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MODELING FOR THE ENERGY POTENTIAL OF BIOGAS POWER PLANTS IN NATIONAL CAPITAL TERRITORY

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Abstract
Biogas is a renewable energy source which is being researched and widely developed as a future alternative energy source that is economical, sustainable, and environmentally friendly. Under the scheme for National Capital Territory, we used 150 cows for example where the dung from the cows is processed. Biogas production in every day which is 54 m^3 or equivalent to 54,000 liters. Biogas can be used as a generating system capable of producing energy of 540 kWh each day with a power of 540 kW. The generator system in this study divided into 2 parts, namely first, a simple generator system (Digester-biogas-Genset 30000W-electricity biogas) which is assumed to operate for 24 hours a day with the energy output from this biogas power plant is 613.8 kWh per day. Generating system, the second is a generator system using HOMER (Thermal-Boiler-Generator Bio 2 kW-Converter of 10 kW-electric load) with an energy output of 613.8 kWh per day. In realizing an efficient biogas-based generating system, so in this study use HOMER software to optimize generator size and value economic power plant with coverage in the form of net present cost (NPC) of Rs.2,50,000.00 and the cost of Energy (COE) of Rs. 1.57 per unit
Keywords: Anaerobic, Biogas, Digester, Energy, Homer

1. Introduction

Energy has a very important role in the activities of human life; the increasing use of energy has become the world's talk, especially in India. Some of the energy which is used by the Indian people today comes from hydro, solar, and fossil fuels, namely petroleum, coal, and gas. Based on India's Energy outlook, the national energy demand continues to increase along with economic growth, populations, energy costs, and governmental policies. An average Gross Domestic Product (GDP) growth rate of 4.14% per year and the population growth rate of 0.78% per year during 2016-2020, the growth rate for the final energy demand is approx. 2.3% per year as per International Energy Agency. “The total primary energy consumption from coal (452.2 Mtoe; 55.88%), crude oil (239.1 Mtoe; 29.55%), natural gas (49.9 Mtoe; 6.17%), nuclear energy (8.8 Mtoe; 1.09%), hydroelectricity (31.6 Mtoe; 3.91%) and renewable power (27.5 Mtoe; 3.40%) is 809.2 Mtoe (excluding traditional biomass use) in the calendar year 2018.” As time goes by, fossil fuels because they are classified as non-renewable energy will sooner or later be depleted or their availability crisis; Based on statistical data on New Renewable Energy and Energy Conservation by International Energy Agency, India has a new and renewable energy source, namely bio-energy with a potential of 18,000 MW with an installed on-grid system capacity of 220.8 MW, of which only a small amount is still being utilized. As a South Asian country, India has abundant bio-energy as energy potential that can be used as renewable energy source to replace fossil energy which is still widely used today, as well as to maintain national energy security [1-2].

Delhi is the National Capital Territory in India that has installed electrical energy capacity from several power plants in several locations generates approx. 2,000 MW of electricity. The power plant used to supply electrical energy by Gas only. Whereas, 54MW of energy is generated from Bio-Waste from 5250 ton of per day waste; The need for electrical energy in Delhi in 2021 is 2,160.30 MW consisting of the government sector of 63.56 MW, the household sector of 1,330.85 MW, the industrial sector of 130.05 MW, the business sector of 508.15 MW, the social sector is 91.31 MW, the public lighting sector is 35.36 MW. With such a large energy demand, Delhi is still experiencing a deficit of 47.32 MW of electrical energy. The impact of the deficit in electrical energy is the occurrence of rotating blackouts in the National Capital Region of Delhi. Utilizing new and renewable energy to overcome the deficit in electrical energy in the Delhi is the best way. In addition to fulfilling energy needs, the use of new and renewable energy can also reduce environmental pollution caused by the use of fossil energy. There is still a lot of potential from biomass in the National Capital Region of Delhi that has not been utilized to overcome the problem of energy in electricity, one of the abundant biomass potentials that are still underutilized is solid waste or garbage [3]. The National Capital Region of Delhi has fertile soils and wild plants that are easily available. With this geographic condition, it is easy to develop the livestock sector. Based on data from Animal Husbandry Statistics Division, livestock in Delhi has a population consisting of 6 types of animals, namely cows, buffaloes, dairy cows, goats, sheep, and pigs approx. 16,00,000 heads, and continued to increase in 2021 to 16,34,128 heads. Of the livestock population, the cattle population has the highest number compared to other animals [4-5].

Previous research has examined the potential for cow dung to be used as a source of power generation, but this study is still a hypothesis, so the test is less accurate in actual conditions. The biogas production process using the anaerobic digestion method made from cow dung, it goes through several stages, each of which has erratic changes that can affect the production of biogas produced [6-7]. In this study, it has also analyzed the economic value that gets positive values so that the design is feasible to be realized. The process of forming biogas has several factors that can affect the production of biogas, namely the temperature in the digester, the growth of microorganisms, inhibiting agents, etc. Previous research that examined cow dung as a raw material for power plants still used potential based calculations, without examining the factors that influence the production of biogas. So that the results obtained are not accurate. A study to calculate the factors that influence the formation of biogas is very necessary because in the process of a biogas power- plant the factors that influence it are very much taken into account in order to obtain optimal results [8-9]. Overcoming the shortcomings in calculations to predict biogas production in previous research has been done by making a mathematical model of each stage of biogas production as a differential and algebraic equation that is simulated in MATLAB software. Modeling is done to make it easier to optimize each process and to control each biogas formation process. In the simulation process, the performance of all stages of biogas that is being in production can be seen so that estimating the biogas production that will be produced from the whole process is more accurate and can optimize the results of biogas production without disturbing the ongoing anaerobic digestion process activities (trial and error).[10]

2. Literature Review

2.1 Related research

Before conducting this research, it is necessary to conduct a literature study which aims to find references and research relevant to the research to be carried out. These references are obtained from journals, books or papers related to this research. Research on the biogas power plant with a balloon type digester, this study analyzes the potential of cow dung to generate electricity using a prototype. The balloon type digester is used for the reason that it is simple to install, easy to assemble and assemble and the price is relatively cheap. The results obtained from the prototype are a mixture of cow dung and water with a 1: 1 ratio of 624 liters of gas can be produced from a plastic drum capable of turning on electricity for 35 minutes with a power capacity of 700 watts [11-13].

Research on the modeling of biogas production in batch type reactors using the Hamming predictor-corrector method, in this study analyzes a model of the biogas production process with a batch type digester. The amount of biogas which is produced from biogas production process was predicted using a model that is commonly used in the anerobic digestion process, namely Anaerobic Digestion Model No. 1 (ADM1) [14]. The ADM1 model is transformed into a system of differential equations and is solved using the Hamming predictor-corrector method. This method is a linear method from the previous points. The simulation of biogas production was carried out for 120 hours by defining the initial substrate concentration of 500 mgCOD / L. On the basis of simulation results, it is known that the maximum concentration of methane obtained at the end of the simulation is 417.48 mgCOD / L. In addition, the growth of microorganisms that digest glucose is faster than the growth of other microorganisms. The simulation results show II-3 that the initial concentration of glucose and microorganisms is very influential on the concentration of methane produced. [15] Research on the simulation of biogas from dairy cow dung, in this study analyzed a simulation model on Matlab for biogas production from cow dung on a dairy farm. Input in this study uses dairy cow dung which is diluted with 25% water after filtering with the output of high-quality fertilizer and biogas consisting of 70-73% methane that is produced from the diluted liquid fraction of dairy cow dung. The model in this study made several modifications based on the hill model to simulate the production of biogas methane in anaerobic digestion. The modified hill model is simulated in Matlab using the eulerian and ode solver methods to obtain changes in methane gas over time. And this study also uses the Matlab editor function block Simulink. The three simulators provide the same response curve with different simulation times [16,17].

Research on the modeling and anaerobic simulation of livestock manure into biogas, this study creates and analyzes a model of biogas production from livestock manure which aims to develop a method for testing the digestion of fertilizers and wastewater for biogas. The model made several additions from the basic anaerobic digestion model no 1 (ADM1), modeling was carried out using Matlab by implementing all the equations and parameters. guidelines to simulate biogas production in certain species [18]. Research on the modeling and simulation of biogas production based on anaerobic digestion of energy crops and manure, this study makes an anaerobic digestion model to improve the accuracy of predicting the dynamics of anaerobic digestion for plants and manure. The model is calibrated using an experimental dataset in a batch process which is mono-fermented corn amylases. Furthermore, the concept is being validated by experimental data in which corn silage has being digested and tested for twenty-eight days in a continuous pilot-scale biogas fermented at uninterrupted raw material loads. The resulting model accurately predicts the flow rate dynamics of CH_4 (methane) and the carboxylic acid concentration. After that, the II-4 calibration model was carried out using ADM1 (Anaerobic Digestion Model no 1) for silage grass and livestock manure. The calibrated model precisely predicts anaerobic digestion from subtract for biogas and methane flow rates, and volumetric concentration dynamics of biomass, carboxylic acid chains, inorganic carbon matter, organic matters, and the pH values. Process modeling in this research uses Matlab [19]. Based on several studies that have been carried out for the calculation of biogas production using mathematical equations based on its potential only and calculated manually; Several supporting studies have carried out the calculation of biogas production by adapting the actual conditions that are implemented in each biogas formation process into a differential equation that is solved using the Matlab simulator. However, this research still focuses on calculating biogas production. The author offers a modeling and simulation in producing biogas and the potential for electrical energy by utilizing cow dung waste. The simulation in this study not only examines the aspect of biogas production, but also involves the potential of electrical energy generated from biogas as well as analyzing the technical and economic aspects. By using modeling and simulation, the author can experiment in complex situations, save money, save time and focus on the important characteristics of the problem compared to the manual method

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(trial-and-error) is less effective, and time consuming. Apart from that, modeling and simulation are also useful for analyzing system performance.

2.2 *Cow Manure*

2.2.1 Definition of Cow Manure

Cow manure is the result of digestion in the form of waste from cows which varies in color from green to black, depending on the food eaten by the cow. After exposure to air, the color of cow dung tends to darken. Cow manure is waste from the digestive process of cattle which is solid and in the process of its disposal it is often mixed with urine and gases, such as methane and ammonia. Nutrient content in cow dung varies depending on the state of the production level, type, amount of feed consumption, and individual livestock [9, 20, 21]; The composition of cow dung that has generally been studied can be seen in table 2.1.

Table 2.1: Composition of Cow Manure.

Compound	Percentage
Hemicelluloses	18.6%
Cellulose	25.20%
Lignin	20.20%
Protein	14.90%
Dust	13%

Specifications of cow dung produced from cows weighing 635 kg, the amount Total solids (TS) can generally also be estimated to be 10-15% of the initial impurity mass. Meanwhile, the number of volatile solids can be estimated at 8-10% of the mass of impurities early [22-24]. The specification of cow manure with a cow weight 636Kg can be seen in table 2.2.

