through the runner. When water passes over the rotating blades of the runner, both the velocity and pressure of water are reduced. Consequently, a reaction force is produced which drives the turbine.

KAPLAN TURBINE

A Kaplan turbine is used for low heads and large quantity of water. The runner of the Kaplan turbine receives water axially instead of radially.



In a Kaplan turbine, water flows radially inwards through the regulating gates all around the sides and then, changing the direction in the runner to axial flow. Consequently, a reaction force is produced which drives the turbine.

ADVANTAGES AND DISADVANTAGES OF HYDRO ELECTRIC POWER PLANT

Advantages of Hydroelectric Power Plant

1. **It is quite neat and clean.**
2. **It is economical in large sizes.**
3. **Running costs are less since no fuel is required**
4. **It can be started in no time.**
5. **It is simple in construction, robust and requires low maintenance.**
6. **It has higher efficiency and long life.**
7. **It helps in irrigation and controlling floods.**

DISADVANTAGES OF HYDROELECTRIC POWER PLANT

1. High capital cost.
2. High cost of transmission lines.
3. Power supply may be affected during the dry season.
4. Skilled and experienced hands are required to build the plant
5. impact on fish to create a hydro plant, a running water source must be dammed.
6. limited plant locations.
7. carbon and methane emissions.
8. susceptible to droughts.
9. flood risk

SITE SELECTION OF HYDROELECTRIC POWER PLANT

1. It should be selected where sufficient water at a reasonable head is available.
2. Reservoir should have a large catchment area.
3. Transportation facilities should be adequate.
4. Possibility of constructing the dam should be there.
5. The land should be cheap.
6. The bearing capacity of the soil should be sufficient so that heavy equipment can be installed.

GEOTHERMAL ENERGY-

Geothermal energy is a renewable and sustainable form of energy derived from the Earth's internal heat. It involves extracting heat from beneath the Earth's surface to generate electricity or provide direct heating and cooling. Geothermal energy resources are found in various forms beneath the Earth's surface. Here are the main types of geothermal resources:

HYDROTHERMAL RESOURCES:

Hydrothermal resources are the most common and developed form of geothermal energy. They consist of underground reservoirs of hot water or steam trapped in porous and permeable rocks.These reservoirs are typically located near tectonic plate boundaries or volcanic areas.Hydrothermal resources are used to generate electricity through geothermal power plants orfor direct heating and cooling applications.

ENHANCED GEOTHERMAL SYSTEMS (EGS):

EGS involve creating artificial reservoirs in areas where natural hydrothermal resources are not present.In EGS, wells are drilled into hot rock formations, and water is injected under high pressure to fracture the rock and create permeable pathways.The injected water is heated by the surrounding rocks and then pumped back to the surface for electricity generation.EGS technology has the potential to expand geothermal energy utilization to a wider range of geographic locations.

GEOPRESSURED RESOURCES:

Geopressured resources are characterized by high-pressure hot brine trapped in deep, sedimentary basins.These resources are typically found in coastal regions where sedimentary rocks have been buried and subjected to geothermal heating.Geopressured resources can provide a combination of geothermal energy and natural gas production.

HOT DRY ROCK (HDR) RESOURCES:

HDR resources are areas where high-temperature rocks are found, but no natural water or steam reservoirs exist.To extract energy from HDR resources, water is injected into the hot rocks, and the resulting steam is used to generate electricity.HDR resources require the creation of permeable fractures in the rocks to allow the circulation of water.

ADVANTAGES OF GEO THERMAL ENERGY

Renewable and Sustainable: Geothermal energy derives from the Earth's natural heat, which is continuously replenished.

Low Emissions: Geothermal power plants emit minimal greenhouse gases and pollutants compared to fossil fuel-based power plants.

Baseload Power: Geothermal plants can provide a stable and constant supply of electricity, as they operate 24/7, regardless of weather conditions.

Local Economic Benefits: Geothermal energy projects create jobs, stimulate local economies, and reduce dependence on imported energy.

