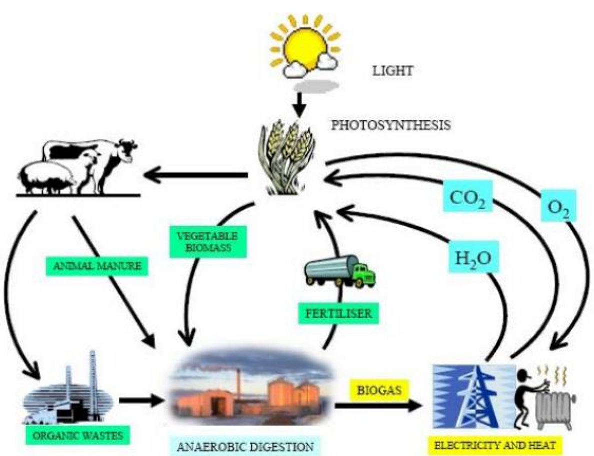
Biogas:

- Biogas is one of the most important bioenergy to solve the environmental and energy challenges to replace natural gas or transportation fuel.
- Biogas produced mainly contains methane (55–65%) and carbon dioxide (30–40%) and traces of impurities (H_2,H_2S and N_2) produced from the decomposition of animal, plant and human waste.
- It is clean but slow burning gas and usually has a calorific value between 5000-5500kcal/kg.
- It can be used directly in cooking reducing the demand for firewood and LPG gas.
- Moreover the material from which biogas is produced retain its value as a fertilizer and can be returned to the soil.
- Biogas has been popular on the name- "Gobar gas"
- Biogas or 'Gobar gas'(mainly cow dung)-Produced from the decomposition of animal, plant and human waste.(piggery waste, poultry droppings-effectively used , algae, crop residues, garbage kitchen waste, paper wastes, sea food, waste from sugarcane refinery, water hyacinth etc.,)
- All cellulosic organic material of animal or plant origin-easily biodegradable-potential raw material for biogas production.
- Biogas –produced by digestion, pyrolysis or hydro gasification.
- Digestion: Biological process that occurs in the absence of oxygen and in the presence of anaerobic organisms at ambient pressure and temperature 35-70^{o}C.
- The container in which this digestion takes place is known as the digester.



Energy from biomass:

► India produces about 450-500 million tonnes of biomass per year.

► EAI estimates that the potential biomass in India varies from about 18,000 MW – Scope for 50,000 MW

► The current share of biofuels in total fuel consumption is extremely low and is confined mainly to 5% blending of ethanol in gasoline, which the government has made mandatory in 10 states.

► Currently, biodiesel is not sold on the Indian fuel market, but the government plans to meet 20% of the country's diesel requirements by 2020 using biodiesel.

► Plants like Jatropha curcas, Neem, Mahua - potential sources for biodiesel production in India.

► India uses several incentive schemes to induce villagers to rehabilitate waste lands through the cultivation of Jatropha.

► The Indian government is targeting a Jatropha plantation area of 11.2 million.

► 63 biomass cogeneration (non-bagasse) projects aggregating to about 211 MW and 153 biomass gasifiers with a total capacity of about 45 MW have been installed in the country during the last four years in various industries for meeting their captive heat and power requirements.

► 11 biomass cogeneration (non-bagasse) projects with a total capacity of about 40 MW have been completed

Biomass-Definition and Types:

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities.

► It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood.

► Types of Biomass: Biomass is highly diverse in nature and classified on the basis of site of origin, as follows:

a. Field and plantation biomass

b. Industrial biomass

c. Forest biomass

d. Urban waste biomass

e. Aquatic biomass

► Biomass is a renewable source of fuel to produce energy because:

1.Waste residues will always exist – in terms of scrap wood, mill residuals and forest resources;
2.Properly managed forests will always have more trees, and we will always have crops and the residual biological matter from those crops

► Biomass in its Traditional solid mass –wood agriculture residue.

► Biomass in non-traditional form-converted into liquid fuels.

