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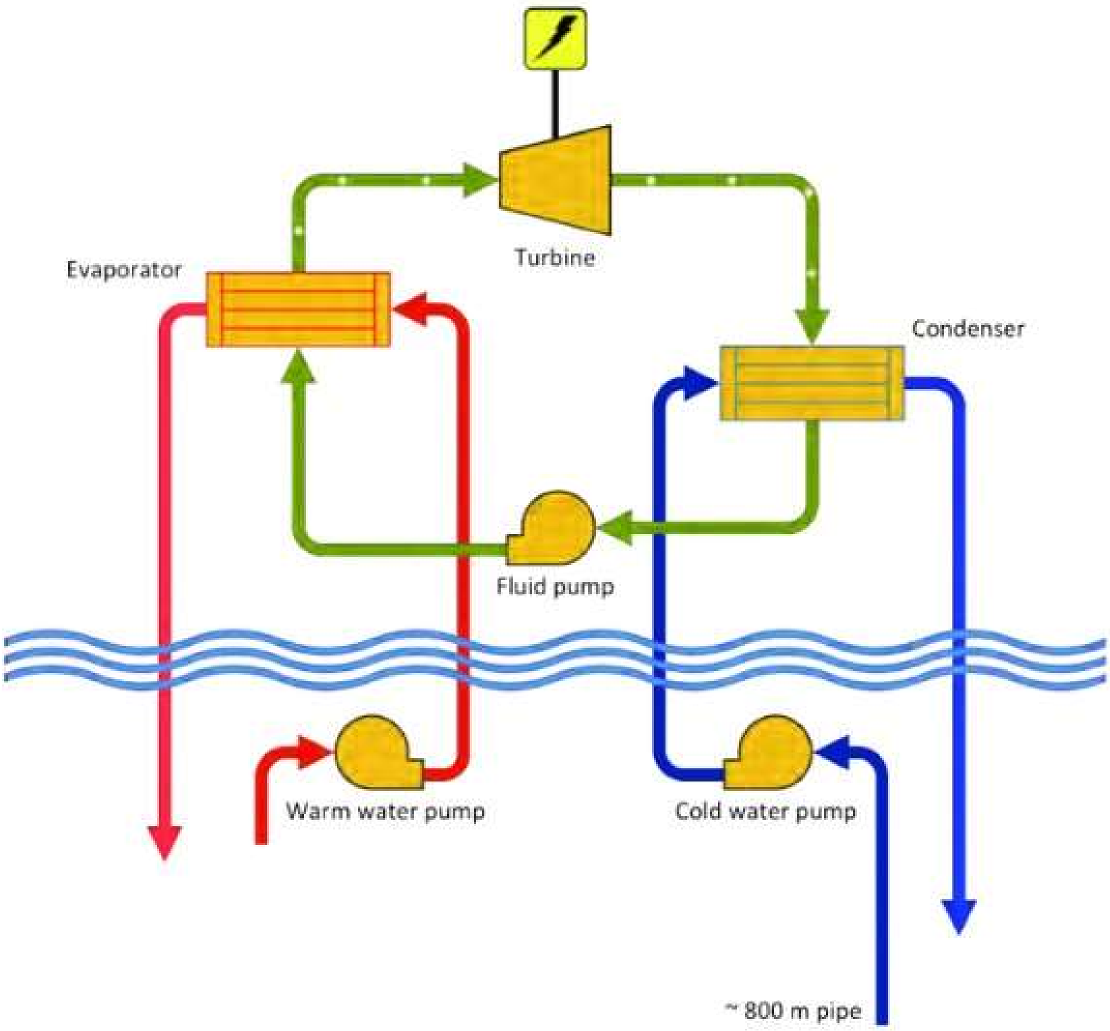
With neat sketch describe the closed cycle OTEC system and state the advantages of OTEC?



The working principle for closed cycle OTEC. A working fluid such as ammonia vaporizes in an evaporator. The gas is led through a turbine, which drives a generator and in turn generates electrical power. A condenser is used to return the fluid to its original state, and using a pump, the process is repeated. Surface sea water is used to heat the fluid in the evaporator, and deep sea water cools it down to liquid state in the condenser. During the process, the surface sea water returned to sea becomes a few °C cooler, and the deep sea water a few °C warmer than previously. Note that the deep sea water, the surface water, and the working fluid never mix; the deep sea water is typically discharged at minimum 60 m depth not to alter the local environment of the surface water layer. Figure by the author.

Advantages of OTEC system :

- Power from OTEC is continuous, renewable, and pollution-free.
- Unlike other forms of solar energy, the output of OTEC shows very little daily or seasonal variation.
- Drawing of warm and cold seawater and returning
- the seawater, close to the thermocline, could be accomplished with minimal environmental impact.