DISADVANTAGES OF GEO THERMAL ENERGY

Location Dependency: Geothermal resources are geographically limited to areas with suitable geological conditions, such as tectonic plate boundaries or volcanic regions.

High Initial Costs: Drilling deep wells and constructing geothermal power plants can be expensive, making it challenging to develop projects in some regions.

Resource Depletion and Recharge: Over-extraction can deplete geothermal reservoirs, requiring careful management to ensure sustainable utilization.

Environmental Impacts: Improper handling of geothermal fluids can lead to the release of harmful gases and chemicals, requiring proper monitoring and mitigation measures.

METHOD OF GENERATION OF GEOTHERMAL ENERGY

Geothermal energy can be generated through different methods depending on the characteristics of the geothermal resource. The primary methods of generating geothermal energy are:

DRY STEAM POWER PLANT (VAPOUR DOMINATED)

•Dry steam from the wells is collected, filtered to remove particles in it and Passed through turbines which drives the generator to produce electricity •Difference from conventional thermal plant are the geothermal steam at lower temp and pressure •And efficiency is less than conventional thermal plants

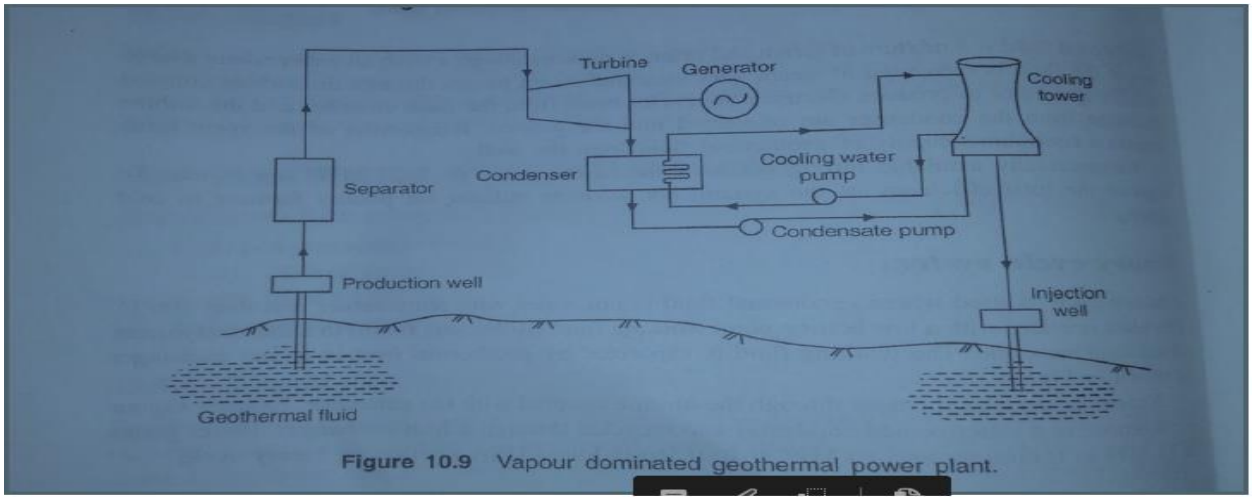
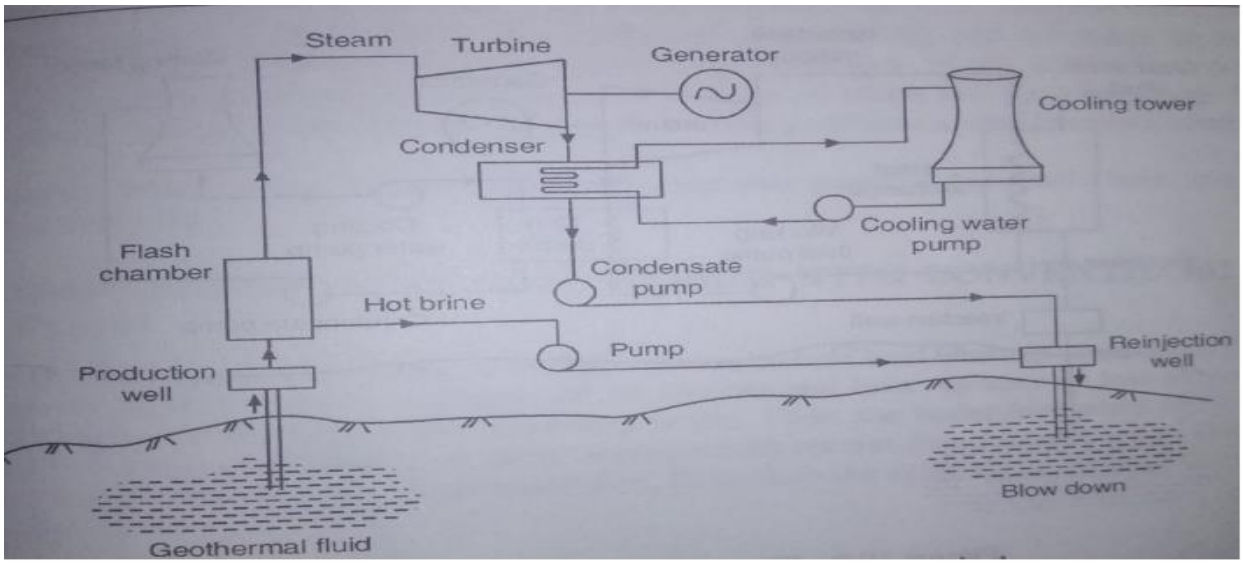