Table 2.2: Cow Manure specifications with a total weight of 635 kg

Specifications	Cows with a weightofs635kg
Dirt	S50.8kgs
Manure	S51.1literss
Total solids (total solid, ts)	S6.35kgs
Volatile solids (volatile solid, vs)	S5.4kgs

2.2.2 Potential for Cow Manure

Waste Cattle farming in India has enormous potential which is spread over several regions. Cattle breeding business requires ideal geographical conditions for the survival of cows. Weather in Delhi is good for cattle farming. Cow manure is a potential raw material for making biogas because it contains starch and lignocelluloses. Usually, cow dung is used as fertilizer and the rest is used to produce methane gas using anaerobic processes. Cow manure is a biomass that contains carbohydrates, protein and fat. Biomass that contains high carbohydrates will produce low methane gas and high CO_2, when compared to biomass that contains high amounts of protein and fat. In theory, the methane production resulting from carbohydrates, protein, and fat is 0.37; 1.0; 0.58 m^3 CH_4 per kg of organic dry matter. Cow manure contains the three elements of organic matter, so it is considered more effective to convert into methane gas. One way to determine the appropriate organic material to be used as an input for the biogas system is by knowing the ratio of carbon (C) and nitrogen (N) or what is called the C / N ratio. Several experiments that have been carried out by ISAT show that the activity of methanogenic bacteria will be best at a C / N ratio of around 8-20 [25-27]

2.2.3 Biogas

Biogas is a gas produced through anaerobic processes (without oxygen) where the molecules are complex carbon contained in organic matter degraded into molecules with simpler structures including CH_4 and CO_2. India mostly uses biogas for cooking or heating, whereas biogas which contains the main ingredient methane (CH_4) can be used as fuel in power plants because it has a fairly large heating value, which is 23,880 BTU / lbm [28]. Biogas is produced when microorganisms, especially bacteria, reduce levels of organic matter without air or anaerobic conditions. Compared to air, biogas is about 20% lighter and has a flame temperature between 655° C to 750° C. Biogas is a gas that is odorless, has no color and burns with a blue embers color similar to liquid petroleum gas (LPG). Biogas burns with an efficiency of 60% in the conventional biogas furnace and a calorific value of 20 MJ / Nm^3. The volume of biogas is usually expressed in normal units of meters per cubic (Nm^3), namely the volume of gas at 0oC and atmospheric pressure. Biogas consists of 50% to 75% methane (CH_4), 20% to 44% carbon dioxide (CO_2) and small amounts of other substances. The biogas composition is as follows [29-33].

The composition of biogas can be seen in table 2.3.

Table 2.3: Compositional Biogas

Concentration	Formulas	Elements (Volume %)
Methane	CH_4	50-75
Carbon dioxide	$C0_2$	25-45
Water Vapor	H_20	2-7
Oxygen	O_2	<2
Nitrogen	N_2	<2
Hydrogen Fluid	H_2s	<2
Ammonia	Nh_3	<1
Hydrogen	H_2	<1

2.2.3 *Biogas formation Process*

The formation of biogas occurs based on chemical principles, namely the occurrence of fermentation of carbohydrates, fats and proteins by methane bacteria which are not mixed with air or what is called anaerobic digestion process. One gram of cellulosic material will produce 825 cm^3 of gas at atmospheric pressure. One gram of fat produces 1.25 liters of biogas at atmospheric pressure. The process of forming methane gas by anaerobic digestion involves a complex interaction of several different bacteria, protozoa, and fungi. Some of the bacteria that play a role are Bacteroides, clostridium butyrinum-coli and other intestinal bacteria. These two bacteria are the main bacteria producing methane and can live in anaerobic conditions. The fermentation process usually takes 7 to 10 days with an optimum temperature of 35°C and an optimum pH of 6.4-7.9. In general, the process of forming biogas is:

$$C_xH_yO_z + \left(x - \frac{1}{4}y - \frac{1}{2}\right)H_2O \rightarrow \left(\frac{1}{2}x - \frac{1}{8}y + \frac{1}{4}z\right)CO_2 + \left(\frac{1}{2}x - \frac{1}{8}y + \frac{1}{4}z\right)CH_4 \quad \ldots..(1)$$

In the formation of biogas, the process consists of the acid hydrolysis step (acidification), and the methanogenesis stage [33-39]. The different stages of biogas formations can be seen in figure 2.1.

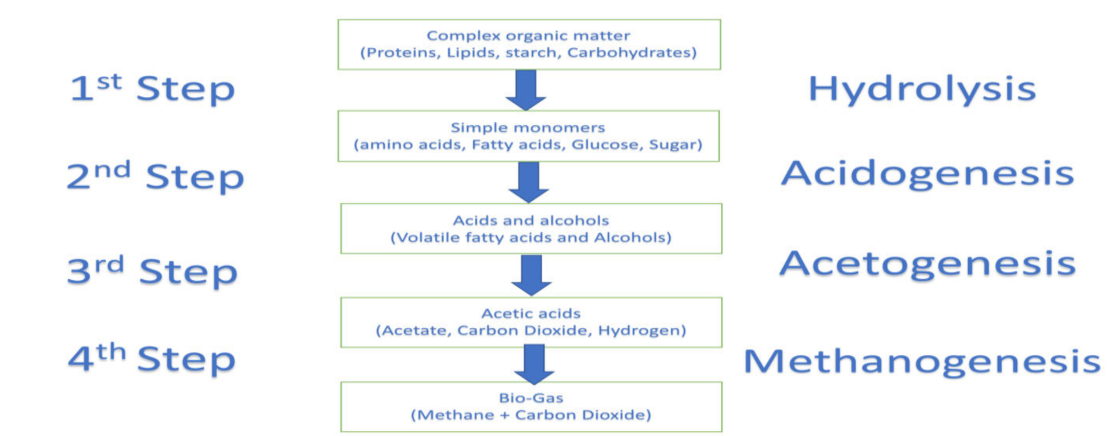

Figure 2.1: Biogas Formation Stages/Phases

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2.2.3 Hydrolysis

At this stage of hydrolysis, it is the breakdown of complex organic materials being simple, changes the structure of the polymer to the monomeric form an insoluble compound with a lighter molecular weight. Lipids turn into acids long chain fat one and glycerin, polysaccharides into sugars (mono and disaccharides), protein into amino acids and nucleic acids, into purines and purimidines. Lipid conversion occurs slowly below 20°C. The hydrolysis process requires exo-enzyme mediation excretion by fermentative bacteria. Hydrolysis of molecules is catalyzed by an extra enzyme's cells such as celluloses, lipases, proteases, etc. [33-39].

$$(C_6H_{10}O_5)\,n + nH_20 \longrightarrow n(C_6H_{12}O_6) \quad \ldots..(2)$$

Cellulose **Glucose**

2.2.4 Acidification

At this stage of acidification, the bacteria will change the polymer simply as a result hydrolysis to acetic acid (CH_3COOH), hydrogen (H_2), and carbon dioxide (CO_2). To converting into acetic acid, bacteria need oxygen and carbon contained in solution. This stage is carried out by obligate anaerobic bacteria and some of them are bacteria facultative anaerobes. These bacteria are anaerobic bacteria that can grow in acidic conditions namely pH 5.5-6.5 which works optimally at a temperature of about 30°C. Acetic acid very much needed which will then be used by microorganisms for formation methane gas. In addition, mixing is necessary for an even metabolism with a water concentration of > 60% [33-39].

$$C_6H_{10}O_5)\,n + nH_20 \longrightarrow (CH_3CHOHCOOH) \quad \ldots..(3)$$

Glucose **Lactic Acid**

$$(C_6H_{12}O_6)\,n + nH_20 \rightarrow (CH_3\,CH_2CH_2COOH) + CO_2 + H_2 \quad \ldots..(4)$$

Glucose **Butyric Acid**

$$(C_6H_{12}O_6)\,n + nH_20 \longrightarrow (CH_3\,CH_2OH) + CO_2 \quad \ldots..(5)$$

Glucose **Ethanol**

2.2.5 Acetogenesis

This acetogenesis stage is an advanced stage of the acidification stage, at this stage about 79% of COD is converted into acetic acid. The formation of acetate depends on the oxidation conditions of the organic matter which are usually accompanied by the formation of CO_2 and hydrogen. Ethanol, butyric acid and lactic acid are converted into acetic acid by acetogenetic bacteria. The reaction is as follows [33-39]:

$$4H_2 + C0_2 \longrightarrow 2H2O + CH4 \quad \ldots..(6)$$
$$CH3CH2OH + C0_2 \longrightarrow CH3COOH + CH4$$
$$CH3COOH + C0_2 \longrightarrow C0_2 + CH4$$
$$CH3CH2COOH + 2H2 + CO_2 \longrightarrow CH3COOH + CH4$$

2.2.6 Methanogenesis

This stage of methanogenesis is the stage where methane and carbon are formed dioxide. Methane is produced from acetic acid or from the reduction of carbon dioxide by bacteria acetotropic and hydrogenotropic using hydrogen. Methane producing bacteria have appropriate atmospheric conditions due to the process of acid-producing bacteria. That acid the resulting acid-forming bacteria will be used for methane-producing bacteria. On at this stage low molecular weight compounds are decomposed by methanogenetic bacteria be a compound with a high molecular weight [33-39].

2.2.7 Biogas Formation Process Parameters

The factors that influence microorganisms are very important in determining speed of the biogas formation process, includes the temperature, pH, nutrition, concentration solid, volatile solid, substrate concentration, time of digestion, stirring of ingredients organic as well as pressure influences. The following is a discussion of these factors [33-39]:

1. Temperature

There are three conditions for anaerobic degasification based on the temperature of the digester, including:

i. Psychrophilic conditions: In these conditions, the digester temperature is between 10-18°C, and liquid organic waste digestified for 13-52 days.

ii. Mesophilic conditions: In these conditions, the temperature of the digester is between 20-45°C, and liquid organic waste digestified for 18-28 days. Compared to the digester in thermophilic condition, in mesophilic conditions, the operation is

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easier, but the biogas produced less and the volume of the digester is larger.

iii. Thermophilic conditions: In this condition, the temperature of the digester is between 50-70°C, and liquid organic waste digestified for 11-17 days. In thermophilic conditions it produces a lot biogas, but the investment costs are high and the operation is complicated. The graph representative anaerobic digestions temperature can be seen in figure 2.2.

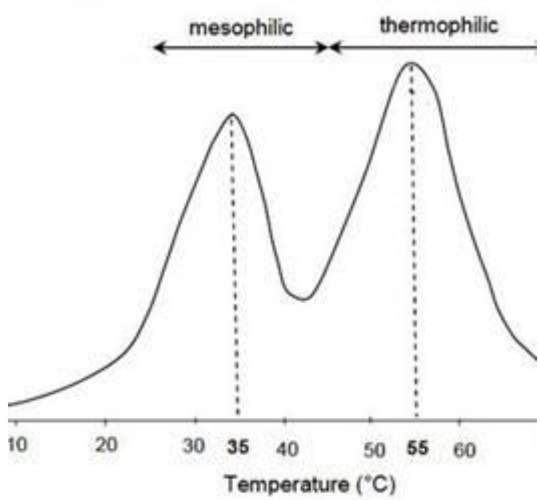

Figure 2.2: Graph Representative Anaerobic Digestion Temperature

The optimal temperature for anaerobic digestion is temperature 30-35° C. These temperature range combines the best situations for bacterial growth and production of methane gas in the digester for a long-time short process. At 35° C, it will digest the mass of the material same will be digested twice as fast as a temperature of 15° C and produces nearly 15 times as much gas at the same processing time. As with the biological process, the methane gas production increases for each increase in temperature of 11-15° C. In other words, the number the total amount of gas which is produced in a fixed amount of material increases with each other with increasing temperature [33-39].

iv. Degree of acidity (pH): In anaerobic decomposition, pH is a factor that affects microbes so that if the pH in the digester is not in accordance with the recommended pH range then the microbes cannot grow to the maximum. It can even cause microbial death which in turn will inhibit methane gas production. Anaerobic bacteria require an optimal pH between 6.2 - 7.6, but that is best1 is 6.6 - 7. At first the media has a pH of ± 6 then it rises up to 7.5. If the pH is smaller or greater, it will have toxic properties against methanogenic bacteria. When the anaerobic process is already on its way towards the formation of biogas, the pH ranges from 7-7.8. PH control is carried out naturally by the NH_4^+ and HCO_3^- ions. These ions will play a role in determining the pH value [33-39].