Disadvantages of an OTEC system

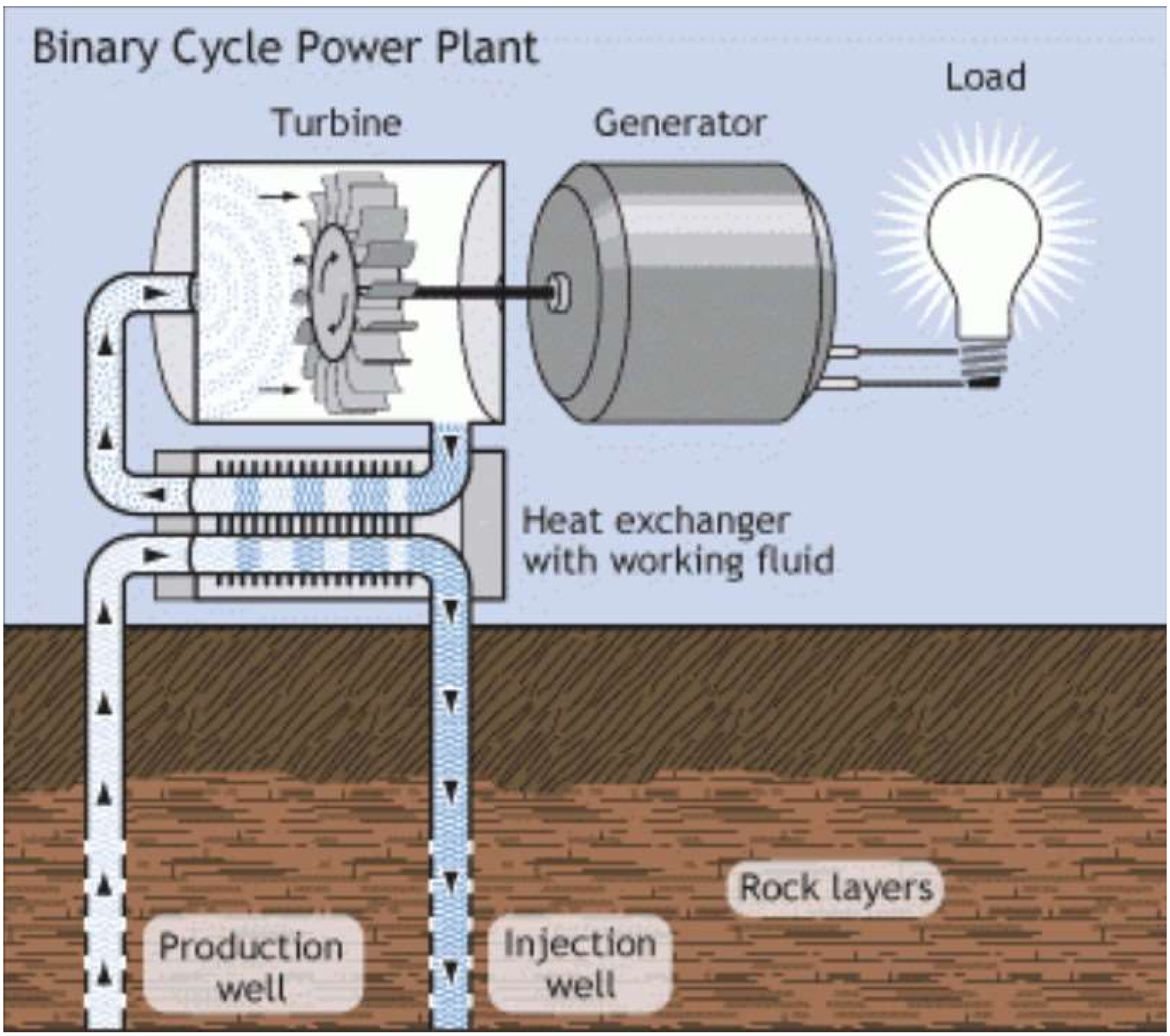
1. Capital investment is very high.
2. Conversion efficiency is very low about 3-4% due to the small temperature difference between the surface water and deep water
3. The low efficiency of these plants coupled with high capital cost and maintenance cost makes them uneconomical for small plants.

With neat Sketch explain the binary geothermal power cycle and List the advantage and disadvantage of geothermal power plant?

Binary Cycle Power Plant

Binary cycle geothermal power generation plants differ from Dry Steam and Flash Steam systems in that the water or steam from the geothermal reservoir never comes in contact with the turbine/generator units. Low to moderately heated (below 400°F) geothermal fluid and a secondary (hence, "binary") fluid with a much lower boiling point that water pass through a heat exchanger. Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbines and subsequently, the generators.

Binary cycle power plants are closed-loop systems, and virtually nothing (except water vapor) is emitted to the atmosphere. Because resources below 300°F represent the most common geothermal resource, a significant proportion of geothermal electricity in the future could come from binary-cycle plants.



Advantages of GPP

Geothermal power plants have lots of advantages.

- **Comparatively ecologically clean**. Unlike coal-fired power plants, geothermal ones use a renewable heat source with a constant supply. Studies have shown that only 6.5% of the total world potential is involved in the industry, which means that energy will last for many years in advance. In addition, the amount of greenhouse gas from geothermal power plants is only 5% in the contrary with coal-fired power plants.
- **More energy**. Geothermal power stations have great capacity – they can gravely help in meeting the demand for energy that grows every year, both in developed and developing countries.
- **Stable prices**. Simple power plants depend on fuel, so the cost of their electricity is varying, based on the market price of fuel. Since geothermal power plants do not use fuel, they do not need to take into account its cost, and they can offer their customers stable electricity costs.
- **Low operating costs.** Geothermal installations require minimal maintenance compared to conventional power plants. As a result, they are reliable and cheap in operation.
- **Renewable and sustainable source**. Geothermal energy will never end, unlike non-renewable energy sources. As long as the earth supports our lives, geothermal energy will exist and geothermal power will work.
- **Permanent power supply**. Unlike other renewable energy sources, geothermal one can provide a constant supply of energy – 24 hours a day, 7 days a week, 365 days a year, regardless of external factors. For example, solar panels can produce electricity only during the day, and wind turbines produce energy only with sufficient wind.

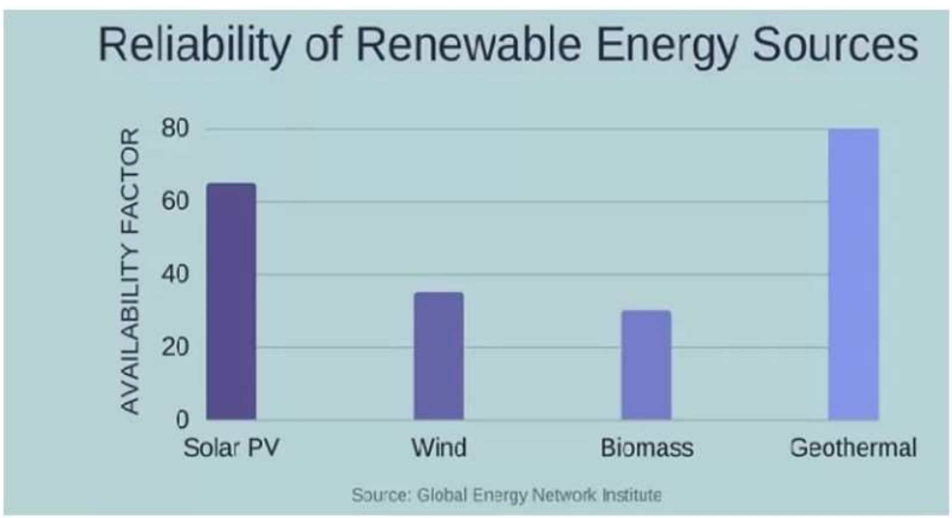


Fig. 2. The availability rate of geothermal energy compared to other renewable energy sources. Source: Greenmatch Online Edition - Advantages and Disadvantages of Geothermal Energy - The Source of Renewable Heat, Dec'18

- **Small area**. They occupy less space than their coal, oil and gas equivalents. Although they will reach far below the earth's surface, their area will be negligible.
- **Low noise work**. There is a little noise in the production of geothermal energy. The main source of noise is the fans that are in the cooling systems. To reduce its level, engineers can install in the generator shops materials with high damping properties. It helps to reduce noise pollution.
- **Energy security**. Using local geothermal resources, the need to supply sources from other countries reduces, which, in turn, lowers dependence on external influences and helps to increase our energy security.