Figure 10.9 Vapour dominated geothermal power plant.

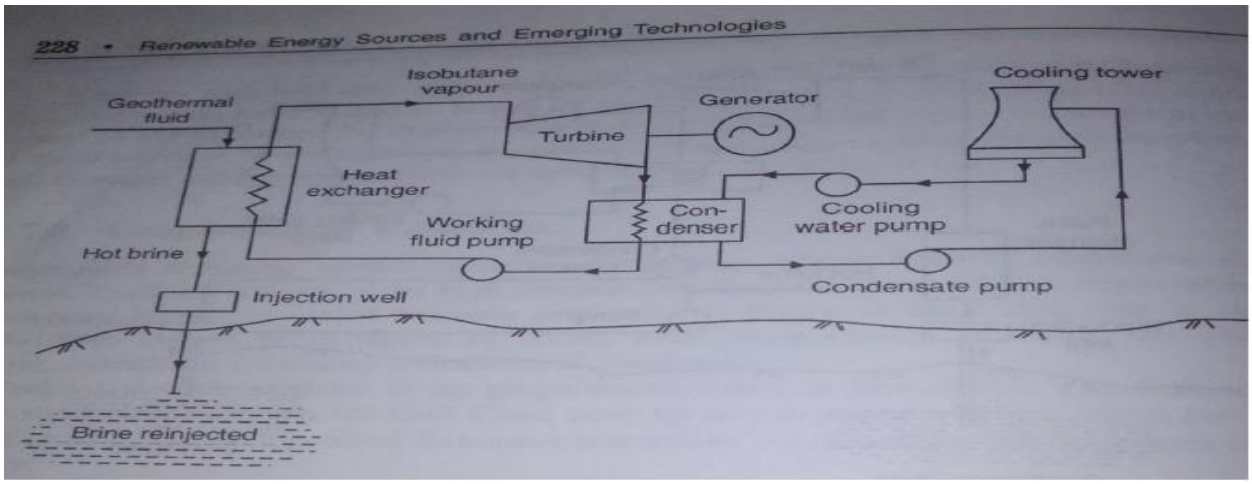
FLASH STEAM POWER PLANTS

•This system is suitable for brine temperature=180 C, Then geothermal fluid is directly used for electrical power generation •Geothermal fluid is a mixture of brine and steam and brine •In flash chamber large part of fluid is converted into steam •Steam pass through turbine ,and electricity is produced by generator •Hot brine from flash chamber and turbine discharge from condenser is re injected into ground •This re injection ensures continued supply of geothermal fluid from well