Here are simplified definitions for each of the biomass categories:

a. Field and plantation biomass: This includes organic materials like crops and trees that are grown specifically to be used as a source of energy or raw materials, such as corn or sugarcane.

b. Industrial biomass: Industrial biomass refers to organic waste materials generated by factories and businesses, which can be used for energy production or other purposes. Examples include wood scraps from a furniture factory.

c. Forest biomass: Forest biomass is the organic matter found in forests, like fallen leaves, branches, and trees. It can be used for various purposes, including producing energy or making paper products.

d. Urban waste biomass: This includes organic waste materials generated in cities, like food scraps and yard waste. It can be converted into energy through processes like composting or biogas production.

e. Aquatic biomass: Aquatic biomass consists of organic matter from water environments, such as algae and aquatic plants. It can be used for purposes like biofuel production or as a food source in aquaculture.

Photosynthesis:

Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can be later released to fuel the organisms' activities (energy transformation).

► This chemical energy is stored in carbohydrate molecules, such as sugars, which are synthesized from carbon dioxide and water – hence the name photosynthesis.

The photosynthetic efficiency is the fraction of light energy converted into chemical energy during photosynthesis in plants and algae.

► Photosynthesis can be described by the simplified chemical reaction

► $6H_2O + 6CO_2 + energy \rightarrow C_6H_{12}O_6 + 6O_2$ where $C_6H_{12}O_6$ is glucose (which is subsequently transformed into other sugars, cellulose, lignin, and so forth)

Factors affecting anerobic digestion:

1] Basic factors
2] Environmental factors

1] Basic Factors :

These factors includes
a) Bacteria
b) Food
c) Contact
d) Time

a) Bacteria :

Depending upon the end products produced by the bacteria they are classified as
i) Acid formers ii) Methane formers or Methanogens
The acid formers are less sensitive to environmental changes and fast growing. The optimum pH range for satisfactory operation of the acid formers is found to be 4.5 to 6.5.
Methane formers are not only specific in the end product but are also specific about the substrate for utilization.

b) Food :

The organic matter to be stabilized is food for bacteria. In anaerobic digestion generally food consists of complex organic materials. The control over the organic characteristics of waste is very difficult. However two factors related to the food can be controlled are solids concentration and frequency of feeding.

c) Contact :

Stabilization cannot occur without actual contact of the bacteria with the food. This contact can take place in several ways but the most effective is mixing. Mixing can be achieved artificially by mechanical mixers or by natural means. Nature mixing occurs primarily by gas production in the digester. In case of mechanical mixing the contents may be stirred continuously or intermittently.Better COD removal efficiency and increased gas production can be achieved by intermittent mixing recirculation of liquid by manual or mechanical means can also be adopted for mixing.

d] Time :

Two main factor may be considered in this aspect namely hydraulic retention time and the solids retention time. The solids retention time reflects the average time for which the biological solids remains in the digester and can be defined as Suspended solids in the system to the Suspended solids removed per day
Use of suspended solids as an indication of the microorganism is adequate in the above formulation since the average retention time of the microorganisms will closely approximate the average retention time of the mixed suspended solids in the system.

SRT depends on the degree of sludge retention achieved and HRT. The SRT/HRT ratio, therefore, directly implies the efficiency of a treatment system. Higher the ratio, more efficient and economic the system will be because maximum SRT gives efficient treatment and minimal HRT reflects the smaller size of reactor which means economy of the process .

2] Environmental Factor :

These factors include
a) Temperature
b) pH
c) Toxics

a) Temperature :

The time required for the stabilization of organic matter depends on the temperature of the digestion. The rate of food stabilization increases and decreases with temperature within certain limits.

b] pH :

The pH of the contents of a digester depends on the relationship between the volatile acid, alkalinity and percentage of carbon dioxide in the digester gas. Many reporters have indicated that the optimum pH for the digestion of organic waste is in the range 6.8 to 7.2 with the limit of the range for operation without significant inhibition being 6.5 to 7.6.

c) Toxics :

Materials which have inhibitory effects on digestion if their concentration become to high include the alkali and alkaline earth cations such as sodium, potassium, calcium and magnesium heavy metals such as copper, nickel and zinc; ammonia and ammonium ion; sulphides and some organic compounds.