Disadvantages of GPP

As it often happens, some advantages can smoothly go into disadvantages, everything will depend from which side to consider a particular question. No wonder that there are two sides of the same coin.

So, the disadvantages of geothermal power plants.

- **Ecological problem**. High environmental consumption of fresh water can be a loss for the environment, which will ultimately lead to its deficit. Liquids extracted from the earth during drilling contain a large number of toxic chemicals (including arsenic and mercury), as well as greenhouse gases (such as hydrogen sulfide, carbon dioxide, methane, ammonia and radon). If they are incorrectly disposed or treated, they can get into the atmosphere or leak into groundwater and damage the environment and human health.
- **Geographical limits**. Geothermal activity is the highest along the tectonic fault lines in the earth's crust. Exactly in these places the geothermal energy has the greatest potential. The drawback is that only few countries can use geothermal resources. Therefore, while having a look at their geographical peculiarities, such countries are the main producers of geothermal energy: the USA, Iceland, Kenya, Indonesia, the Philippines, Mexico. No wonder that geothermal power plants in these countries entered the rating of the largest in the world as of March 2018 (in megawatts), Fig. 3

- **Seismic instability**. There are reasons to believe that geothermal structures have caused underground shakings in different parts of the world. Despite the fact that seismic activity is often insignificant, it can lead to building damage, injuries and death. In 2006, scientists blamed the geothermal exploration project in Basel (Switzerland) for causing a series of earthquakes. Some of these earthquakes were estimated in 3.4 points on a Richter scale. Further research in 2011 revealed a strong correlation between geothermal exploration and seismic activity.
- **Expensive construction**. Geothermal power plants require significant investments. Although they have low operating costs, the cost of their construction may be much higher than coal, oil and gas plants. Much of these expences concerns the exploration and drilling of geothermal energy resources. Traditional power plants do not require exploration and / or drilling. What is more, geothermal power plants require specially developed heating and cooling systems, as well as other equipment that can withstand high temperatures.
- **Possible exhaustion**. Studies show that without careful management, geothermal tanks can be exhausted. In such cases, the geothermal power plant will become unnecessary until the tank is restored. The only inexhaustible option is to get geothermal energy directly from the magma, but this technology is still in the process of development. This option is worth investing at least because the magma will exist billions of years.

Explain the working of KVIC biogas model

KVIC MODEL

KVIC type biogas plant

This mainly consists of a digester or pit for fermentation and a floating drum for the collection of gas. Digester is 3.5-6.5 m in depth and 1.2 to 1.6 m in diameter. There is a partition wall in the center, which divides the digester vertically and submerges in the slurry when it is full.

The digester is connected to the inlet and outlet by two pipes. Through the inlet, the dung is mixed with water (4:5) and loaded into the digester. The fermented material will flow out through outlet pipe. The outlet is generally connected to a compost pit. The gas generation takes place slowly and in two stages.

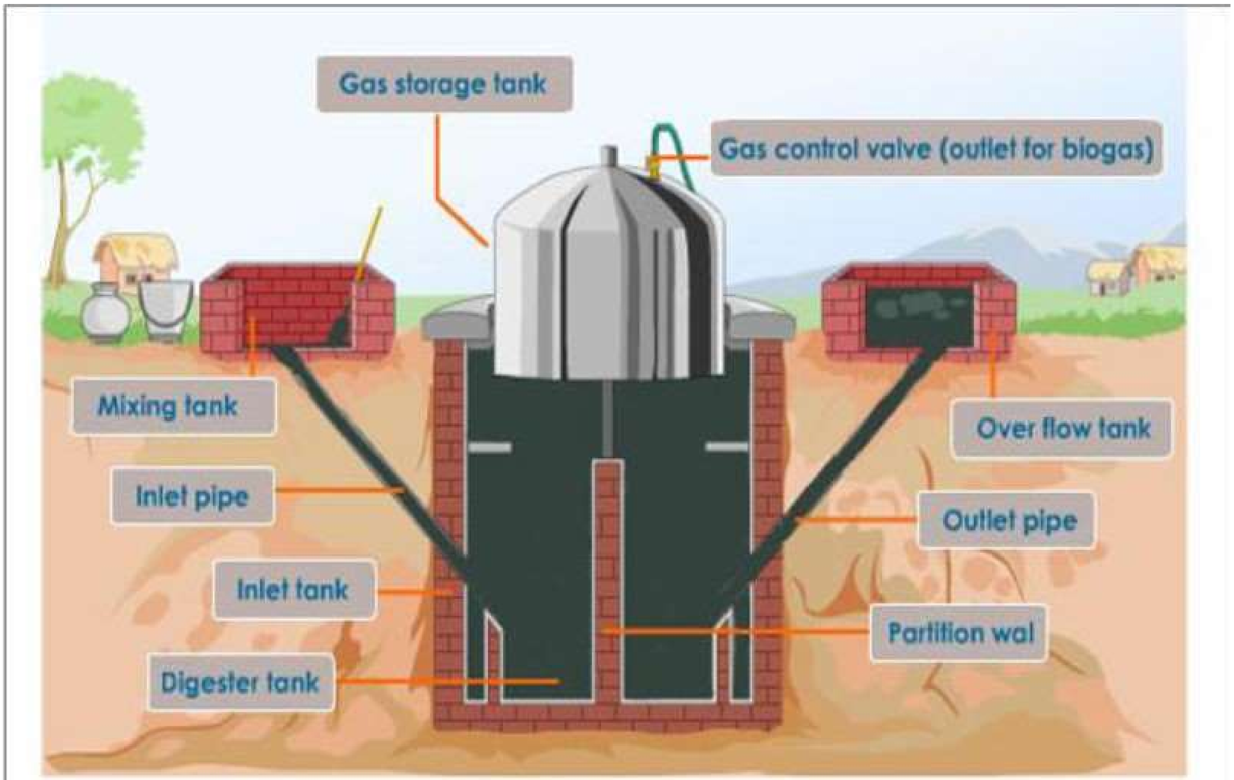
In the first stage, the complex, organic substances contained in the waste are acted upon by a certain kind of bacteria, called acid formers and broken up into small-chain simple acids.

In the second stage, these acids are acted upon by another kind of bacteria, called methane formers and produce methane and carbon dioxide.