BINARY CYCLE POWER PLANTS:

•This system is used when geothermal fluid is hot water with temperature less than 100C •This plant operate with a low boiling point fluids like isobutene and Freon in a thermodynamic closed rankling cycle •The working fluid is vaporized by geothermal heat in heat exchanger •The vapor expands in turbine , make the turbine to rotate •The exhaust vapor condensed in condenser



BIO ENERGY

Bioenergy is a form of renewable energy generated when we burn biomass fuel

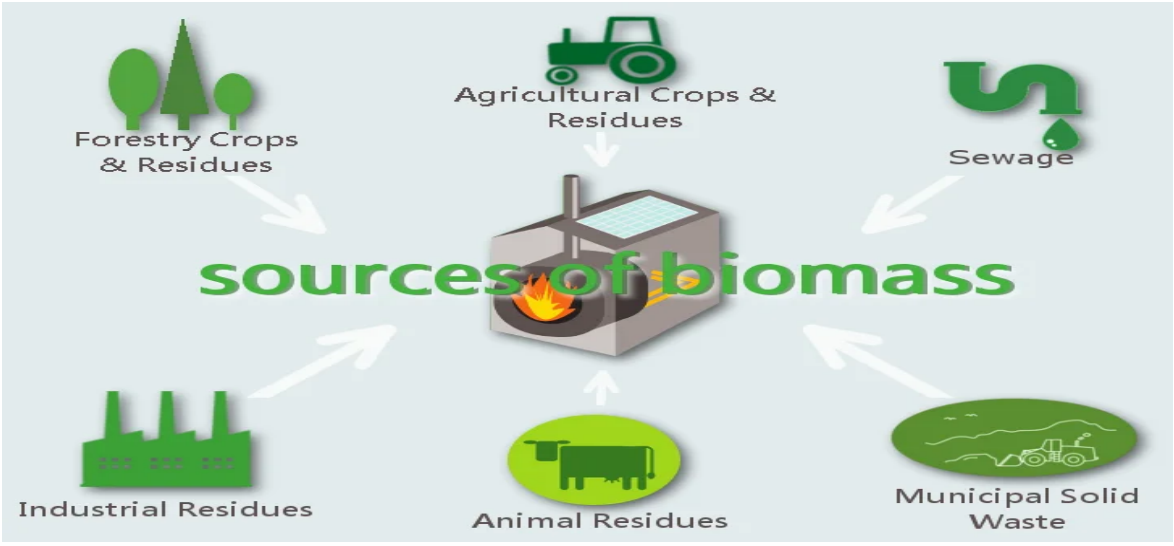
BIOMASS

Biomass is organic mater produced by plants and their derivatives

• Which includes residues from agriculture and forestry, animal waste, solid wastes, liquid wastes and industrial wastes

• It is a renewable energy source

• It can also be considered as a form of solar energy(solar energy → Photosynthesis→



Biomass resources fall into three categories

• Biomass in its traditional solid mass(wood and agricultural residues → burned directly to get energy)

• Bio mass in non traditional form(Liquid fuels : Biomass converted into ethanol and methanol)

• Biogas(Obtained from fermentation of biomass anaerobicaly)

BIOMASS RESOURCES

• Forrest: Timber and charcoal

• Agricultural crop residues : Rice husk , wheat straw, cotton sticks and sugar cane(We convert these items to bio fuel)

• Animal waste: animal dung's and it is also raw material for bio gas plant

• Municipal solid waste : commercial waste, human excreta and house hold garbage

• Liquid wastes from domestic sewage

• Industrial wastes :Pulp and paper industry, starch glucose industry and palm oil industry wastes

BIOMASS CONVERSION TECHNOLOGIES

>Densification

>Combustion and incineration

>Thermo chemical conversion

>Bio chemical conversion

DENSIFICATION

• Bulky biomass is reduced to better volume to weight ratio by compressing in a die at a high temperature and pressure

• It is shaped to briquettes or pellets so that it can easily transport and store than natural biomass