Classification of biogas plants:

Biogas plants are broadly classified as

1. Continuous and batch types-as per the process.

2. Dome and drum type-shape

3. Different types of drum type

Continuous plant

► Continuous plants are fed and emptied continuously.

► They empty automatically through the overflow whenever new material is filled in. Therefore, the substrate must be fluid and homogeneous.

► Continuous plants are suitable for rural households as the necessary work fits well into the daily routine.

► Gas production is constant, and higher than in batch plants. Today, nearly all biogas plants are operating on a continuous mode. Continuous plant:

► Single digester

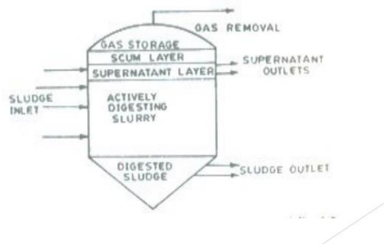
► Raw material charged regularly and the process goes on without interruption except for repair and cleaning

► Raw material is self buffered- thoroughly mixed with the digesting mass, where dilution prevents souring and biogas production is maintained.

► Continuous process may be completed in a single stage or separated into two stages.

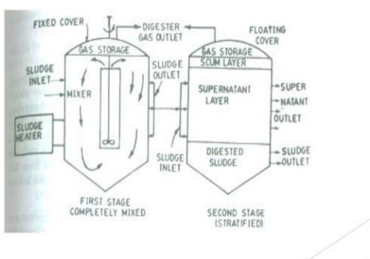
► Single stage process: Digestion of waste materials in a single chamber or digester is called single stage process, in two chambers or digester is called multi stage process. Entire process of conversion of complex organic compounds into biogas is completed in a single chamber.

SINGLE STAGE CONTINUOUS PLANT



► Double stage process: In double stage process, acidogenic and methanogenic stage are physically separated into two chambers. Thus, the first stage of acid production is carried out in a separate chamber and only diluted acids are fed into the second chamber where bio-methanation takes place.

Two stage digestion process



Batch Plants:

► Feeding is between intervals, the plant is emptied once the process of digestion is complete.

► Battery of digesters are charged along with lime and urea etc, and allowed to produce gas for 40-50 days.

► These are charged and emptied one by one in a synchronous manner which maintains a regular supply of the gas through a common gas holder.

► Freshly charged digester is aerated for a few days after which it is closed to atmosphere.

► Biogas supply may be utilised after 8-10 days.

► Expensive –unless operated on large scale.

► Batch plants are filled and then emptied completely after a fixed retention time.

► Each design and each fermentation material is suitable for batch filling, but batch plants require high labour input.

► As a major disadvantage, their gas-output is not steady.

Floating gas holder type of biogas plant:

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

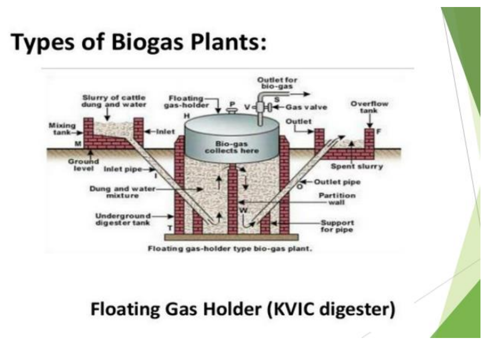
Construction

► Mixing Tank - present above the ground level.

► Digester tank - Deep underground well-like structure. It is divided into two chambers by a partition wall in between.

► It has two long cement pipes: i) Inlet pipe opening into the inlet chamber for introduction of slurry.
► ii) Outlet pipe opening into the overflow tank for removal of spent slurry. Gas holder - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.

► Over flow tank - Present above the ground level.



► Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank.

► The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe.

► The plant is left unused for about 2 months and introduction of more slurry is stopped.

► During this period, anaerobic fermentation of biomass -produces biogas in the digester.