Gas holder

The gas holder is a drum constructed of mild steel sheets. This is cylindrical in shape with concave. The top is supported radically with angular iron. The holder fits into the digester like a stopper. It sinks into the slurry due to its own weight and rests upon the ring constructed for this purpose. When gas is generated the holder rises and floats freely on the surface of slurry. A central guide pipe is provided to prevent the holder from tilting. The holder also acts as a seal for the gas.

The cost of drum is about 40% of total cost of plant. It requires periodical maintenance. The unit cost of KVIC model with a capacity of 2 m3/day costs approximately Rs.14, 000 .



Fixed Dome type Biogas Plant

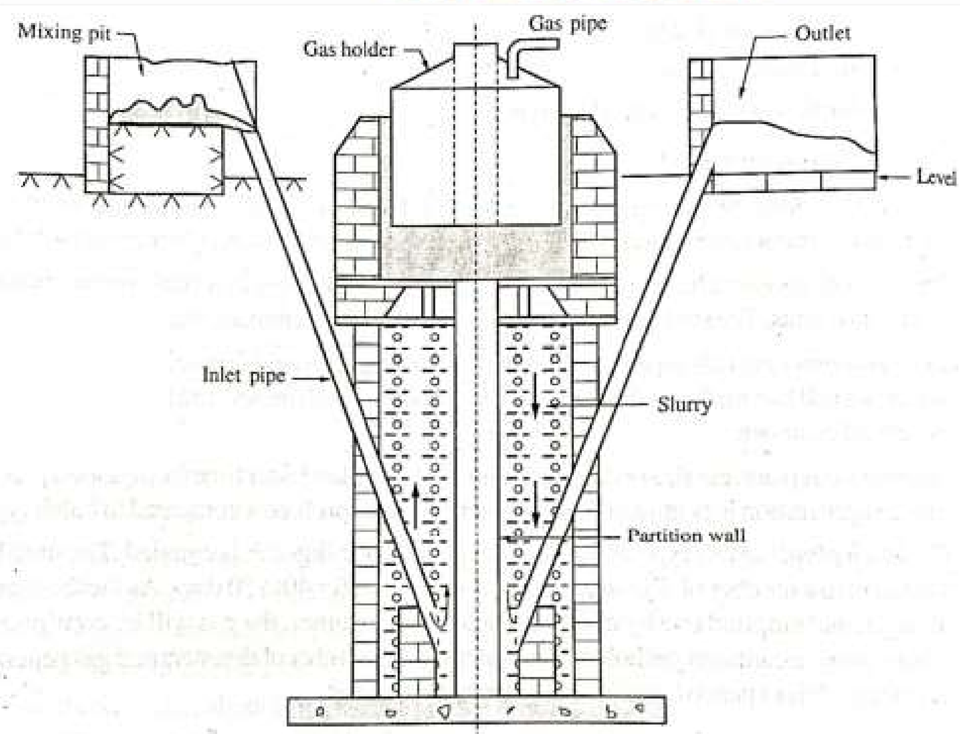


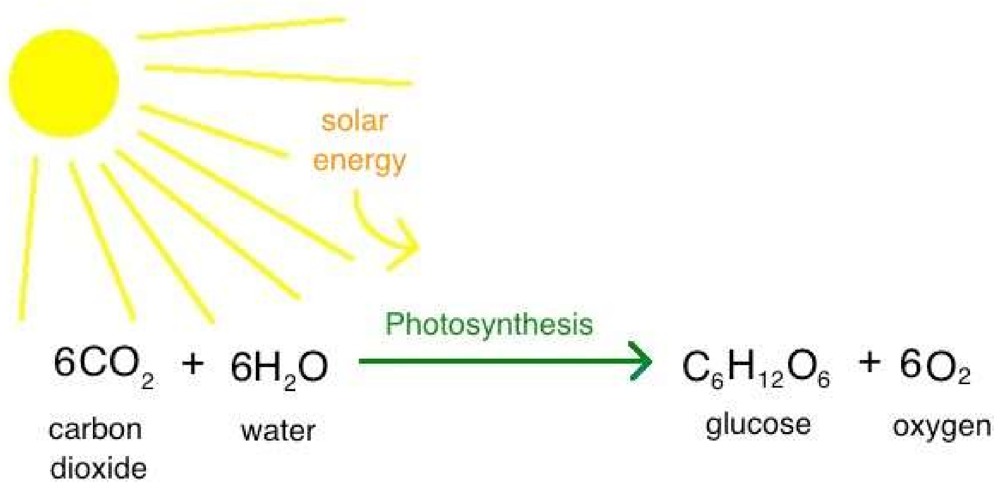
Fig. **Circular digester with floating gas holder (KVIC digester)**

Expain the photosynthesis process and energy plantaion.

Photosynthesis is the process in which light energy is converted to chemical energy in the form of sugars. In a process driven by light energy, glucose molecules (or other sugars) are constructed from water and carbon dioxide, and oxygen is released as a byproduct. The glucose molecules provide organisms with two crucial resources: energy and fixed—organic—carbon.

- **Energy.** The glucose molecules serve as fuel for cells: their chemical energy can be harvested through processes like cellular respiration and fermentation, which generate adenosine triphosphate—ATP, a small, energy-carrying molecule—for the cell's immediate energy needs.

- **Fixed carbon.** Carbon from carbon dioxide—inorganic carbon—can be incorporated into organic molecules; this process is called **carbon fixation**, and the carbon in organic molecules is also known as **fixed carbon**. The carbon that's fixed and incorporated into sugars during photosynthesis can be used to build other types of organic molecules needed by cells.



Significance of Energy Plantations

Energy plantations are the plants planted only for use as fuel. The woody plants have been used since ancient times to generate fire for domestic and industrial purpose. In recent years, to meet the ever growing demand of energy, plantation of energy plants is been encouraged. We are all aware that trees are cut in many of the forest belts of India like Gangetic plains, Siwalik region and foot-hills of Himalayas.

In terms of fuel wood production, India is the biggest, but the per capita fuel wood production is very low. In India, people of hill area hardly get fire-wood plants and they have to go to interior of forest to collect wood-falls. Also introduction of technologies developed for plains is not achievable in these areas.

For example, they cannot be motivated to use solar cooker, because of being solely traditional and religious. Even gobar gas plant cannot be useful in hills, due to low temperatures. Therefore, renewable source of energy is highly desirable for survival of population in hills and for reducing the pressure on forests. And thus, energy plantation has got great support in our country.