• Used in hotels, bakeries

COMBUSTION

• Natural biomass is directly burned to produce heat

• This heat is used for cooking , space heating and for electricity

• This method is inefficient (30% to 90% losses)

• Incineration is the process of burning completely the solid biomass to ashes by high temperature in presence of oxygen

• Combustion is applicable to all fuels (solid, liquid and gaseous)

• Incineration is a special process where the dry municipal solid waste is incinerated to reduce the volume and produce heat , steam and electricity

THERMO CHEMICAL CONVERSION

• Thermo-chemical conversion is a process to decompose biomass with various combinations of temperature and pressure

• It includes pyrolysis and gasification

• Pyrolisis: Biomass heated in absence of oxygen or limited supply of oxygen to produce a liquid fuels and solid residue(charcoal)

• Gasification is conversion of a solid biomass at high temperature with controlled air into a gaseous product (the output gas is known as producer gas contains H2,CO,CH4,N2,CO2)

• This gas is used to produce heat and steam or IC engines and gas turbines

BIO CHEMICAL CONVERSION

• There are two types of bio chemical conversion

1. Anaerobic digestion

2. Ethanol fermentation

1.Anaerobic digestion :

• This process converts the cattle dung , human waste and other organic waste with moisture content into biogas through anaerobic fermentation in absence of air.

• It is a two stage process

• First stage : organic waste is converted into fatty acid,alcahol,sugars,H2,CO2.

• Second stage: This products converted by methane forming bacteria into CH4 and CO2 at temp 30-55 Celsius

2.Ethanol fermentation

• Ethanol can be produced by decomposition of biomass containing sugar ,like sugarcane ,potato ,corn , grape into sugar molecules such as glucose and sucrose

• Ethanol is used as fuel

BIOGAS

BIOGAS CONVERSION

BIOGAS consists of 55-65 % Methane ,30-40 % CO2 and other impurities such as hydrogen and Nitrogen. It can be produced from the decomposition of animal ,plant and human waste .It is a clean but slow burning gas .Cow dung is the major material ,from which biogas is produced .Pig dung can also be used for biogas generation. Biogas is produced by the processing of digestion .Digestion is a biological process that takes place in the absence of oxygen and in the presents of anaerobic at ambient pressure and temperature of 35 to 70 degree Celsius .

FACTORS AFFECTING BIOGAS PRODUCTION

1.Solid to water ratio
- **Cattle dung(18% solid matter and 82% water)**
- **Anaerobic fermentation proceeds faster rate if solid matter is 9%**
- **To reduce solid matter ,water is added**
- **To increase solid matter crop residues is added**

2.Volumetric loading rate
- **It is expressed as the quantity of organic waste fed into digester/day/unit volume**
- **Overloading and under loading reduce the biogas production**

3. Temperature
- **Temperature effects the bacterial activity . Methane formation is optimum at temp 35 to 38 Celsius**
- **Biogas production decreases below 20 C and stops at 8 C**

4.Seeding:
- **Cattle dung contain both acid forming bacteria and methane forming bacteria**
- **Acid forming bacteria multiplies at fast rate while methane forming bacteria grow slowly**
- **To accelerate fermentation seeding of methane forming bacteria is required**

5.PH value:
- **PH value indicate the concentration of hydrogen**
- **For optimum biogas production PH value should lies between 6.8 and 7.8**

6.Carbon to nitrogen ratio(C/N):
- **Methane forming bacteria requires carbon and nitrogen for it survival . Consumption of carbon is 30 to 35% more than nitrogen .Favorable C/N ratio is 30:1**

7.Retention time :
- **The period for which the biomass slurry is retained inside the digester is called retention time**
- **It refers to the volume of digester /volume of slurry added per day**
- **Eg:120 litre digester which is fed at 5 litres/day have a retention time of 24 days**