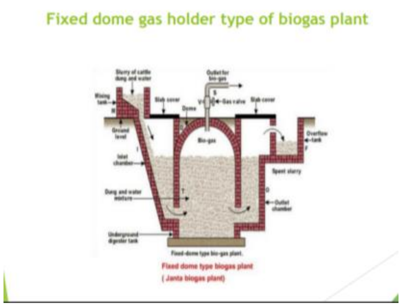
► Biogas being lighter rises up- starts collecting in the gas holder. The gas holdermoving up. The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry.

► The spent slurry is now forced into the outlet chamber from the top of the inlet chamber.

► When the outlet chamber gets filled with the spent slurry, the excess - outlet pipe into the overflow tank. This is later used as manure for plants.

► The gas valve - gas outlet is opened- supply of biogas. continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

Fixed dome gas holder type of biogas plant:



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

► Mixing tank present above the ground level.

► Inlet chamber: The mixing tank opens underground into a sloping inlet chamber.

► Digester: The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling. The ceiling of the digester has an outlet with a valve for the supply of biogas.

► Outlet chamber: The digester opens from below into an outlet chamber.

► Overflow tank: The outlet chamber opens from the top into a small over flow tank.

Slurry-biomass are mixed with an equal quantity of water in the mixing tank.

► The slurry is fed into the digester through the inlet chamber.

► When the digester is partially filled with the slurry-slurry is stopped and the plant is left unused for about 2 months.

► During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water. As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.

► As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber. From the outlet chamber, the spent slurry overflows into the overflow tank. The spent slurry is manually removed from the overflow tank used manure.

► The gas valve connected to a system of pipelines is opened when a supply of biogas is required.

► To obtain a continuous supply of biogas, a functioning plant can be fed continuously –slurry.

Advantages of biogas plants:

1.Reduces burden on forests and fossil fuels

2.Produces a clean fuel - helps in controlling air pollution

3.Provides nutrient rich manure for plants

4. Controls water pollution by decomposing sewage, animal dung and human excreta.

Limitations of biogas plants:

✓Initial cost of installation of the plant is high.

✓Number of cattle owned by an average family of farmers is inadequate to feed a biogas plant.

Factors affecting bio digestion:

1. **Temperature**:

 - The temperature affects how well biogas is produced.

 - Different ranges include thermophilic (hot), mesophilic (moderate), and psychrophilic (cold).

 - Most efficient temperature for biogas production is around 32-35°C.

2. **pH (Acidity)**:

 - pH levels are crucial for the process.

 - The best pH range for biogas production is around 6.5-7.2.

3. **Feedstock (What You Put In)**:

 - Different organic materials can be used, like food waste, manure, or plant matter.

 - The type of material, its composition, and how easy it breaks down affect biogas production.

4. **BOD and COD (Organic Content)**:

 - These measures show how much organic matter is in the waste.

 - More organic matter means more biogas potential.

5. **C/N Ratio (Carbon to Nitrogen Ratio)**:

 - Balance between carbon and nitrogen is important.

 - Too high or too low a ratio can affect biogas production.

6. **Solid Content and Particle Size**:

 - The amount of solid material and its size influence biogas production.

 - Smaller particles and a moderate solid content are better.

7. **Moisture Content**:

 - The right level of moisture is essential for biogas production.

 - Typically, 60-80% moisture content works well.

8. **Organic Loading Rate (How Much You Feed the Digester)**:

 - The amount of organic material added to the digester affects biogas production.

- The rate should be balanced for best results.

9. **Hydraulic Retention Time (HRT)**:

   - It's the time the waste stays in the digester.

   - The right HRT depends on factors like temperature and type of waste.

10. **Co-Digestion (Mixing Different Types of Waste)**:

   - Combining different types of waste materials can improve biogas production.

   - It helps maintain the right balance for efficient digestion.

These factors play a role in how much biogas is produced from organic waste.

Cofiring and Dry Process:

Cofiring:

1. **Cofiring Definition**: Cofiring is the process of burning a mixture of biogas and another fuel source, such as natural gas or biomass, in the same combustion system to generate energy.

2. **Sustainable Energy**: Cofiring promotes sustainable energy by using biogas, a renewable resource, alongside conventional fuels. This reduces greenhouse gas emissions and dependence on non-renewable energy sources.