For obtaining good amount of biomass, afforestation and forest management government has started many plans like social forestry, silviculture and agro-horticulture practices in waste and barren lands. These programmes include growing of drought resistant, salt resistant, pollutant resistant and high density energy plantations (HDEP) in waste and barren

The technique used in high density energy plantations, HDEP is the practice of planting trees at close spacing. Here the trees grow rapidly due to struggle for survival. It provides fast and high returns with many opportunities of permanent income and employment.

Features of Energy Plantations

The attractive features of energy plantations are:

- Good amount of heat content of wood
- Wood low in sulphur and non-polluting
- Ash from burnt wood is a valuable fertiliser
- Raising plantations in erosion-prone lands helps to reduce soil erosion
- Help in rural employment generation

List the factors affecting biogas generation

2.8 Factors affecting biogas generation

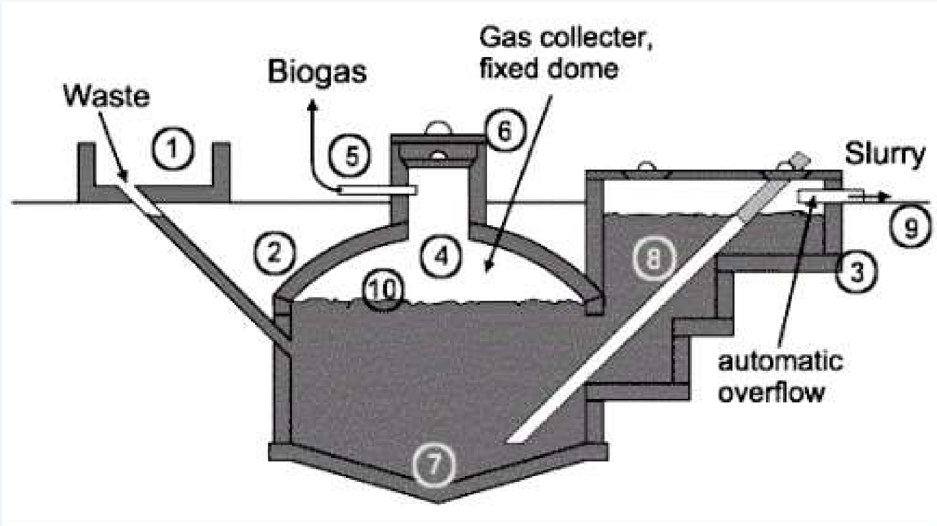
1. **PH or hydrogen ion concentration:** In the digester, a suitable PH range is to be maintained to provide constant supply of the gas. In a PH range of 6.5 to 7.5, microorganisms will be very active and bio-digestion will be very efficient. The addition of some material to the digester causes variations in the PH value and results in the imbalance of bacteria population. For sewage solids, the ideal PH is from 7 to 7.5.
2. **Temperature:** The temperature ranges from 35°C to 38°C results in better methane formation. The gas generation starts decreasing at 20°C and ceases completely at 10°C.

3. **Total solid content of feed material:** In order to get total solid content of 8 to 10%, the cow dung is to be mixed in the range of 1:1 by weight. Around 80-82% of moisture is present in raw cow dung and remaining 18-20% is called total solids. The adjustment made in total solid content increases the bio-digestion rate.
4. **Loading rate:** The amount of raw material supplied to the fermentation tank (digester) per day per unit volume is known as loading rate. For municipal sewage treatment plants, the loading rate ranges from 0.5 to 1.6 kg/m/day. The optimum range of loading rate ranges from 1.2 to 5.3 kg/m°/day. High loading rate, results in the formation of acids and thus fermentation stops.
5. **Seeding:** Seeding is nothing but the increase in number of methane formers by artificial means. It uses digested sludge which is rich in methane formers. But higher seeding is also not desirable as gas production decreases beyond certain limits due to reduction of total solid contents of the cow dung.
6. **Uniform feeding**: In order to provide good fermentation in the digester, a control over quality and quantity of raw material supplied to the digester is essential. Therefore, all the time uniform feeding of digester is necessary.
7. **Carbon nitrogen ratio of the input material:** For an optimal digestion rate, a carbon nitrogen ratio of 30: 1 is necessary. High carbon in raw material slows down the digester. High nitrogen content of the raw material may stop the fermentation process. The ammonia formed due to nitrogen and hydrogen may kill methane producers.
8. **Diameter to depth ratio:** It was investigated that the maximum gas production rate occurs with diameter to depth ratio of 0.66 to 1.0. But the effect of temperature at different depths also plays important role is deciding this ratio.
9. **Nutrients:** In digester, the bacteria always require C, H_2, O_2, P and S. Out of these nutrients, the supply of N_2 and P are always short. In order to compensate this, extra raw material which is rich in phosphorus and N, must be added to increase the gas generation rate.
10. **Mixing or stirring or agitation of content of digester:** In digester, a proper mixing of slurry is required to improve the fermentation process. Slight mixing results in good fermentation and the digestion may be retarded due to violent agitation.
11. Retention period or feeding rate: The temperature and feed stocks influence the retention period of the material for biogas generation. Usually, the retention period is kept from 30 to 45 days.

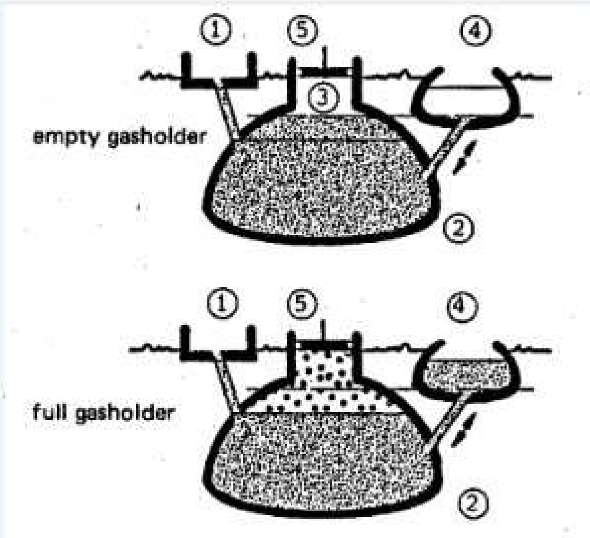
With neat sketch explain the working of fixed dome biogas model

Fixed-dome 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. The costs of a fixed-dome biogas plant are relatively low. It is simple as no moving parts exist. 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. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and cracks).