v. Solids Concentration Factor (Total Solid Content / TS): Total solid content is the amount of solid material present in waste in organic material during the digester process occurs, which indicates the rate of destruction / decomposition of solid organic waste materials. Ideal concentration solids for producing biogas are 7-9% dry content, this condition can make the anaerobic digester process run well. It should be noted that TS concentrations should be kept at no more than 15% as it will inhibits metabolism. When introducing organic material into the biodigester must be added with a certain amount of water, the function of the water here is in addition to maintains TS <15%, also to simplify the mixing process, the process of flowing organic material into the biodigester and for facilitates1 that the gas stream formed at the bottom can flow to the passage over the biodigester [33-39].

vi. Volatile Solids (VS): VS or volatile solids is part of the TS solids that change into the gas phase at the acidification and methanogenesis stages as in the process fermentation of organic waste. In laboratory scale testing, the current weight is part the solid organic material is burnt out in the gasification process at a temperature of 538 °C called volatile solid. The following is a table of volatile solids (VS) components. The volatile solid components can be seen in table 2.4

Table 2.4 Volatile Solid Components

Component	TS%
Cellulose	31
Hemicelluloses	12.2
Lignin	12
Kanji	12.4
Protein	12.6

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Ether	2,6
Ammonia	0.5
Acid	0.1
Total	**83.4**

It can be seen from the table above that the components of volatile solids (VS) generally consist of cellulose, hemicellulose, lignin, starch, protein, ether, ammonia and acids. The size of VS is about 83.4% TS. Taking into account that the TS from animal feces is not far from 10%, it is necessary to add some animal food waste in the biodigester, apart from containing high C / N it also has the potential for high biogas production because it contains high TS [33-39].

vii. Duration of the Digestion Process: The duration of the digestion process (Hydraulic Retention Time) or HRT is the amount of time (in days) the digestion process in the anaerobic tank counts from the entry of organic matter to the initial process of forming biogas in the anaerobic digester. From the biogas generation as a whole HRT covers 70-80% of the total time. The total time of HRT depends on the type of organic material and the treatment of organic matter before the digestion / digester process is carried out. If too much volume of material is inserted (overload) it results in the filling time being too short, the raw material will be pushed out while gas is still produced in small quantities.

viii. Carbon Nitrogen (C / N) Ratio Anaerobic processes will be optimal if given food ingredients containing carbon and nitrogen simultaneously. Carbon is needed to supply energy while nitrogen is needed to form the structure of bacterial cells. The C / N ratio shows the ratio of the sum of the two elements. For materials that have a carbon amount of 15 times the amount of nitrogen will have a C / N ratio of 15 to 1. The C / N ratio with a value of 30 (C / N = 30/1 or carbon 30 times the amount of nitrogen) is a digestion process at an optimum level, if other conditions also support. The process will run slowly if there is too much carbon, because nitrogen will run out first. Conversely, if there is too much nitrogen (low C / N ratio; for example, 30/15) then the carbon will run out first and the fermentation process will stop. One study showed that the metabolic activities of methanogenic bacteria would be optimal at the C / N ratio of 8-20 [40]. The following is a table showing the C / N ratio of some organic materials in common use:

ix. Volatile Solids (VS): VS or volatile solids is part of the TS solids that change into the gas phase at the acidification and methanogenesis stages as in the process fermentation of organic waste. In laboratory scale testing, the current weight is part the solid organic material is burnt out in the gasification process at a temperature of 538 °C called volatile solid. The following is a table of volatile solids (VS) components. The C/N ratio of organic materials can be seen in table 2.5.

Table 2.5 C/N Ratio of Organic Materials

RAWH **MATERIAL**	**C/N**H **RATIO**
Human Decoration	8
Goat Dung	121
Sheep Dung	191
Corn Waste	601
Wheat Waste	901
Duck Waste	8
Chicken Poop	101
Pig Dung	181
Cow Dung	241
Dirt Gajah	43
Rice Waste	7
Saw Dust	2

x. Stirring of Organic Materials: Stirring is very beneficial for the ingredients in the anaerobic digester, which provides the opportunity for the material to remain mixed with bacteria and to maintain an even temperature throughout the digester. With stirring, it will minimize the potential for material which is settling at the bottom of digester and the concentration is firmly distributed, and the potential for all materials to undergo an anaerobic fermentation process is greater. In large digesters the mixing system is very important. The purpose of stirring is to keep the solid material away from settling on the bottom of the digester. In addition, stirring can facilitate the release of gas produced by bacteria to the biogas reservoir [33-39]. Effect of Pressure has an important role, the higher the pressure in the digester, the lower the biogas production in the digester, especially in the hydrolysis and acidification processes. The pressure is maintained between 1.15-1.2 bar in the digester [33-39].

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xi. Toxic and Inhibitor Compounds The anaerobic fermentation process of inhibiting compounds or inhibitors can be divided into 2 types, namely physical inhibitors and chemical inhibitors. Physical inhibitors are temperature and chemical inhibitors, also known as toxins, include heavy metals, antibiotics and volatile fatty acids (VFA) [33-39].

2.2.9 *Equations for the Formation of Biogas*

The following are some of the equations that determine the process of biogas formation from the fermentation of organic waste in anaerobic digester [34-36]. The theoretical decomposition time equation is the time the organic material is in the digester tank. When this process occurs, the growth of anaerobic bacteria decomposes, the process of decomposing organic matter, and stabilizes the formation of biogas to its optimum conditions. Overall, the hydraulic retention time or HRT covers 70% -80% of the total biogas formation time if the biogas formation cycle is idea, time the process of introducing organic matter directly obtains biogas as the final process without adding organic material again [33-39]. HRT can be formulated into the following equation:

$$HRT\ (days) = \frac{Volume\ Digester\ (m^3)}{Daily\ Organic\ Ingredient\ Addition\ Rate \frac{m^3}{day}} \quad \ldots..(8)$$

If the dry solid material is DM (Dry Material) or it is also called Total Solid (TS) ranges from 4-12%, so the optimum breakdown time (Optimum Retention Time) ranging from 10-151 days. If the Dry material value is greater than 1 the percentage value of material solids dries above, it means that the organic matter has a denser concentration so it takes a long-time breakdown time becomes specific, so that1 the length of time equation applies the following specific retention time or SRT:

$$SRT = \frac{Organic\ Solids\ in\ Anaerobic\ Digester\ (kg)}{Daily\ Organic\ Ingredient\ Addition\ Rate \frac{kg}{day}} \quad \ldots..(9)$$

For specific organic matter as above, the rate of addition of organic waste (Specific Loading Rate) or SLR can be seen as follows:

$$SLR = \frac{(kg\ ODM)}{m^3 - day} = \frac{Added\ Organic\ Ingredients (kg \frac{ODM}{day})}{Volume\ Digester\ (m^3)} \quad \ldots..(10)$$

The depth of the digester1 tank greatly affects the SLR value and when the parameters otherwise it can be maintained in ideal conditions, the maximum SLR values obtained range from 3-6 kg ODM / m^3-day.

- *Specific Biogas Production Equations*

Specific Biogas Production (SBP1) is a digester efficiency indicator value. Minimum conditions are 1.5 and the ideal target is 2.5.

$$SBP\ (day - 1) = \frac{Biogas\ Production\ (m^3/day)}{Volume\ Digester\ (m^3)} \quad \ldots..(11)$$

- ***Specific Methane Production Equations***

Methane Production Specific (Specific Methane Production) or SMP, relates to the total energy produced against that energy potential owned organic waste (feedstock). For organic waste from plants / seeds energy value between 0.3 - 0.4 (%) and for some types of animal waste can value up to 0.8%;

$$SMP\ (m^3\ CH_4/kg\ \ ODM (day - 1) = \frac{Volume\ Gas \left(\frac{m^3}{day}\right)}{Organic\ Material\ Addition\ Rate \left(kg\ ODM{-}day\right)} \quad \ldots..(12)$$

2.2.10 *Equations for the Forming energy to power*

The conversion of biogas energy for electric power generation can be done using several technologies, namely, gas turbines, microturbines and the Otto Cycle Engine. The need for biogas, such as gas concentration of methane and biogas pressure, load requirements and availability of available funds, are significantly affected by the choice of this technology. [41-50]. In the book Renewable energy conversion, transaction and storage by Bent Sorensen, that 1 kg of methane gas is equivalent to 6.13 x 10^7 J, while 1 kWh is equivalent with 3.6 x 10^7 Joule. For a gas density of 0.656 kg / m^3, so that is 1 m^3 methane gas produces 11.17 kWh of electricity. Then it can be assumed that the conversion potential biogas into electrical energy as follows:

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$$W = CH_4 * 11,17\, kWh \qquad \text{.....} \quad (13)$$

Where:
W = Electrical energy that can be produced (kWh)
CH_4 = Methane (M^3)
The Energy conversion from methane gas to electrical energy can be seen in table 2.6.

Table 2.6 Energy Conversion from Methane Gas to Electrical Energy

Energy Type	Energy Equivalent
1 kg of Methane Gas	$6.13 * 10^7$J
1 kWh	$3.6 * 10^6$J
1 m^3 of Density Methane Gas Methane gas is 0.656 Kg / m^3	$4.0213 * 10^7$J
1 m^3 of Methane Gas	11.17KWh

2.2.11 Equations for the Formation of Biogas

A biogas generator set or known as a biogas generator is a tool which has two main components, namely the engine and the generator that uses it biogas to produce electricity. This driving machine can be moved because of the combustion of gas fuel in it which is then used for generate mechanical energy. In the presence of mechanical energy which is coupled with generator, then there is a conversion of mechanical energy into electrical energy [51-57]. The following are the main components of a Biogas Generator:

1. Compressor is a mechanical power generator that functions to generate heat energy comes from the atmospheric air to meet the needs of the process combustion gas in the gas turbine combustion chamber. In the process of operation, the compressor is supported by tools, namely the intake air filter and the inlet gate fan.

2. Combustor is the combustion chamber which is the generator of heat energy from the process gas fuel. In the operation process, the combustor is supported by assistive tools namely gas station, control system, fuel nozzle, and igniter system (ignition system).

3. Gas Turbine is a mechanical energy generator from the heat energy conversion process into kinetic energy and further into capable mechanical energy drive the turbine shaft with mass gas burning fuel. In the operating process,

the gas turbine is supported by tools, namely a lubricating oil system, control oil system, turning motor, pony motor, starting motor, cooling water system, exhaust duck system, and turbine supervisory instrument.

3. Generator is a tool to convert mechanical energy from the turbine shaft into electrical energy.

The Biogas generator image can be seen on figure 2.3:

Figure 2.3: Biogas Generator

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2.2.12 Economic Model

- *Total Net Present Cost (NPC)*

  NPC is the value of all costing that are incurred during the lifetime, less the present value of all income earned over the lifetime. This Costs include capital costs, replacement costs, O&M costs, fuel costs, emission fines, and power purchase costs from the grid. Economic models for the HOMER simulation use the Net Present Cost (NPC) which is the total cost of installing and operating the system during the project lifetime [58-65]. Net Present Cost (NPC) itself can be calculated using the following equation:

$$NPC = Capital\ Cost + Replacement\ Cost + O\&M\ Cost + Fuel\ Cost\ + Salvage$$

  Where:
  Capital Cost = Cost of capital components (Rs)
  Replacement Cost = Cost of component replacement (Rs)
  O&M Cost = Operational and maintenance costs (Rs)
  Fuel Cost = Fuel cost (IDR)
  Salvage = Cost remaining on components (Rs)

- *Cost of Energy (COE)*

  The Cost of Energy (COE) is the costing that is being required to produce each 1 kWh of electrical energy, that is, the result of dividing the annual costs and energy production annual. The COE value of each scenario uses the following equation:

$$COE = \frac{TAC}{E_{tot,served}} \quad \text{..... (14)}$$

Where:
$E_{tot,served}$ = Total annual energy used to serve the load(kWh)
TAC = Total Annualize Cost or total annual costs incurred for generating reserves. (Rs.)