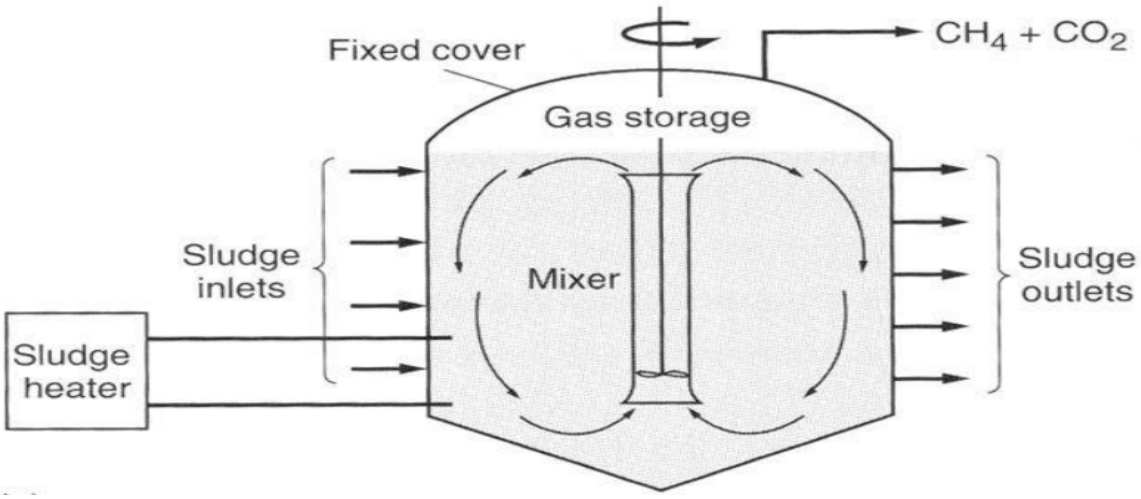
CLASSIFICATION OF BIOGAS PLANT

The biogas plants are built in different sizes and shapes depending on the process carried out. These plants are mainly classified as: 1. Continuous or batch type, 2. Dome and drum type.

1.Continous and batch type
- a.Single stage process
- b.Double stage process

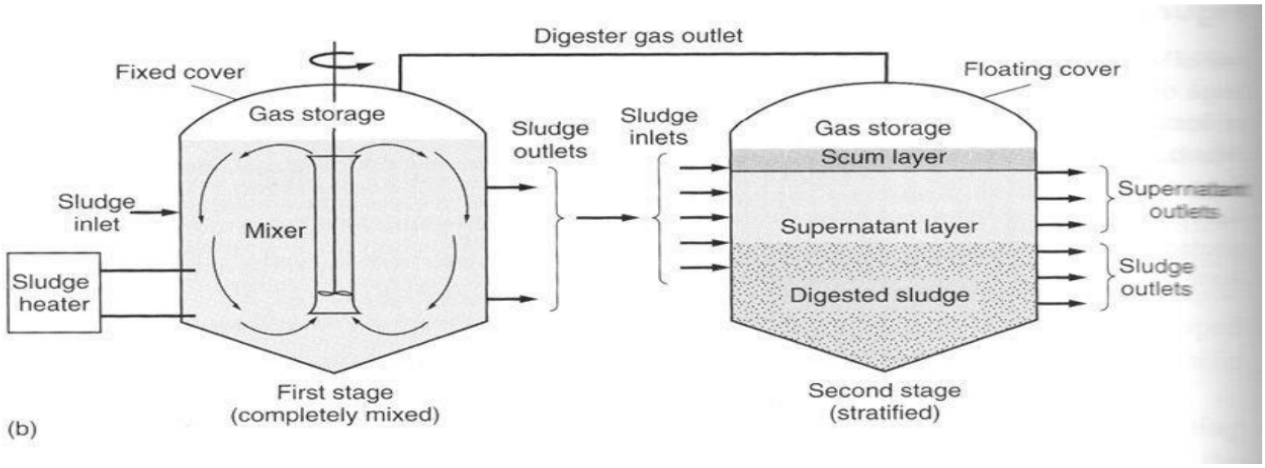
2.The Dom and Drum type
- a.Floating gas holder plant
- b.Fixed dom digester