Fixed dome plant Nicarao design: 1.Mixing tank with inlet pipe and sand trap. 2.Digester. 3.Compensation and removal tank. 4.Gasholder. 5.Gaspipe. 6.Entry hatch, with gastight seal. 7.Accumulation of thick sludge. 8.Outlet pipe. 9.Reference level. 10.Supernatant scum, broken up by varying level.



Basic function of a fixed-dome biogas plant: 1.Mixing pit, 2.Digester, 3.Gasholder, 4.Displacement pit, 5.Gas pipe

What are the prolems associated with OTEC?

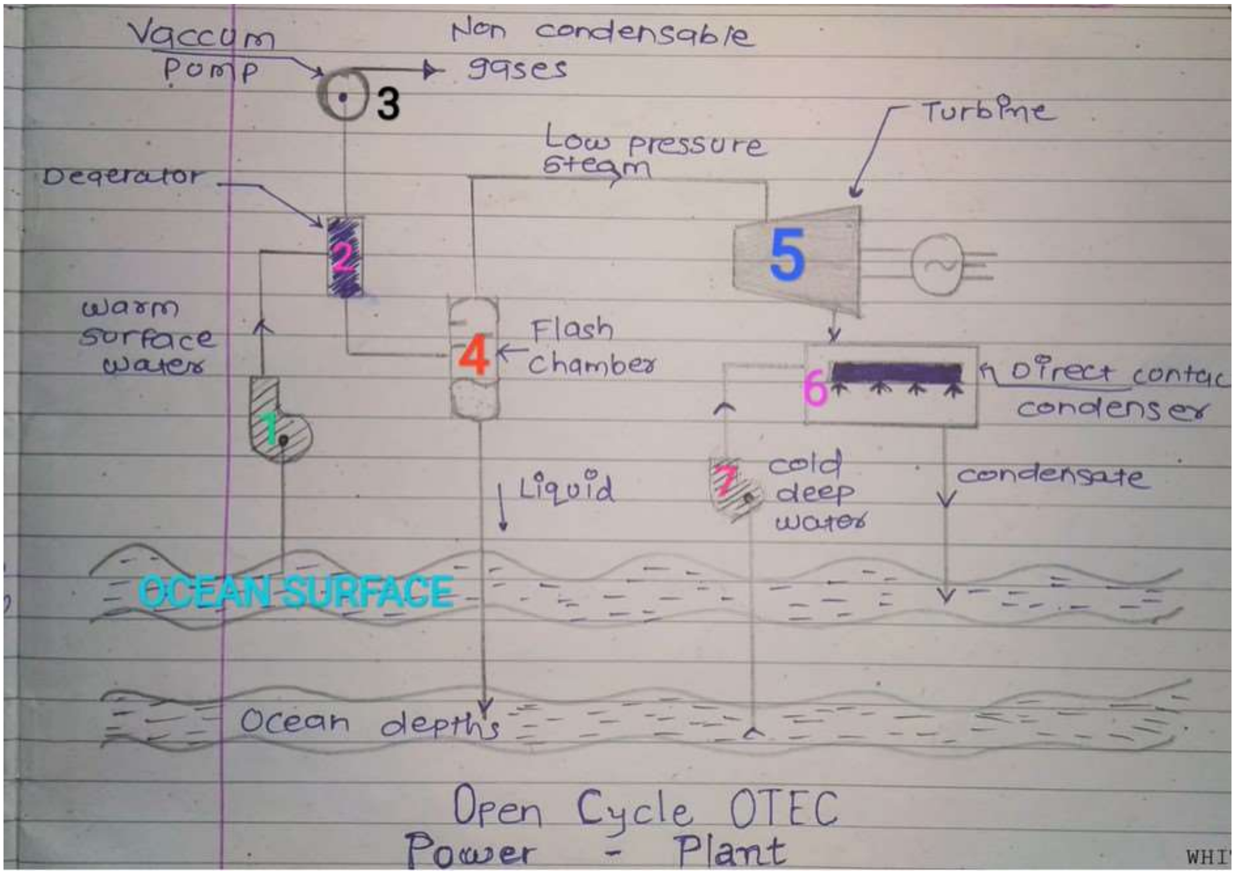
Disadvantages of an OTEC system

1. Capital investment is very high.
2. Conversion efficiency is very low about 3-4% due to the small temperature difference between the surface water and deep water
3. The low efficiency of these plants coupled with high capital cost and maintenance cost makes them uneconomical for small plants.

4.4.2 Disadvantages:

1. The cost of power produced by OTEC system is considerably high because of its very poor generating efficiency (5%) and huge capital costs.
2. OTEC plants must be located only where the difference in temperature must be 20°C and above around the year for its economic and practical operation. Ocean depths must be available fairly close to shore-based facilities for economic operation. Floating plantships can provide such flexibility.
3. Construction of OTEC plant and lying of pipes in coastal water are difficult and may cause localized damage to reefs and marine ecosystems.
4. Although successful testing of OTEC is experimentally established, this technology is not yet established on commercial basis.
5. Some additional developments of key components is essential as deep sea water pipe lines, low pressure turbines and condensers for the further development of OTEC system.

With neat sketch explain the working of open type OTEC system



- **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.

What are the problems associated with Biogas generation?

4. When cattle dung and water is not properly mixed, volatile fatty acids will be accumulated and results in failure of digester.
5. It is necessary to maintain an optimum range of PH and volatile fatty acids, otherwise digester will not work properly.
6. There is chance of leakage of gas from gas holder in case of Janata Model

2.6 Problems involved with Biogas production

1. Handling of effluent slurry is a major problem and sufficient open space is to be provided to dry the slurry. It also requires human animal labor to carry effluent to the field.
2. The methanogenic bacteria involved in gas generation are very sensitive to temperature and affects the gas generation rate.
3. Due to lack of knowledge about Biogas generation, some persons add urea fertilizer which results in toxicity of ammonia nitrogen and decreases gas production.

Discuss the properties of Hydrogen with respect to its utilization as a renewable form of energy

3.1 Properties of Hydrogen

Hydrogen is an odorless and colorless gas. It has the simplest and lightest atom with one protoı and one electron and molecular weight of 2.016. Important properties are listed and comparec with natural gas and gasoline in Table below.