3. Proposed Methodology

This research is a simulation research that aims to find a picture through a simple or small-scale system (modeling), in the model will be made changes to variable or control to see the effect. Research simulation aims to provide an overview of the application of a technique through process modeling so that the technique will not suffer unexpected losses prior to its application. This research was conducted using a mathematical model has been made in previous studies and continues the study of research previously, namely utilizing biogas into electrical energy. The conversion process to be done through a simulation to get a model that fits the case or the problem is there. In this research will also analyze technical aspects and economy, namely NPC (Net Present Cost) and COE (Cost of Energy). In this study, it was started from a literature study related to previous research to support the research that will be carried out. Furthermore, potential data collection raw materials for cow and buffalo dung in National Capital Region, then doing modeling and simulation of biogas production from cow dung using the anaerobic method digestion. Furthermore, modeling and simulating the conversion of electrical energy from biogas production that has been obtained from previous simulations. After that he will do it analysis of electrical and economic energy resulting from the modeling process that has been done. The stages to be carried out in this research are in accordance with figure in 3.1.1 and 3.1.2:

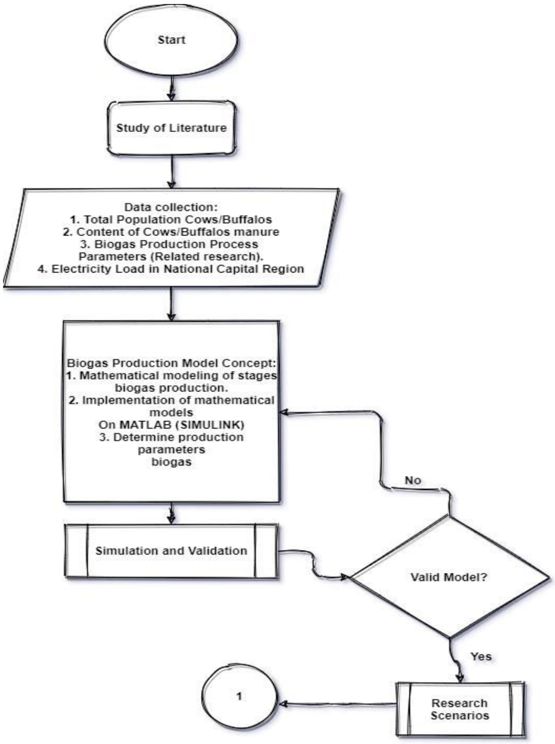

Figure 3.1.1: Research Flowchart

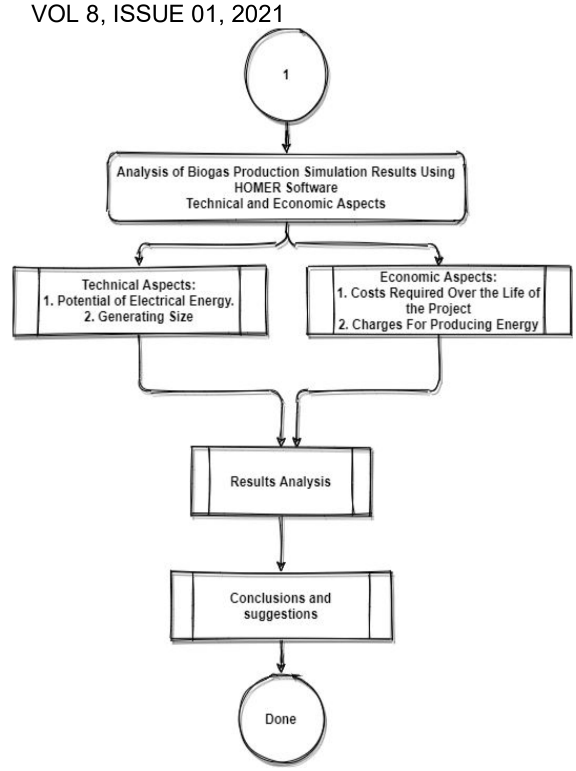

Figure 3.1.2: Research Flowchart continued

- **Literature Study**

This stage collects some of the research needed to be used references in this research, namely Final Project, Thesis, books and journals. On each Related research will be analyzed in the theory used, research methods and results. In the book you will find a theory that supports this research in better results.

- **Data Collection**

This research uses modeling and simulation methods with an approach literature using MATLAB software. Therefore, data is needed to support it this research. The data required consists of:

1. The originating statistics for the population of cattle cow and buffalo in National Capital Territory. This data is used to obtain potential cow & buffalo dung that will be produced.
2. Data on the content of cow & buffalo dung will be used as input parameters simulation of biogas production.
3. Anaerobic digestion process parameter data from related research (Experimental results and related journals)
4. National Capital Territory electricity load data which will be used to analyze technical aspects.

* Mathematical Modeling of Biogas Production Stages

This simulation research needs to determine the stages of the intermediate biogas production process other hydrolysis, acidogenesis, acetogenesis, and methanogenesis to be carried out on Matlab worksheet.

- **Hydrolysis Process Modeling**

The first stage of the anaerobic digestion process is the process of hydrolysis. The process can be interpreted as the rate of change during the anaerobic digestion process in the biodegradable concentration of volatile solids (BVS) in the reactor. This mechanism depends on the feed material type, the flow rate of the feed, the effective reactor volume and the reactor temperature. The following equation is the hydrolysis process:

Defines the portion of raw waste that can serve as a substrate:

$$Sb_{in} = B_o . Svs_{in} \quad \ldots..(15)$$

Defines the portion of the biodegradable raw material which is originally in acidic form:

$$Sv_{in} = A_f . Sb_{in} \quad \ldots..(16)$$

Mass balance of biodegradable volatile solids:

$$\frac{d(Sb)}{dt} = (Sb_{in} - Sb)\left(\frac{F_{feed}}{V}\right) + \frac{\mu_m . K_1 . X_{acid} . X_{meth}}{\frac{K_s}{S_b} + 1} \quad \ldots..(17)$$

Where:

B_o= Biodegradability Constant $\left(\frac{kg\ BVS\ /\ m^3}{kg\ VS\ /\ m^3}\right)$

A_f = Acidity Constant $\left(\frac{kg\ VFA\ /\ m^3}{kg\ BVS\ /\ m^3}\right)$

Sb = biodegradable volatile solid concentrations in (kg / m^3)

Sb_{in} = The concentration of biodegradable volatile solids in the reactor feed (kg / m^3)

F_{feed}d = Feed flow rate (m^3 / day)

K_1 = Yield factor

K_s = Half Monod constant velocity for acidogens (kg / m^3)

X_{acid} = Concentration of acidogens (kg / m^3)

X_{meth} = Methanogens concentration (kg / m^3)

μ_m= Max. growth rate of acidogens (d^{-1})

V = Reactor volume (m^3)

The maximum growth rate for methanogens that can be expressed as a function of the temperature dependence of the reaction rate using the following empiric:

$$\mu_m T_{react} = \mu_{mc} . (T_{react}) = 0.013 . T_{react} - 0.129 \quad \ldots..(18)$$

Where:

μ_{mc} : Maximum growth rate for methanogens (d $^{-1}$)

T_{react} : Reactor temperature (° C).

- **Acidogenesis Process Modeling**

The acidogenesis stage is the rate of change in the concentration of volatile fatty acids during the fermentation process. This process depends on the total concentration of VFA in the reactor (type of feed material), feed flow rate, volume1effective reactor, and reactor temperature. The following equation is the acidogenesis process:

$$\frac{d(Sv)}{dt} = (Sv_{in} - Sv)\left(\frac{F_{feed}}{V}\right) + \frac{\mu_m . K_2 . X_{acid}}{\frac{K_s}{S_b} + 1} + \frac{\mu_{mc} . K_3 . X_{meth}}{\frac{K_{sc}}{S_v} + 1} \quad \ldots..(19)$$

Where:

Sv = Total volatile fatty acid concentration in the reactor (kg / m^3)

Sv_{in} = The total volatile fatty acid concentration in the reactor feed (kg / m^3)

K_2 = Yield factor

K_3 = Yield factor related to methane gas growth rate

K_{sc} = Half Monod constant velocity for methanogenesis (kg / m^3).

- **Acetogenesis Process Modeling**

The 3rd stage of the AD process is the acetogenesis process. This process depends on the acidogens concentration, the type of feed ingredient, the feed flow rate, the effective reactor volume and the reactor temperature. The following equation is the process of acetogenesis:

$$\frac{d(X_{acid})}{dt} = \left[\frac{\mu_m}{\frac{K_s}{S_b} + 1} - K_d - \frac{F_{feed}/^b}{V}\right] . X_{acid} \quad \ldots\ldots (20)$$

Where:

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b = Retention time factor estimated
K_d = Acidogens specific mortality rate (d^{-1}).

3.8 MODELING OF THE METHANOGENESIS PROCESS

The methanogenesis stage determines the concentration of methanogens which is used to produce methane. This process depends on retention time, the feed flow rate, the effective reactor volume and reactor temperature:

$$\frac{d(X_{meth})}{dt} = \left[\frac{\mu_m}{\frac{K_{sc}}{S_v} + 1} - K_{dc} - \frac{F_{feed}/^{b}}{V} \right] . X_{meth} \qquad \ldots..(21)$$

Information:
K_{dc} = Specific mortality rate from methanogens (d^{-1})
$.X_{meth}$ = concentration of methanogens presents in (kg $/m^3$)
The equation for the amount of methane output is as follows:

$$F_{meth} = V.\frac{\mu_{mc}}{\frac{K_{sc}}{S_v} + 1} - K_4.X_{meth}$$

Information:
K_4= Yield factor related to methane gas flow.

- Implementation of a Mathematical Model of Biogas Production Using Matlab (Simulink)

After all the data is obtained, anaerobic digestion system modeling simulation is performed at SIMULINK. This modeling is done based on existing mathematical modeling. Implementation of mathematical models in Matlab can use text code or SIMULINK. SIMULINK uses blocks contained in the SIMULINK library, these blocks function as mathematical functions, each block has a different function such as add, subtract, multiply, divide, integral etc. Biogas production parameters will be entered into each block according to the respective parameter values.

- **Reactor Modeling**

SIMULINK block shape shown in Figure 3.2 is a form of model based on combining all mathematical models of the biogas production process into a system.