3. **Efficiency**: Cofiring can improve the efficiency of power plants by utilizing biogas, which may not be available in large quantities on its own, to complement traditional fuels.

4. **Emission Reduction**: It helps reduce emissions of greenhouse gases and pollutants compared to burning fossil fuels alone.

5. **Flexibility**: Cofiring offers flexibility in using different energy sources, making it easier to transition to cleaner and more sustainable energy production.

Dry Processing:

1. **Dry Processing Definition**: Dry processing in biogas production involves the use of solid-state fermentation or digestion, where the feedstock (organic waste) is in a dry or semi-dry form.

2. **Feedstock Types**: Dry processing can use a wide range of feedstock, including agricultural residues, food waste, and organic materials with low moisture content.

3. **Lower Water Content**: Unlike wet or liquid-based digestion, dry processing requires less water, making it more water-efficient.

4. **Reduced Storage and Transportation Costs**: Solid-state digestion reduces the need for storing and transporting liquid slurry, which can be expensive.

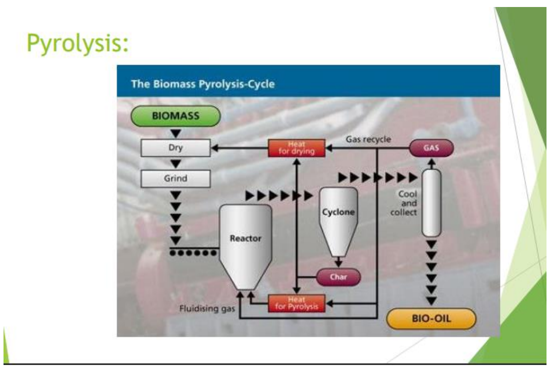
5. **Biogas Yield**: While dry processing can produce biogas, it generally has a slower digestion rate and lower biogas yield compared to wet digestion methods. However, it's a viable option for specific types of feedstock.

6. **Solid Digestate**: Dry processing generates solid digestate, which can be used as a valuable soil conditioner or fertilizer.

7. **Sustainability**: Dry processing can contribute to sustainable waste management and energy production, especially for feedstock types that are not well-suited for wet digestion.

Both cofiring and dry processing play roles in sustainable energy production and biogas utilization, offering solutions for using organic waste and reducing the environmental impact of energy generation.

Pyrolysis:



► Biomass can be converted into gases, liquids and solids through Pyrolysis at temperatures of 500-1000^{o}C by heating in a closed vessel in the absence of oxygen.

► Pyrolytic destructive distillation wood used to recover methanol, acetic acid, turpentine and charcoal.
► It can process all forms of organic materials, including rubber and plastics.

► The gases produced are a mixture of nitrogen, methane, carbondioxide, carbon monoxide and other hydrocarbons.

► Liquid produced are oil like materials and

► Solid are similar to charcoal.

Pyrolysis:

1. **Definition**: Pyrolysis is a process where organic materials, like biomass, are heated without oxygen.

2. **Temperature**: It's typically done at temperatures above 500°C to break down complex organic compounds.

3. **No Combustion**: Because there's no oxygen, the biomass doesn't burn; instead, it turns into gases, bio-char, and bio-oil.

4. **Products**: The result of pyrolysis includes bio-oil (liquid), bio-char (solid), and syngas (gaseous).

5. **Factors**: The amount of each product depends on factors like the temperature and how fast the heating happens.

6. **Bio-oil**: Bio-oil is a mixture of organic compounds. It's less valuable as fuel compared to petroleum, but it can be used for heating or further refined into renewable fuels.

Uses:

7. **Transport**: Bio-oil is denser than biomass, making it easier and cheaper to transport.

8. **Distributed Processing**: Small pyrolysis units on farms can convert biomass to bio-oil, which can then be transported to central locations for further refining.

9. **Bio-Char**: Bio-char, another product of pyrolysis, can be used to enhance soil quality. It helps the soil retain water and nutrients, reducing pollution and erosion.

10. **Carbon Sequestration**: Using bio-char in soil can also help capture carbon, contributing to efforts to combat climate change.

In simple terms, pyrolysis is a way to convert organic material into useful products like bio-oil and bio-char, which can be used for fuel and improving soil.