S.N.	Properties	Gasoline	Natural gas	Hydrogen
1.	Density (kg/m^3)	730	0.78	0.0837
2.	Boiling point, (°C)	38 to 204	−156	−253 (20.3 K)
3.	Lower heating value, (MJ/kg) (MJ/m^3)	44.5 32	48 37.3	125 10.4 (gas), 8520 (liquid)
4.	Higher heating value, (MJ/kg) (MJ/m^3)	50.8 36.6	55 42.6	141.90 11.89 (gas), 10046 (liquid)
5.	Flammable limit, % in air	1.4–7.6	5–16	4–75
6.	Flame speed, (m/s)	0.4	0.41	3.45
7.	Flame temperature, (°C)	2197	1875	2045
8.	Flame luminosity	High	Medium	Low

What are the different methods of hydrogen production? explain in brief?

3.2 Production

Although hydrogen is the third most abundant element on the earth, it does not exist in free state, except for small quantities in the upper atmosphere. It is, therefore, not a primary energy source. However, large amounts of combined hydrogen are present in compounds such as water, fossil fuels and biomass. It can therefore, be produced through two routes:

(a) Fossil fuels, such as natural gas, coal, methanol, gasoline etc., and biomass are decomposed by thermo-chemical (steam reforming or partial oxidation) methods to obtain hydrogen. The CO produced in the process is eliminated by water gas shift reaction. This route of hydrogen production causes CO_2 emission. The energy content of the produced hydrogen is less than the energy content of the original fuel, some of it being lost as excessive heat during production.

(b) Hydrogen can also be produced by splitting water into hydrogen and oxygen by using energy from nuclear or renewable sources such as solar, wind, geothermal, etc., through electrical or thermal means (i.e. electrolysis and thermolysis respectively). Water splitting is also possible through bio-photolysis process using solar radiation.

Splitting of water is thus possible at the expense of renewable energy to produce secondary fuel H_2. On use, H_2 and O_2 recombine to produce water again and energy is released. This route is therefore a clean and sustainable route of energy supply.

3.2.1 Thermo-chemical Methods

Steam reforming of methane is the most energy efficient, commercialized technology currently available and most cost effective when applied to large, constant loads. The method accounts for 95 per cent of the hydrogen production in USA. The steam reforming method has been described in the previous section on fuel cell.

3.2.2 Electrolysis of Water

Electrolysis is the simplest method of hydrogen production. Currently, this method is not as efficient or cost effective as thermo-chemical method using fossil fuels or biomass. But it would allow for more distributed hydrogen generation and open the possibilities for use of electricity generated from renewable and nuclear resources for hydrogen production.

An electrolysis cell essentially consists of two electrodes, commonly flat metal or carbon plates, immersed in an aqueous conducting solution called electrolyte, as shown in Fig. below. A direct current decomposes water into H_2 and O_2, which are released at cathode (-ve electrode) and anode (+ve electrode) respectively. As water itself is poor conductor of electricity, an electrolyte, commonly aqueous KOH is used.

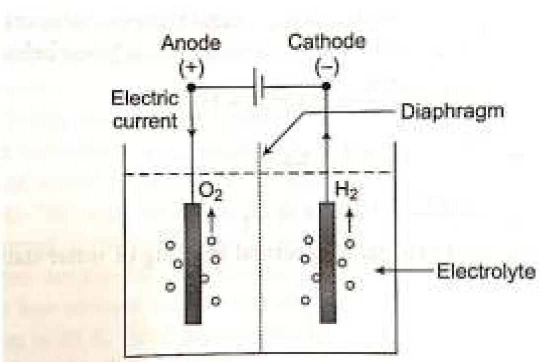


Figure Electrolytic cell

Ideally, a decomposition voltage of 1.23 V per cell should be sufficient at normal temperature and pressure; however, due to various reasons a voltage of about 2 V per cell is applied in practice. The energy required is 3.9-4.6 kWh per m^3 of hydrogen produced. About 60-70 per cent of this energy is actually utilized in electrolysis. Therefore, the efficiency of electrolysis process is about 60-70 per cent, which can be improved up to 80 per cent by using catalyst such as porous platinum or nickel. A diaphragm (usually woven asbestos) prevents electronic contact between the electrodes and passage of gas or gas bubbles. Electrolysis method is most suitable when primary energy is available as electrical energy, e.g. solar photovoltaic energy. It is also suitable where cheap electricity is available from other sources such as wind, geothermal, etc.

3.2.3 Thermolysis of Water

When primary energy is available in the form of heat (e.g. solar thermal), it is more logical to produce hydrogen by splitting water directly from heat energy using thermolysis. This would be more efficient than conversion of heat, first to electricity (using heat engine - generator) and then producing hydrogen through electrolysis. The efficiency of thermal plant is usually in range 32-38 per cent and that of electrolysis is 80 per cent. The overall efficiency through thermal-electrical-hydrogen route would thus be only 25-30 per cent.

Direct thermal decomposition of water is possible but it requires a temperature of at least 2500°C; because of temperature limitations of conversion process equipment, direct single-step water decomposition cannot be achieved. However, sequential chemical reactions at substantially lower temperature can be devised to split water into H_2 and O_2. In the reaction series, water is taken up at one stage and H_2 and O_2 are produced in different stages. The energy is supplied as heat at one or more stages and partly released at some stage in the cycle. Apart from decomposition of water, all other materials are recovered when the cycle is completed. Therefore, the method is known as thermo-chemical cycle. The efficiency of conversion from heat energy to hydrogen is better than its conversion through electrolysis route only when the upper temperature of thermo-chemical cycle is above 700 °C. For the upper temperature of 950 °C the efficiency of conversion is about 50 per cent. This is a marked improvement over what is possible through electrolysis route. Several thermo-chemical cycles have been proposed and are under investigation. One such cycle is given below:

$$2\,CrCl_2 + 2\,HCl \xrightarrow{325\,^\circ C} 2\,CrCl_3 + H_2$$

$$2\,CrCl_3 \xrightarrow{875\,^\circ C} 2\,CrCl_2 + Cl_2$$

$$H_2O + Cl_2 \xrightarrow{850\,^\circ C} 2\,HCl + \tfrac{1}{2}\,O_2$$

At present, no commercial process for thermal splitting of water using thermo- chemical cycle is in operation.

3.2.4 Biophotolysis

In this method the ability of the plants (especially algae) to split water during photosynthesis process is utilized. An artificial system is devised, which could produce hydrogen and oxygen from water in sunlight using isolated photosynthetic membrane and other catalysts. Since this process is essentially a decomposition of water using photons in the presence of biological catalysts, the reaction is called photolysis of water.