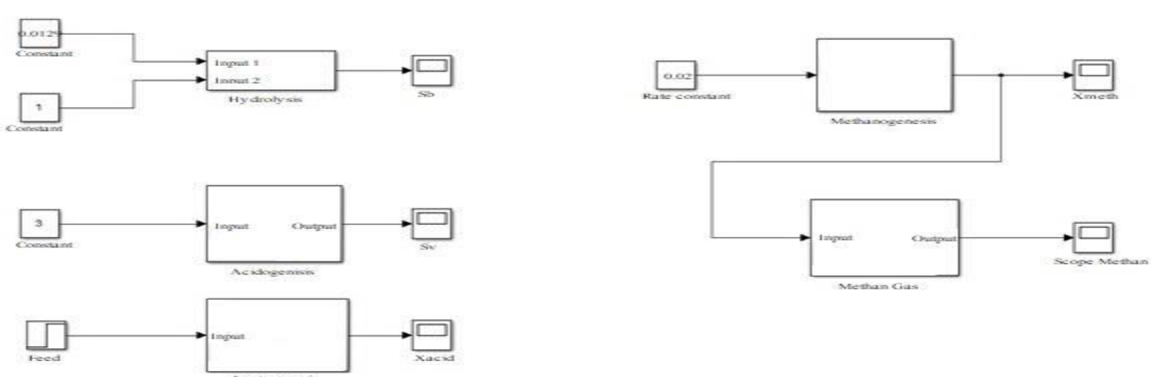

Figure 3.2: SIMULINK Reactor Model

- **DETERMINING BIOGAS PRODUCTION PARAMETERS**

The rate of the biogas formation process which is largely depend on the factors that affect microorganisms, including temperature, pH, nutrients, solids concentration, volatile solids, substrate concentration, digestion time, stirring of organic matter and the influence of pressure. The following are the parameters for each biogas production process:

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- **Simulation and Validation**

After modeling, simulation testing of the system that has been modeled is carried out. Simulations were carried out using SIMULINK MATLAB R2014a. To run the simulation on Simulink by selecting the run button to run the created model. If, when running there is an error, a diagnostic viewer will appear which will explain the errors that occurred in the system. Then there will be a re-evaluation of the system model until there are no more errors. To see the results of the model, by selecting the Scope Fmeth block, a graph will appear which is the result of the model created. After obtaining the results from the system model that is made, verification is carried out. Whereas, validation is an action to prove a research is correct with a benchmark so as to achieve the desired results. The purpose of validation is to ensure the results of a study are close to real or maintain the credibility of proposed scheme.

In this study, validation was carried out using a mathematical equation from the study entitled "Simulation of a Biogas Reactor for Dairy Manure" then the initial step of modeling will use the same variables and parameters from the research above, then see the results of the model made whether it is in accordance with the results of the reference research or not, if appropriate, the research can be continued to the next stage. Verification aims to ascertain whether the model is suitable or not. The suitability refers to the standard theory of conversion of potential cow dung into biogas, namely 1 kg of cow dung (cattle dung) dung produces **0.023-0.04 m^3** of biogas. If, the results of the system model made are in accordance with the reference standard, then change the input parameters according to the case will be examined, the parameters that are changed are F_{feed} (input feed), T_{react} (temperature), and V (digester volume). If the results of the model made deviate too far from the reference standard, then re-evaluate the model. After the results are in accordance with the reference standard, you can proceed to the next stage.

4. Result and Simulation

- **Calculation of the Potential of Biogas in a Dairy Cattle**

In calculating a biogas power plant from cow dung, a farm location is required to obtain the basic model of the generator. This calculation uses a model in the dairy cows/buffalo's dung as an example of a potential case as proposed in section below.
.

- **Potential hypothesis for the Biogas Plant**

The fixed dome type biogas reactor is designed for 10 cows (with 25 kg / day / head of cow dung and 45 days of retention time) with a reactor capacity of 18 m^3. Based on the results of the Matlab and Homer test of these activities and literature references as shown in the following table 4.1: -

Table 4.1 Sample performance of the biogas plant

Description	Referenced	Test Results and Analysis
1. Material Conditions (Cow Dung)		
• Total Solid, Kg/ Head / Day	4.8	4.2
• Volatile Solid, Kg / Head / Day	3.9	3.8
• Water Content, %	6.9 – 8.9	13.59
• C/N Ratio	1:20 1:30	1:17
• Cod, Mg/Ld	-	19 800
• -BOD/COD	-	0.06
2. Conditions in The Reactor (Process)		
- Temperature, ^{O}C	35	25–27
- pH	7.0 - 8.01	7-8.61
3. Chemical Content of Biogas		
- CH_4, %	501-1601	76.131
- CO_2,%	301-1401	21.881
- H_2S, µg / m^3	<1%	1543.461
- NH_3, µg / m^3	-	40.121

4. Discharge sludge Condition from the Reactors (Effluent) - Cods - Bod/Cods - Nutrient content (Main), - % • Nitrogen • Phosphorus • Potassium	5001-12500	1 960
	0.51	0.37
	1.451	1.82
	1.101	0.73
	1.101	0.41
5. Performance • Lighting, m^3 / Hour	10.11 - 0.151 (Illumination Equivalent To 60 Watts of Bulbt≅T100 Candles power≅ 620tlumens). Pressure: 170-851 Mmmh$_2$o1	0.15-0.3 Pressure=30-60 mmh$_2$o
• Gas Stove, m^3 / Hour	0.2 - 0.45 0.3 m^3 / Person/Day Pressure: 75-901 Mmmh$_2$o	0.2-0.4 Pressure=60-85 mmh$_2$o

From the existing data, we try to calculate the biogas capacity generated from the existing potential, the percentage of Total Solid and Volatile Solid obtained is the sample of 20 kg / day cow dung as: -
%Total Solid = 14.2 kg / head / day: 120 kg / head / day = 121 %
%Total Volatile Solid = 13.8 kg / head / day: 120 kg / head / day = 119 %
So, for the example Delhi Capital Region, which produces (8-20 kg/head/day), taking 15 kg / head / day and considering data for 150 cattle as: -
Total Solid = 121% * 115 kg / head / day * 1501 = 472.51kg / day
Volatile Solid = 119%*1 15 kg / head / day * 1501 = 427.5 kg / day
Based on the potential mentioned above for biogas for cow dung as: -
Potential Biogas Volume = 0.04 m^3/kg *2,250 kg/ day = 90 m^3/ day
K = Volume of biogas production as: -
V_S = 190 m^3 / day:427.5 kg / day
K = 121% m^3/ kg ≈ 121%

- **Methane Production Calculation**

Energy production using biogas is proportional to the amount of methane gas production. With a known biogas production value (V_{BG}) of 90 m^3 / day and by using table 4.3 (depicted under); then it can be seen that the production of methane gas (V_{MG}) is, V_{MG} = 65.7% * V_{BG} = 65.7% x 90 m^3 / day =59.13 m^3 / day.

- **Electrical Energy Productions calculations:**

With the known volume of methane gas produced, namely 59.13 m^3 / day, and Conversion Factor (F_K) (m^3 of methane gas is equivalent to 11.17 kWh), so that the potential for electrical energy produced is, E = V_{MG} x F_K = 59.13 * 11.17 = 660.428 kWh / day. The power generated by the Biogas Power Plant is the energy generated per day divided by 24 hours, namely:
P = (E / 24) *time = (660.428 / 24) *24 = 660.428kW ≈ 0.660 MW So from the calculation of the available potential data, the following results are obtained: and presented in table 4.2: -
-

Table 4.2: Result of biogas capacity calculations

No.	Type of the Calculation involved in the Process	Calculated Results
1.	Potential of Cow Dung (Q)	15 Kg / Day

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2.	Calculation of the sum Of Total Solids (Ts)	4.725 Kg / Day
3.	Calculation of The Amount of Volatile Solid (Vs)	4.275 Kg / Day
4.	Calculation of The Volume of Biogas Production (V_{bs})	90 m^3 / Day
5.	Calculation of The Volume of Methane Gas (V_{gm})	59.13 / Day
6.	Calculation of Potential Electrical Energy (E)	660.428 kWh / Day
7.	Power Generating from the Power Plant (Biogas Power)	660.428 Kw in a Day

- **Digester Design**

Digester Type and Dimension Design

From the available potential it is possible to design a digester for produce biogas. As explained in chapter II a design digester there are several considerations that must be considered. design digester with consideration of several aspects as follows: -

- Temperature

For countries such as India, an unheated digester is used for soil temperature conditions of 20 - 30 ^{o} C (Mesophilic - 20 – 40^o C).

- Degree of Acidity (pH)

Bacteria thrive in moderately acidic conditions (pH between 6.6 - 7.0) and pH should not be below 6.2. Therefore, the main key in the operational success of the biodigester is to keep the temperature constant (fixed) and the material input accordingly. Filling material C / N ratio - The ideal requirement for the digestion process is C / N = 20 - 30. Therefore, to obtain high biogas production, it is necessary to extract carbon (C) materials such as straw, or N (for example: urea) to achieve a C / N ratio = 20 - 30. Based on the data obtained, Cow dung has C / N = 24 so that it is sufficient for the process to obtain the required pH.

- Digester Design

As initial data, the potential for dairy cow dung is 2,250 kg / day. In simple terms, the sequence of biodigester facility design begins with the calculation of the volume of the biodigester which includes the potential of the raw materials present in producing methane gas, determining the biodigester model, designing storage tanks and ending with determining the location. The digester used in this plan uses the fixed dome type or fixed dump digester type. This model is the most popular model in Indonesia, where all digester installations are made in the ground with a permanent construction. Besides being able to save land space, making a digester in the soil is also useful for maintaining a stable digester temperature and supporting the growth of methanogenic bacteria. Digester of this type has advantages Low construction costs due to simple construction and long life.

The digester uses a flow type, where the raw material flow is entered and the residue is removed at certain intervals. The length of time the raw material is in the digester reactor is called the retention time (RT). The construction parts in this type of digester include:

a. Gas storage room (gas collecting chamber).
b. Gas storage chamber.
c. Fermentation Chamber Volume.
d. Hydraulic Chamber Volume (hydraulic chamber).
e. Volume of the sludge layer.

Furthermore, the size and type of digester used will be designed based on the potency and available literature data.

Digester size planning is seen from the daily amount of cow dung, the ratio of the composition of the mixture of water and cow dung, digestion time and the volume of biogas produced. The daily amount of manure produced at Capital is approx. 2.25 tons or 2,250 kg while the composition of the mixture of water and organic waste is to obtain 8% solids, solids refer to the amount of Kg t_s (total solid). Based on the calculations above, the total solid produced is 472.5 Kg. To obtain water that is added to make biogas raw material, fresh cow dung is mixed with water in a ratio of 1: 1. So that the amount of water added = the potential amount of cow dung = 2,250 kg / day then; Q_t = 4,500 kg / day Based on available data storage time (HRT) of cow dung in the digester. Storage time depends on the ambient temperature and biodigester temperature. With tropical conditions like India, at a temperature of 25- 35 ° C, the digestion time is approximately 25-35 days, a short digestion time can reduce the volume of the digester and vice versa the digestion time length can increase the volume of the digester. By determining the digestification time is 30 days, then with equations given below, can be determined the working volume of the digester, where the working volume of the digester is the sum of the digestification room volume (V_{DR}) and the storage volume ($V_{Storage}$),

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namely: -

The working volume of the digester = V_{DR} + $V_{Storage}$, where $V_{Storage}$ + V_{DR} = Q_t x HRT (digestion time), then:
V_{DR} + $V_{Storage}$ = Q_t x HRT
= 4,500 Kg / day x 30 days
= 1,35,500 Kg

Because approximately 80% of the total Q (raw material) is water, we assume the density Q (raw material) ≈ density of water (1000 kg / m^3)
Volume = m / ρ
V_{DR} + $V_{Storage}$ = 1,35,000 Kg / 1000 kg / m^3 = 135m^3 = V_1

Based on table 4.3 the assumption of geometrical equations for the size of the digester tank is obtained:
$V_{Storage}$ + V_{DR} = 80% V_1 or V_1 = ($V_{Storage}$ + V_{DR}) / 0.8
V_1 = 135 / 0.8
V_1 = 168.75 m^3

If building a digester size of 168.75 m^3 apart from being impractical in maintenance it is also less possible due to limited land, so look for a much smaller size digester with more than 1 digester, making it possible for maintenance and if there is damage to one of the digester others are still able to produce biogas as fuel for their electricity generation. It is determined that the digester to be built is 50 m^3 in size so that the number of digester sizes that must be built is:
Number of digester =168.75 m^3/50 m^3 = 3.375≈ 4 digester pieces.
For the digester size (V) 50 m^3, by reviewing the geometric equation assumptions in Table 4.3 it is obtained:

$V_{Storage}$ + V_{DR} = 80% V
= 80% * 50
= 40 m^3

Volume of gas storage room (Vc) = 5% * V = 5% * 50 = 2.5 m^3
The volume of the sludge storage layer ($V_{Sludge\ storage}$) = 15% * V
= 15% * 50 = 7.5 m^3

Storage volume ($V_{Storage}$) = 0.5 ($V_{Storage}$ + V_{DR} + V_s) C.
C is the rate of gas production per m^3 per day, based on the table the C value 3.4, for cow dung is 0.21, then:
$V_{storage}$ = 0.5 ($V_{storage}$ + V_{DR} + $V_{sludge\ storage}$) K.
= 0.5 * (40 + 7.5) * 0.21 = 4.99 m^3

From the value of $V_{storage}$ = 4.99 m^3 so that it can be seen the value of V_{DR}, namely: $V_{storage}$ + V_{DR} = 40, V_{DR} = 40 - 4.99 = 35.01 m^3
From the geometric assumption it is also known that $V_{Storage}$ = V_H = 4.99 m^3, meaning that the biogas will occupy the entire gas storage space (fixed drump digester type) according to the volume of gas produced. So that the volume of each part of the digester is known, namely:
V ─ Total Digester volume = 50 m^3
V_c - Volume of the gas collecting chamber = 2.5 m^3
$V_{storage}$ - Volume of gas storage chamber = 4.99 m^3
V_{DR} - Volume of the fermentation chamber =35.01 m^3
V_H - Volume of the (Hydraulic chamber) = 4.99 m^3
$V_{sludge\ storage}$ - Volume of the sludge layer = 7.5 m^3

- **Process Hydrolysis Acidogenesis, Acetogenesis and Methanogenesis.**
  The anaerobic decomposition in biopolymers organic complexes into methane gas are carried out by combined activities microbes. In general, this decomposition can be classified into four reactions, namely: hydrolysis, acidogenesis, acetogenesis and methanogenesis.
- **Process Hydrolysis Modeling**
  The hydrolysis stages, the decomposition of the polymeric organic material into soluble monomers, such as carbohydrates (polysarides) are broken down into glucose: -

$$(C_6H_{10}O_5)n + nH_2O \rightarrow n(C_6H_{12}O_6) \quad \ldots..(22)$$

Therefore, the hydrolysis stride was incorporated into the Anaerobic Digestion Model in which the degradable particulate organic substrate, X_c are partially disintegrated into carbohydrates (X_{CH}), proteins (X_{PR}) and lipids (X_{LI}) and is described by

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Equation shown below. The hydrolysis of X_{CH}, X_{PR} and X_{LI} are defined as under: -

$$\frac{dXc}{dt} = -K_{dis}Xc + D_{in}\,(Xc_{in} - Xc) + k_{dec,x1}X1 + k_{dec,x2}\,X2 \quad \ldots..(23)$$

$$\frac{dXch}{dt} = -K_{hyd,ch}\,Xch + D_{in}\,(Xc_{in} - Xch) + f_{ch,xc} + k_{dis}\,Xc \quad \ldots..(24)$$

$$\frac{dXpr}{dt} = -K_{hyd,pr}\,Xpr + D_{in}\,(Xpr_{in} - Xpr) + f_{pr,xc} + k_{dis}\,Xc \quad \ldots..(25)$$

$$\frac{dXli}{dt} = -K_{hyd,li}\,Xli + D_{in}\,(Xli_{in} - Xli) + f_{li,xc} + k_{dis}\,Xc \quad \ldots..(26)$$

In where $\mathbf{k_{dis}}$ is the constraint for degeneration process; the macrobiotic substrate application, **S**1, incorporate the conditions interrelated to hydrolysis, as shown:

$$\frac{dSl}{dt} = D_{in}\,(Sl_{in} - Sl) - (k_1\mu_1X1) + k_7\left(k_{dis}\,Xc - k_{dec,x1}X1 - k_{dec,x2}X2\right) + k_8\{\left(k_{hyd,ch}\,Xch - f_{ch,xc}k_{dis}Xc\right) + \left(k_{hyd,pr}\,Xpr - f_{pr,xc}k_{dis}Xc\right) + \left(k_{hyd,li}\,Xli - f_{li,xc}k_{dis}\right) \quad \ldots..(27)$$

In where $\mathbf{k_7}$ is the yield-coefficient of-substrate disintegration and $\mathbf{k_8}$ the yield-coefficient of hydrolysis of-carbohydrates, proteins and lipids however the simulation depicting the scenario using Matlab is as under that can be seen in figure 4.1, SIMULINK block shape shown in, is a form of model based on mathematical modeling in formula 17: -

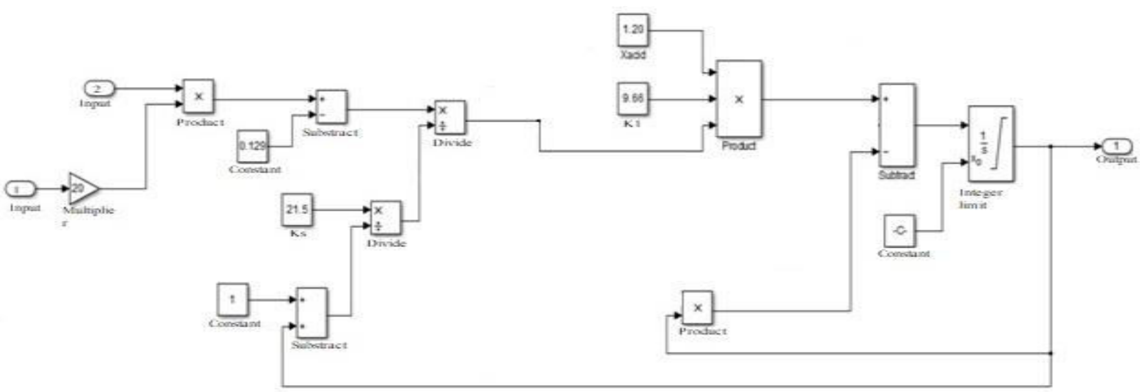

Figure 4.1: Process Hydrolysis Modeling

- **Process Acidogenesis**

In the acidogenesis stage, the bacteria generate acid and transform short-chain compounds into acetic acid, hydrogen and carbon dioxide formed in the hydrolysis stage. These bacteria are anaerobic bacteria that can grow and thrive in acidic conditions. To produce acetic acid these bacteria, require oxygen and carbon obtained from dissolved oxygen in solution, the formation of acid under anaerobic conditions is very important to form methane gas by microorganisms in the next process. In addition, these bacteria also turn alcohol, organic acids, amino acids, carbon dioxide, H_2S and a little methane gas into low molecular compounds. Acetic acid, propionic acid, butyric acid, H_2 and CO_2 are the most relevant compounds in the stage of acidogenesis. Furthermore, it contains small quantities of formic acid, lactic acid, valeric acid, methanol, ethanol, butadienol and acetone. Acid-forming bacteria can usually survive more abrupt conditions than methane-producing bacteria. These bacteria, if in anaerobic conditions, are able to produce staple food for producing methane gas and the resulting enzyme activity on proteins and amino acids will free amino salts which are the only source of nitrogen that can be accepted by methane-producing bacteria, therefore the simulation of below formulation is as under, SIMULINK block shape shown in Figure 4.2 is a form of model based on mathematical modeling in formula 19 and can be seen in figure 4.2.

$$K_1\,S_1 \xrightarrow{r_1} X_1 + k_2S_2 + k_4CO_2 \quad \ldots..(28)$$

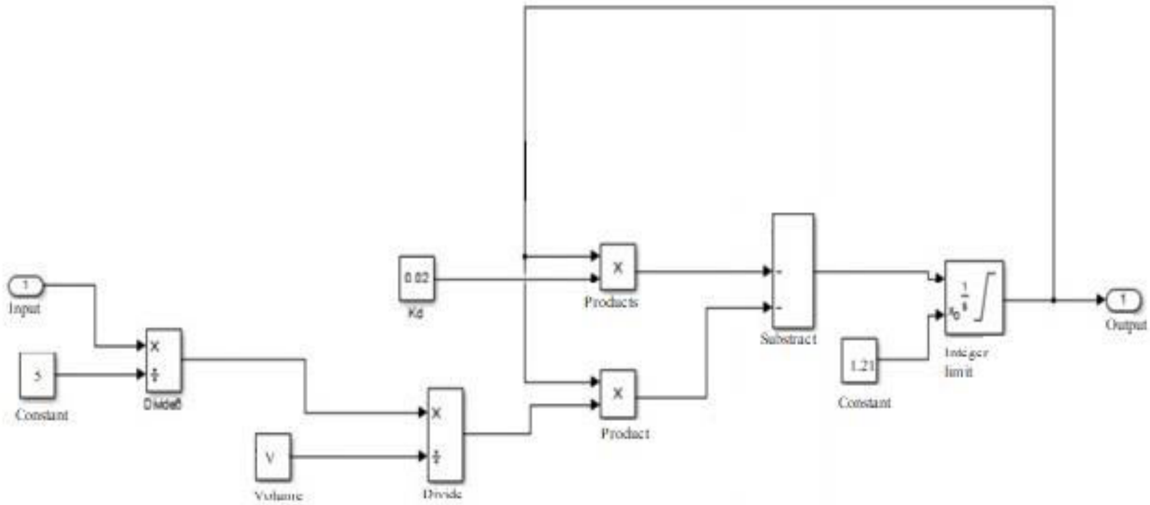

Figure 4.2: Process Acidogenesis Modeling

- **Process Acetogenesis**

Other results such as alcohol and Volatile Fatty Acid (VFA) from the process acidogenesis will be oxidized by acetogenic bacteria. On phase in this acetic acid and H_2 gas are produced which are used to form the gas methane. In the acidogenesis phase, about 20% acetic acid and 4% have been produced H_2 gas. In anaerobic environments, facultative microbes are able to break down acids long carbon chain fats such as propionic and butyric acids become acids acetate and H_2 gas. Therefore, at this stage, the acetogenic bacteria are producing hydrogen converting fatty acids and ethanol / alcohol to acetate, carbon dioxide and hydrogen. This advanced conversion is very important for success in biogas production, because methanogens cannot use fatty acid compounds and ethanol directly as: -

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_2COOH + 2CO_2 + 4H_2 \quad \ldots..(29)$$

The Acetogenesis modeling can be seen in figure 4.3, SIMULINK block shape shown in Figure 4.3 is a form of model based on mathematical modeling in formula 20.