Types of Biomass Fuels:

There is different type of Biomass.

1.Woody Fuels. Wood wastes of all types make excellent biomass fuels and can be used in a wide variety of biomass technologies.

2.Forestry Residues.

3.Mill Residues.

4.Agricultural Residues.

5.Urban Wood and Yard Wastes.

6.Dedicated Biomass Crops.

7.Chemical Recovery Fuels.

8.Animal Wastes.

Biomass Power Plants:

1. **Capacity**: In 2009, the United States had about 12 GW of biomass power generation, which was 1.1% of its total capacity. Globally, there's around 50 GW of biomass power capacity.

2. **Plant Sizes**: Most biomass power plants are relatively small, often under 100 MW, and are mainly found in the United States and Europe.

3. **Future Growth**: Biomass power capacity is expected to increase in the coming years.

Conversion Methods:

4. **Combustion**: Currently, the primary way to convert biomass into electricity is through combustion, which is like burning the biomass to generate power, similar to coal-fired power plants.

5. **Other Methods**: There are alternative methods like biomass gasification (converting biomass into a combustible gas) and anaerobic digestion (forming methane). However, these methods are not as widely used or commercially proven as combustion.

Operation:

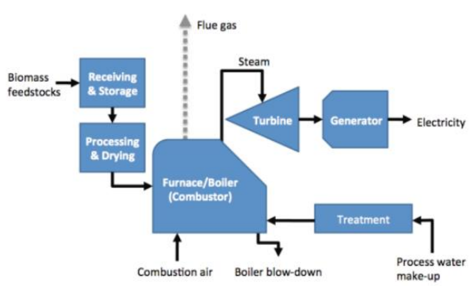
6. **Similarity to Coal**: Biomass power plants work much like coal-fired power plants. They store biomass and preprocess it, then burn it in a combustor to generate steam that powers a turbine and generator.

7. **Co-Firing**: Some power plants can use both coal and biomass as fuel, which can be cost-effective because coal is denser and easier to transport over long distances.

8. **Plant Size**: Coal power plants are often much larger and more efficient than biomass power plants due to coal's higher energy density.

9. **Scalability**: Biomass power plants can vary in size and fuel mix, and there are no strict limits on plant size in the modeling systems used.

In simple terms, biomass power plants convert organic material into electricity. The most common method is burning the biomass, similar to coal plants. There are other methods, but they are not as widely used. Biomass plants are typically smaller than coal plants, but they can still be effective for generating power.



Biogas Digester Design:

- A study focused on designing and building a 2.15 m3 pilot plastic biogas digester for generating biogas.

- The design considered the size of the digester, inlet and outlet chambers, and cover plate.

- The digester's digestion chamber was made from high-density polyethylene (HDPE) plastic, while the inlet and outlet chambers used bricks and cement.

- The goal was to overcome issues like leakage seen in previous designs.

- A ventilation test was conducted to ensure the digester doesn't leak.

Biogas Production:

- Biogas is produced through a process called anaerobic digestion, which involves microbes breaking down organic materials in the absence of oxygen.

- It results in biogas composed mainly of methane (CH_4) and carbon dioxide (CO_2), which can be used for energy purposes like cooking.

Challenges in Biogas Digesters:

- Traditional biogas digesters are made from bricks, cement, metals, or reinforced concrete and may experience issues like leakage, UV radiation damage, and corrosion.

- These traditional materials can be expensive due to labor and materials costs.

Innovative Approach:

- The study used a cost-effective approach by constructing the digestion chamber from high-density polyethylene (HDPE) plastic and using bricks/cement for the inlet and outlet chambers.

- HDPE plastic was chosen for its non-corrosive, insulating, cost-effective, and easy-to-maintain properties.

Unique Aspects:

- The study introduced the use of composite materials (plastic and bricks/cement) for the biogas digester.

- A ventilation test was performed to ensure the digester doesn't leak, which can improve biogas production.

Importance:

- This innovative approach can provide a more affordable and efficient way to construct biogas digesters, making biogas technology more accessible and reliable.

- The study contributes to the knowledge and development of biogas technology.