There are three distinct functional components coupled together in the system as shown in Fig. below: (i) photosynthetic membrane, which absorbs light, split water to generate oxygen, electrons and protons, (in) an electron mediator, which is reducible by photo-synthetically generated electrons and (in) a proton activator that will accept electrons from the reduced mediator and catalyze the reaction: $2\ H^+ + 2\ e^- \rightarrow H_2$

A system with chloroplast (small bodies containing the chlorophyll in green plants) as a photosynthetic membrane to split hydrogen and oxygen, ferredoxin as e^- mediator and hydrogenase (an enzyme) or finely dispersed platinum as proton activator, has been successfully tested. The method is being extensively studied further.

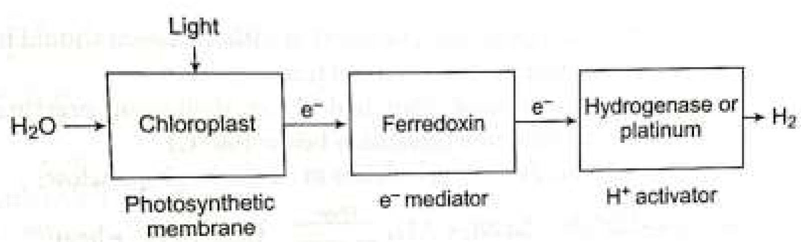


Figure Functional components of biophotolysis

Write a short notes of safe utilizaton of hydrogen energy and on safe hydrogen energy transportaion.

By their nature, all fuels have some degree of danger associated with them. The safe use of any fuel focuses on preventing situations where the three combustion factors—ignition source (spark or heat), oxidant (air), and fuel—are present. With a thorough understanding of fuel properties, we can design fuel systems with appropriate engineering controls and establish guidelines to enable the safe handling and use of a fuel.

A number of hydrogen's properties make it safer to handle and use than the fuels commonly used today. For example, hydrogen is non-toxic. In addition, because hydrogen is much lighter than air, it dissipates rapidly when it is released, allowing for relatively rapid dispersal of the fuel in case of a leak.

Some of hydrogen's properties require additional engineering controls to enable its safe use. Specifically, hydrogen has a wide range of flammable concentrations in air and lower ignition energy than gasoline or natural gas, which means it can ignite more easily. Consequently, adequate ventilation and leak detection are important elements in the design of safe hydrogen systems. Because hydrogen burns with a nearly invisible flame, special flame detectors are required.

In addition, some metals can become brittle when exposed to hydrogen, so selecting appropriate materials is important to the design of safe hydrogen systems. In addition to designing safety features into hydrogen systems, training in safe hydrogen handling practices is a key element for ensuring the safe use of hydrogen. In addition, testing of hydrogen systems—tank leak tests, garage leak simulations, and hydrogen tank drop tests—shows that hydrogen can be produced, stored, and dispensed safely.

As more and more hydrogen demonstrations get underway, hydrogen's safety record can grow and build confidence that hydrogen can be as safe as the fuels in widespread use today.

Hydrogen can be transported as a pressurized gas or a cryogenic liquid; it can be combined in an absorbing metallic alloy matrix or adsorbed on or in a substrate or transported in a chemical precursor form such as lithium, sodium metal, or chemical hydrides. Carbon-bound forms of hydrogen such as today’s gasoline, natural gas, methanol, ethanol, and others are not considered in this report, since their properties and use are well understood. However, comparisons with such conventional fuels will be made when necessary to help clarify the issues related to hydrogen.

Write a short notes on application of biogas.

Applications of Biogas

1. Biogas as a Cooking Fuel and Some Common Indian Burner Designs
2. Burner Designs Commonly used in China
3. Use of Biogas as a Lighting Fuel
4. Utilisation of Biogas for Pumping Water and Miscellaneous other Applications
5. Biogas as a Fuel for Running IC Engines
6. Biogas as a Vehicle Fuel
7. Applications of Biogas for Power Generation
8. Fuel Cell Linked Biogas Systems

The use of biogas is a green technology with environmental benefits. Biogas technology enables the effective use of accumulated animal waste from food production and of municipal solid waste from urbanization. The conversion of organic waste into biogas reduces production of the greenhouse gas methane, as efficient combustion replaces methane with carbon dioxide. Given that methane is nearly 21 times more effective in trapping heat in the atmosphere than carbon dioxide, biogas combustion results in a net reduction in greenhouse gas emissions. Additionally, biogas production on farms can reduce the odours, insects, and pathogens associated with traditional manure stockpiles.

Discuss the scope of geothermal energy in India.

Geothermal Energy in India

According to the **International Geothermal Energy Agency (IRENA)** and the **Global Geothermal Alliance (GGA),** the global capacity of the installed geothermal power plants across the globe increased from 9,992 MW to 13,909 MW from 2010 to 2019. This is for countries like the USA, Philippines, Italy, Iceland, Japan, Indonesia, Mexico, etc. However, there are no installed and fully functional geothermal power plants in India.

The Geological Survey of India found that 350 locations in India across 11 states could provide geothermal energy. The profitable harnessing of GE could be done in the seven key locations:

- Puga Valley, Ladakh in the Himalayas
- Sohana, in Rajasthan, Haryana
- West Coast in Maharashtra- Goa
- Cambay, in Gujarat
- The Son, Narmada, and Tapi belt (SONATA)
- The Godavari and
- The Mahanadi belts

Scope of Geothermal Energy in India

The potential for harnessing geothermal energy in India is vast. The capacity of the geothermal power plants to be installed in India is estimated to be 10,600 MW. The current documented uses or applications of geothermal energy in India have been for fisheries and crop drying.

An Indian company is looking to seek technical help from an Iceland company Reykjavik Geothermal for the proposed geothermal power plant in Puga valley, Ladakh.

In 2019, a pilot-scale project in Gujarat was started by the Centre of Excellence for Geothermal Energy (CEGE). Similarly, other proposed areas have been subjected to more exploration in India.

The proposed geothermal power plants in India are

- Puga Valley (Jammu and Kashmir)
- Tatapani in Chhattisgarh
- Godavari Basin Manikaran in Himachal Pradesh
- Bakreshwar in West Bengal
- Tuwa in Gujarat
- Unai and Jalgaon in Maharashtra
- Rajgir and Munger in Bihar and Jharkhand

Under the proposed Geothermal Energy Policy, the Ministry of New and Renewable Energy of India (MNRE) has proposed to provide grants for geothermal energy project for generating power, industrial use, public use like greenhouse cultivation, space heating, cooking, etc., and Ground Source Heating Pumps (GSHPs).