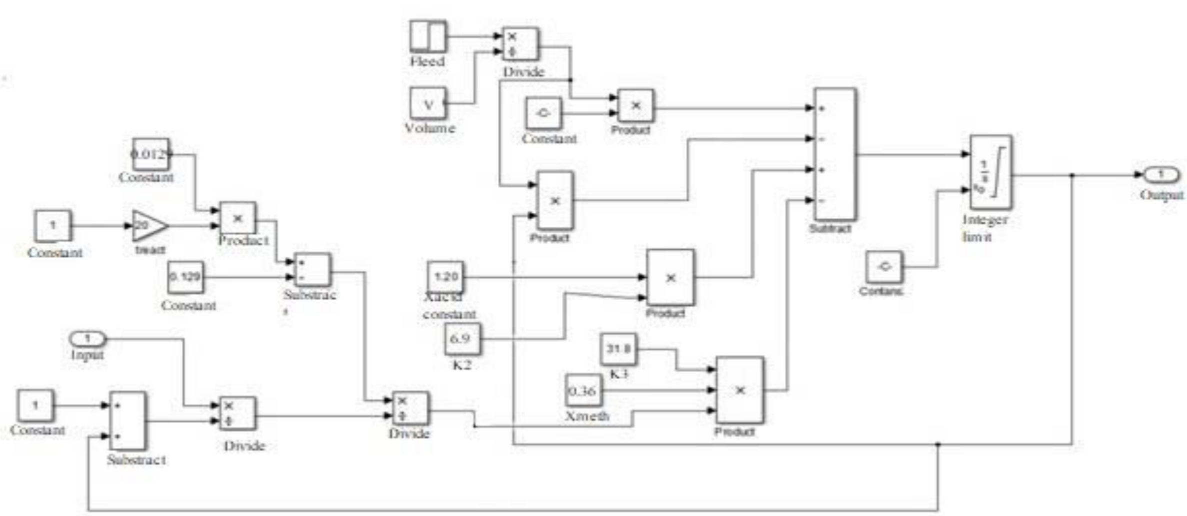

Figure 4.3: Process Acetogenesis Modeling

4.3.4 PROCESS METHANOGENESIS

Methanogenesis is the final stage of all conversion stages anaerobic organic matter into methane and carbon dioxide. On In the early stages of growth, methanogenic bacteria depend on the availability of nitrogen in the form of ammonia and the amount of that substrate used. In the methanogenesis stage, methanogenic bacteria synthesize low molecular weight compounds become heavy compounds high molecule. For example, these bacteria use hydrogen, CO_2 and acetic acid to form methane and CO_2. Acid-producing bacteria and methane gas work together symbiosis. Acid-producing bacteria form a favorable environmental state ideal for methane producing bacteria. Meanwhile, gas-forming bacteria methane uses acids produced by acid-producing bacteria. Without this symbiotic process, it will create toxic conditions for acid-producing microorganisms as: -

a. Acetolactic methane bacteria break down acetic acid into:

$$CH_3COOH \rightarrow CH_4 + CO_2 \qquad \ldots\ldots(30)$$

b. Methane bacteria synthesize hydrogen and carbon dioxide into:

$$2H_2 + CO_2 \rightarrow CH_4 + 2H_2O \qquad \ldots\ldots(31)$$

Methanogenic bacteria are very sensitive to environmental changes. If the pH is below 6, the methanogenic bacteria cannot survive the Matlab simulation is depicted as under, SIMULINK block shape shown in Figure 4.4 is a form of model based on mathematical modeling in formula 21 and the methanogenesis process modeling can be seen in figure 4.4.

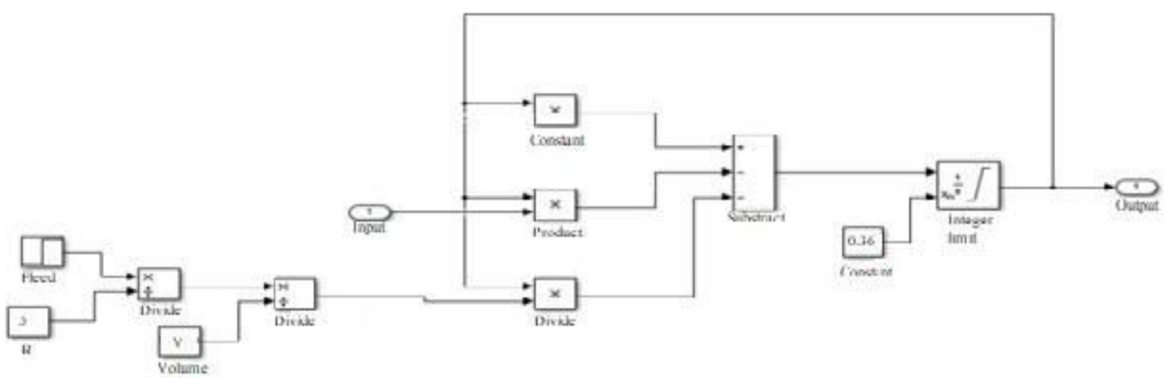

Figure 4.4: Process Methanogenesis Modeling

Therefore, using the above simulation modeling techniques, the amount of methane gas output is depicted as under and can be seen in figure 4.5: -

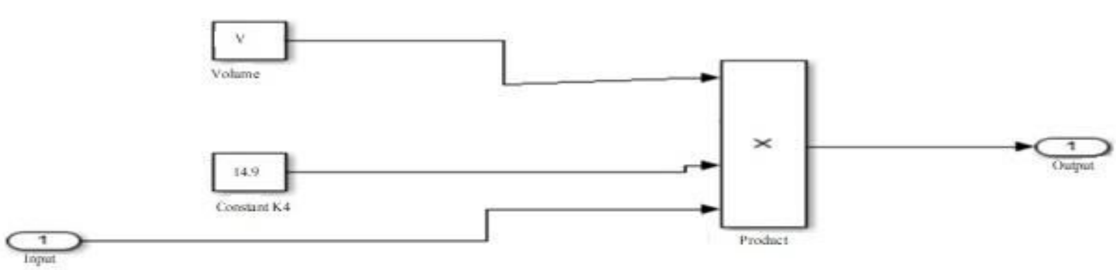

Figure 4.5: Modeling of the amount of methane gas output.

- **Gas Rector**

  In terms of construction, generally biogas reactors can classify into three types, namely fixed dome, floating drum and reactor balloon. Fixed dome represents a reactor construction that has a fixed volume so that gas production will increase the pressure in the reactor. While floating drum means that there are parts in the reactor construction that can move to adjust to the increase

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in reactor pressure. Movement of parts the reactor also marks the start of internal gas production biogas reactor. When viewed from the flow of raw materials (waste), a biogas reactor can also divide into two, namely the batch type (tub) and continuous (flow). In tub type, Reactor raw materials are placed in the container (specified space) from the start until the completion of the contamination process. This is only commonly used at stages experiments to determine the gas potential of a type of organic waste; whereas, in the flow type, there is a flow of raw materials in and out of residues at any given time. The length (time) the raw material is inside a biogas reactor is called the hydraulic retention time. The contact between raw materials and acid bacteria / methane, are two important factors that play a role in the biogas reactor. Schematic of fixed dome biogas reactor is inculcated in the solution the simulation depicted as under and can be seen in figure 4.6:

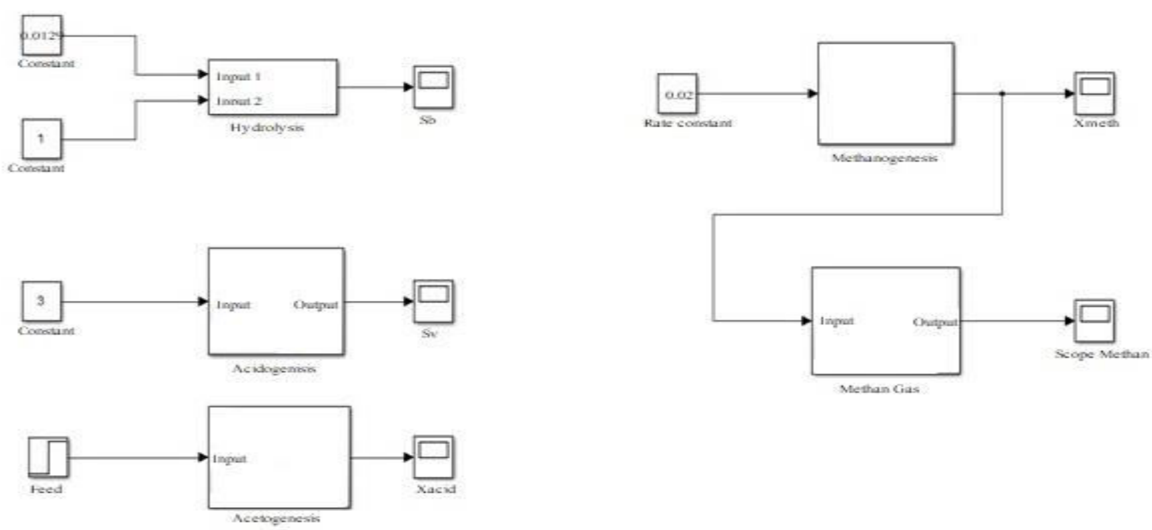

Figure 4.6: Reactor Model

- **Simulation Results**

The pressure in the reactor in the study, this is measured directly using Matlab so it can be seen that the process the reaction in the reactor for generate how much pressure that is generated as well as to know the increase that happens until the gas content is inside the material runs out. Based on the test preliminary, each repetition is carried out during the simulation to the point i.e., increase in methane gas production based on various temperatures. (Below simulated graphs shows X-Axis - time in days, while Y-axis consists of pressure in SI unit i.e., Pascal or N/m^2) and the result of simulations at temperature of 20°C,30°C,40°C, can be seen in figure 4.7,4.8,4.9 respectively.

- **Simulation results with scenario 20° C**

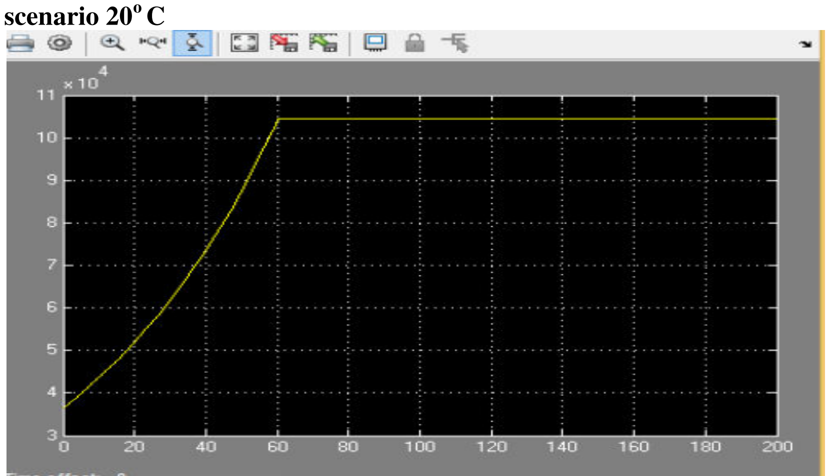

Figure: 4.7: Simulation Result of Converting Biogas Energy Scenario 20°C

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- **Simulation results with scenario 30° C**