Single-Stage Digestion



• The entire process of conversion of organic compounds into biogas is completed in a single chamber
• The chamber is regularly fed with raw material while the residues are taken out

Two-Stage Digestion

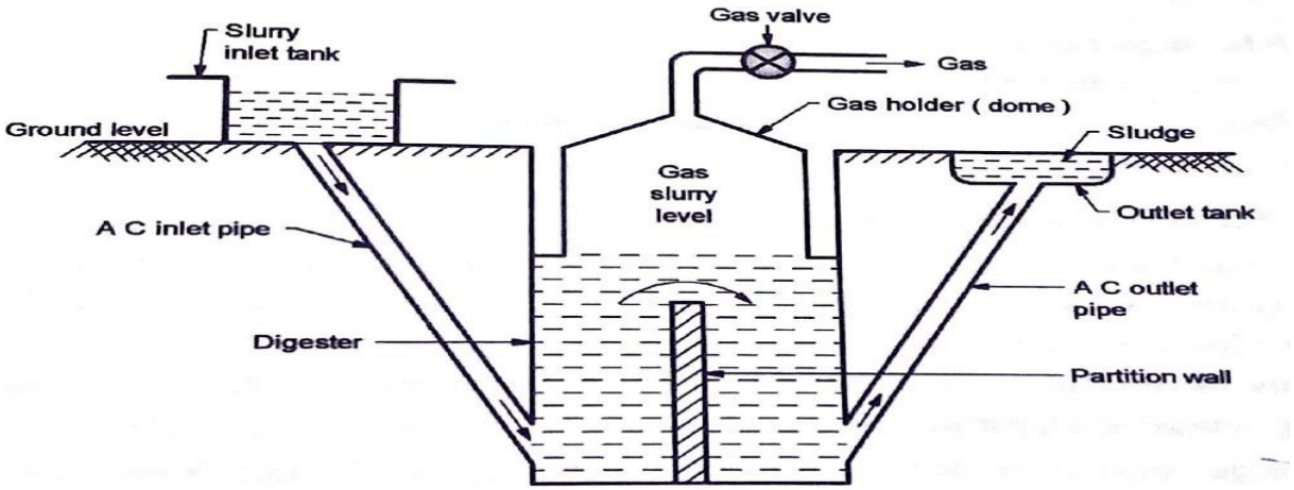


The acidogenic stage and methanogenic stage are physically separated into two chambers
• acid production is taken place In first chamber and it is fed to the second chamber where bio methanation takes place
• The biogas is collected from second chamber
Features of continues plant
• It will produce gas continuously
• It requires small digestion chamber
• It needs lesser period for digestion

BATCH PLANT

- **The feeding is between intervals ,the plant is emptied once the process of digestion is complete**
- **In this a battery of digesters are charged along with lime and urea and allowed to produce gas for 40-50 days**
- **These are charged and emptied in synchronous manner to maintain the supply of gas**
- **These plants are expensive and generally installed in European countries**

FLOATING DRUM TYPE(CONSTANT PRESSURE)



When the animal or Biological waste is put in the Inlet tank of the floating type digester (KVIC ,Khadi Village Industries Commission model) .It will goes to the Digester chamber ,then react with the slurry inside the digester chamber and gas will be developed. The biogas will goes upward to the gas holder. The biogas will collected from the gas pipe which connected on the top of the gas holder drum ,since the high pressure created inside the digester chamber the gas will be easily flow to the load .The waste solid material ,sludge will goes out to the outlet tank .This sludge will utilized for agriculture purpose as manure.