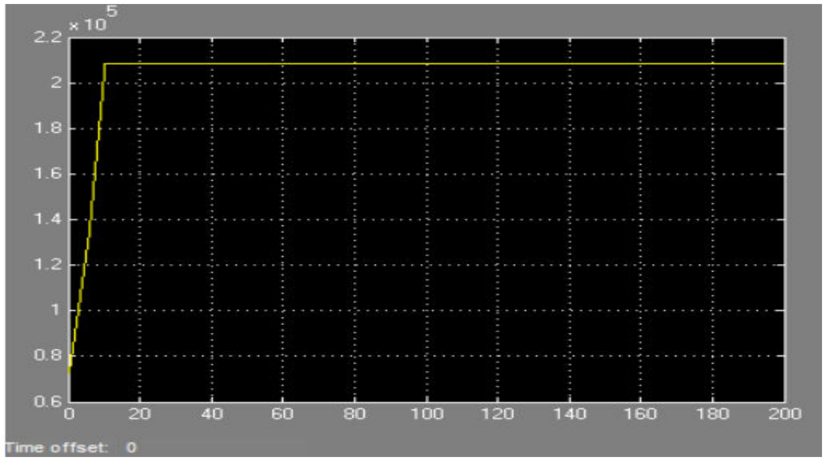

Figure: 4.8: Simulation Result of Converting Biogas Energy Scenario 30°C

- **Simulation results with scenario 40° C**

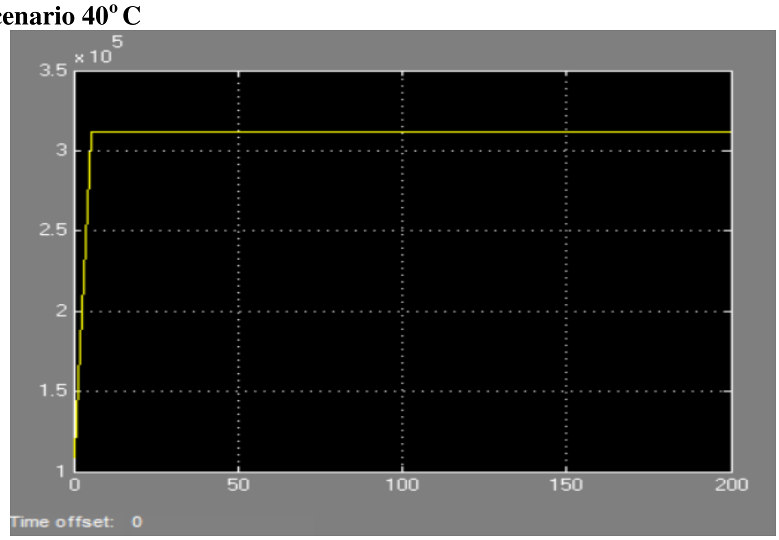

Figure: 4.9: Simulation Result of Converting Biogas Energy Scenario 40°C

- **Biogas Production**
  The biogas production process begins by diluting the manure with water with 1:1 ratio. Excessive water in the system can block the biogas channel, lowers the heat level of the fire, and makes the fire red. Stirring is possible at any given time to prevent solids from settling on the tank bottom. The manure that has been mixed with water is forwarded into the digester until it closes the channel enter and output, then wait for approximately 10-40 days. Then filling the digester can be done twice a day, namely morning and evening. The first gas produced must be discarded because it is dominated by CO_2 gas. Next, biogas production can be carried out normally so that CH_4 gas production will increase and CO_2 gas will decrease by a percentage of 54%: 27%. Furthermore, biogas can be obtained connected to a stove or electric generator. The gas produced is very good for combustion because it is able to generate a high enough heat, the fire is blue, no smelly, not smoky. The following is a schematic of the biogas production process.
- **Break Event Point**
  Break Even Point is a situation in which a company in a position does not experience gains or losses. This can happen if fixed costs and sales volume are used by the operation only to offset fixed costs and variable costs. The company suffers a loss if profits are only adequate to cover operating expenses and a portion of the fixed costs. In the meantime, the corporation will experience a profit if profits outweigh sales expenses and fixed costs. The components of the cost calculation at Break Even Point are as follows:
- **Fixed Costs**
  Fixed costs are the costings whose value tends to be stable without being influenced by the units produced. So, this one component is constant or appears during production or when production is not carried out by the company. Examples of fixed costs at companies are labor costs, machine depreciation costs, water costs, and so on.

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- **Variable Cost**
  Variable costs are the costings whose value depends on the quantity of units or goods produced. So, this one component is its cost per unit does not remain or change according to the ongoing production action. So, for example, if production stops, variable costs decrease or don't exist and if production increases, variable costs will also increase. Some examples of variable costs are raw material costs, electricity costs, and so on.
- **Selling Price**
  The selling price is the selling price of electricity produced by the company. This selling price needs to be known because it is included in the Break Event Point calculation formula. The following is a formula for finding the Break Even Point value based on sales.

$$BEP = \frac{FC}{VC/P}$$

Where;
FC is a Fixed Cost
P is the Price per Unit
VC is Variable Cost

- **Biogas Potential**
  As mentioned earlier cow can produce 8 kg to 20 kg of manure, of which one cows can produce biogas 0.36 m^3 / day, so if calculated, biogas produced from the cattle farm (having 150 cows) is 54 m^3 / day. It is known that 1 m^3 biogas can generate electric power of 11.17 kWh so that for 54 m^3 biogas can generate energy for:
  The amount of energy = volume of biogas * energy generated per m^3
  =2542$m^3$2*11.17 kWh
  = 603.18 kWh
  So, the theoretical amount of biogas energy in per cattle farm in National Capital Territory is 603.18 kWh with a power output of 603.18 KWh per day
- **Biogas Generator**
  The specifications of the biogas generator that will be used depicted in table 4.3 below: -

Table 4.3 Biogas Generator Set Specifications

Features	Double Cylinder
	4-stroke
	OHV
	Air-cooled
	Three phase AC
AC voltage-	220/230V
AC Outputs-	Running Power: 30KW
	Peak Power
Frequency	50/60Hz
Starting system	Recoil or Electric start
Fuel	Biogas
Weight	150Kg
Other	Min. Fuel Consumptions: 2m^3 /hour

Assuming the biogas generator will be operated 18 hours a day (in two shifts: morning and evening), and then the energy output from this biogas-based power plant is:
Energy = Power * Time
= 30 KW * 18 hours
= 540 KWh

The capacity of the digester with a power of 603.18 kwh and if you know the generator engine with a capacity of 540 kwh with the capability 603.18 kwh digester, then the digester can hold gas for 1.117 days. As for the biogas needed to turn on the generator for 18 hours based on minimum consumption of biogas stated in the generator specifications (2m^3 / hour) is = 18

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hours * 2m^3 / hour = 36 m^3 / day. Meanwhile, the gas produced by 150 cows is 54 m^3 in 18 hours. So, the process of forming biogas to drive a generator is at least 36 m^3. Therefore, m^3 for 18 hours of use, it may take as long $\frac{36m^3}{54\, m^3} = 0.667\ days$ the length of time the generator set operates for a biogas volume of 54 m^3 can be determined by the following calculation:

$$\frac{\textbf{The volume of biogas production}}{\textbf{Biogas for generator}} = \frac{54}{2} = 27\ \textbf{hours}$$

- **Homer Analysis**

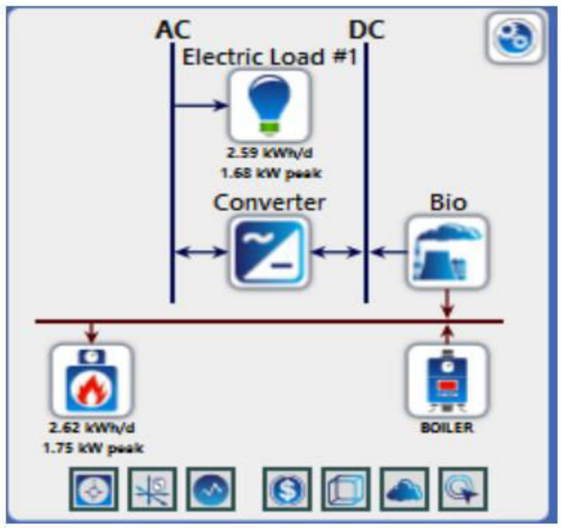

Figure 4.10 Schematic of the biogas power plant design

In Figure 4.10 there are several components including thermal loads, boilers, generators biogas, converters, and AC loads. The function of thermal load is as energy for heating water in the boiler. The function of the boiler in the circuit above is as a container where the process occurs heating water to produce hot steam. The function of the generator is as energy generator electricity. The converter function is to convert the DC current from the generator into the acceptable AC current used by AC loads. The following is a systematic process in Figure 4.13.

1- The thermal load heats the water in the boiler.
2- Water that has been heated in the boiler will produce hot steam.
3- The hot steam is directed to rotate the motor in the generator which then will generate electrical energy that is DC.
4- DC current from the generator flows to the converter to be converted into AC current.
5- AC current is applied to the load.

- Economic Analysis
  The economic value of the biogas power plant is shown in Table- 4.4

Table 4.4 The Economical Value of the Biogas Power Generation System

Assessment Criteria	**Score**
Total energy production (KWh) Per Year	1,97,100
Net present cost Of Materials (Including Generator, Digestor, Tank, Pipeline and Other)	Rs-2,50,000
Cost of energy (RS/KWH) Per Year	1.268

The total energy production using the biogas power generation system generates power amounting to Rs. 1.268 per kWh / year. The result of the total energy produced can be seen in Table 4.5 and will be calculated using formulation as Energy = Volume of Biogas * Energy generated per m^3.

Table 4.5: Data on Total Energy Production per Year

Component	**Output Production (KWh) In A Year**
Generator (Operating 18 Hrs. A Day) R(540kwh*365days) in a year	1,97,100

$$E_{tot.prod} = 1,97,100\ kWh\ (197.10MWh) in\ a\ complete\ year$$

The results of net present cost calculation using Homer software can be seen in table 4.6 below:

Table 4.6: Results of Net Present Cost Calculation for HOMER Software

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic biogas generator	200000	0	10	14,608.01	-152.581	2,14,455.43
Homer Load Following	10	10	10	10	0	10
System Converter	399.99	10	39.97	10	01	439.97
Other	50,000	10	45,249.7	10	0	95,249.71
System	2,50,999.98	0	45,289.68	14,608.01	-152.581	3,10,745.09

NPC = 2,50,999.98 +0 + 45,289.69 + 14,608.01 – 152.58
NPC = 3,10,745.09
Cost of Energy system Rs.3,10,745.09, total energy yield data serve loads and costs total per year used to calculate the Cost of Energy can be seen in Table 4.7 and calculated using equation $NPC = Capital\ Costs + Replacement\ costs + O\&M\ costs + Fuel\ Costs - Salvage$.

Table 4.7: Data on Total Energy Serving Expenses and Costs per Year

Assessment Criteria	Score
Total Energy Serving Load (kWh / year)	1,97,100 (Average Consumption)
Total Annual Fee (Rs)	3,10,745.09

$$COE = \frac{Rs.3,10,745.09}{1,97,100kWh} = 1.57\text{Rs. / kWh in a year}$$

5. Conclusion and Suggestions

- **Conclusion**

From the research conducted it can be concluded that:

- National Capital Territory with a population of 150 heads (example) of cattle has the potential to produce 0.36 m^3 per cattle of biogas with the potential for electrical energy generated 603.18 kWh (***603.18 KW power***).
- Selection of a biogas generator set with a capacity of 30 kW suitable for use as an engine for converting biogas energy into electrical energy in a simple generator system with the HOMER generating system using a frequency of 50Hz.
- A simple generator system (Digester-biogas-Genset Biogas 30000 W-electricity) which is assumed to operate for 18 hours a day can generate energy of 540.00 kWh while the HOMER generator system for 24 hours can produce the 603.18 kWh electric energy).
- The remaining 63.18 m^3 can be utilized for cooking and boiling as fuel usages in ordinary course of business, livelihood and to counter any losses.
- Investment in the construction of a simple generator system (Digester-biogas-Genset Biogas 30 kW of power resulting 540.00 kWh) will be more easily realized as compared to the construction of a HOMER generating system (Thermal-Boiler-Generator Bio 30 kW-Converter 603.10 kWh electricity load) with consideration of a fairly the economical price of Rs.1.57 of per unit in a year. Consequently, which is much cheaper and more economical to existing electricity.
- By the use of cow dung which is Municipal solid waste (basically biodegradable organic waste), we can reduce the municipal solid waste generation and air pollution to some extent in Delhi.

- **Suggestions**

The suggestions in this study are:

- For the construction of a biogas-based power plant system in National Capital Region, it will be more efficient and economical with a simple generator system (Digester-biogas-Biogas Generator 30000 W-electricity) compared to the HOMER generating system (Thermal-Boiler-Generator Bio 30 kW -Converter 10 kW-electric load).
- It is necessary to hold further studies of course with different parameters regarding the biogas-based power plant system in National Capital Region so that the construction of the generator can be realized so that it can be distributed to the community.

- The bio-waste that is being generated during the production of biogas, can be used as manure for agriculture and farming which is much more effective and better than the harmful chemical compounds that is being used for agriculture and farming.

Declaration of Competing Interest

The authors declare no conflicts of interest concerning the research, authorship and publication of this article.

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