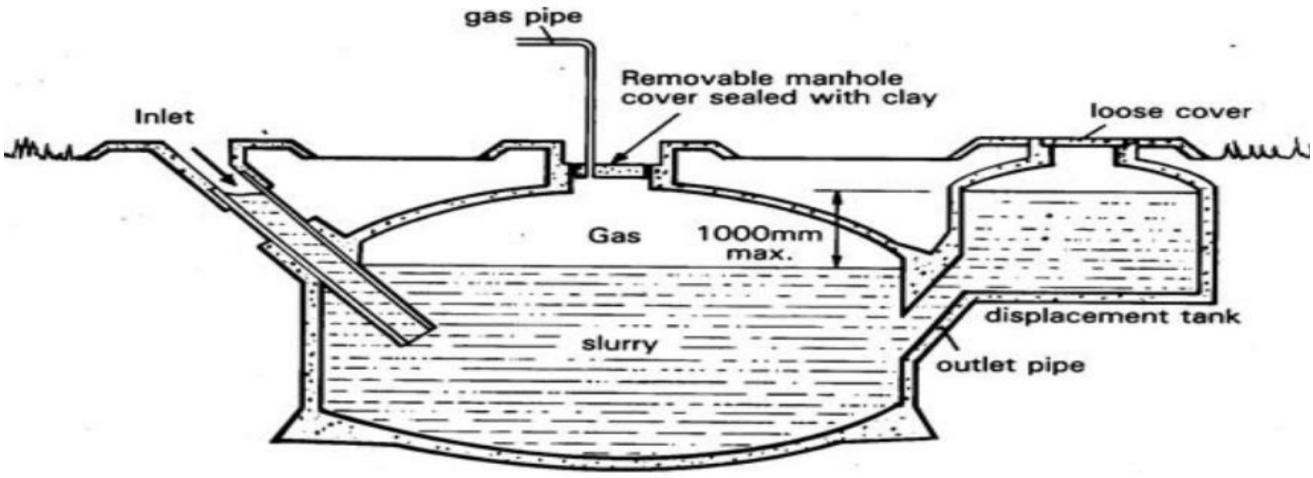
ADVANTAGES

1.Higher gas production per unit volume
2.No problem of gas leakage
3.Constant gas pressure
4.No separate pressure equalizing devices needed .when fresh water is added to the tank or digested slurry is with drawn

DISADVANTAGES

1.It has higher cost because of made up of steel (MS)
2.Heat loss is more (though the metal gas holder)
3.Gas holder requires painting once in a year
4.Flexible pipe joining the gas holder to the main gas pipe requires maintenance
5.It will damage by UV rays in the sun

FIXED DOME TYPE PLANT(CONSTANT VOLUME)



In Fixed dom digester ,the gas holder and digester chamber are combined. It is best suitable for batching process .especially when daily feeding adopted in small quantity. Fixed dom digester is usually constructed below the ground level and is suitable for cooler region .Local materials can be used for it`s construction .Pressure inside the digester varies and gas will collected from the chamber .It is more effective because of no serious problems are faced by this plant during it`s working.

ADVANTAGES

1.It has low cost compared to floating drum type because of it uses only cement and bricks
2.It has no corrosion trouble
3.It`s temperature will be constant and heat insulation is better
4.Cattle and human waste can be fed in to the plant
5.No maintenance

Disadvantages

1.This plant needed services of skilled persons
2.Production of gas per unit volume is also less
3.It has variable gas pressure.

Pyrolysis vs Gasification

	Pyrolysis	Gasification
DEFINITION	Pyrolysis is the process of thermal conversion of organic matter using a catalyst in the absence of oxygen	Gasification is a thermo-chemical process that converts biomass into a combustible gas called producer gas (syngas)
THEORY	Decomposition of material in the absence of gas to produce heat, combustible liquid and combustible gas	Decomposition of material in the presence of a little amount of oxygen to produce heat and combustible gas
USE OF OXYGEN	Occurs in the absence of oxygen	Occurs in the presence of a small amount of oxygen
PRODUCTS	Heat, combustible liquid and combustible gas	Heat and combustible gas
COMPONENTS IN THE END PRODUCT	Carbon monoxide and hydrogen gas	Carbon monoxide, hydrogen gas and water vapor
TEMPERATURE	350°C – 600°C	800°C – 1200°C
USES	Applications in food manufacturing, production of fuel from biomass, production of ethylene, to treat plastic waste, etc	Heat production, production of electricity, etc.