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The Model of Biogas Utilization from Livestock Manure Using Farmer Group Approach to Meet Alternative Energy at Household Scale

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Abstract

This study aims to analyze the potential of waste generated from the application of integrated farming systems through biogas production produced as alternative fuel for households. The results showed that the waste of integrated farming system in the form of livestock manure can produce biogas and organic fertilizers that can be used by farming managers as an input for production activities and for sale. A cow can produce biogas around 600-1000 liters per day. The use of biogas as an alternative fuel for stoves and lamps can save household expenditure to buy fossil fuels. Besides avoiding scarcity of fossil fuels, it can also reduce the negative impact of livestock farming activities. In addition, people using biogas are participating in the mitigation of greenhouse gases.

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This study develops a model of biogas utilization using farmer group approach where each group, consists of 20 people, manage a number of 20 to 50 cows. The group members exploit biogas from cow's manure with the concept of 'come with grasses, go home with biogas'. They use biogas bags, so that bio-digesters at cow's stalls are operated to refill biogas.

Keywords: Alternative fuels; waste; mitigation.

1. Background

Energy is one of the most essential needs for living things, especially humans. Without the existence of energy source, humans will have difficulty in running their wheel of life. This occurs because almost all human activities require energy. Humans need energy sources for their daily life, ranging from driving vehicles for transportation to various household appliances, such as cooking and lighting tools.

Human population in Indonesia continues to increase annually. According to the Central Bureau of Statistics, in 2015, Indonesia's human population was 254.9 million with a population density of 134 people/km2. Indonesia's human population growth rate is 1.38 per year in 2010 - 2015. It is projected that human population of Indonesia in 2015 - 2025, over the next 10 years, continues to increase by 30 million, to become 284.9 million by the year 2025. Along with human populationincrease, food and energy needs are also increasing. Therefore, measures and solutions are needed to fulfill the needs. One of them is the development of integrated farming systems.

Integrated farming system is an agricultural model consisting of many business units that prioritize the efficiency of the use of inputs and outputs. In this system, an output of a business unit is used as an input for other sectors so that no materials are wasted. The combination of these internal and external factors is a mutually beneficial interaction in order to meet the objectives of the manager or farmer. Integrated farming systems can also produce final products in the form of biogas that can meet energy needs for households.

Biogas is a gas-shaped energy that can be used as an alternative energy for electricity and fuel. It is called biogas because in its formation there is a role for fermentation bacteria (living things) and organic raw materials. According to [8], biogas can be produced from the processing of household waste and the residue of animal waste, thus biogas has a great opportunity in its development since its material can be obtained from residential areas.

The purpose of this study is to analyze the potential of waste generated from the application of integrated farming systems. In addition this study aims to analyze biogas production originating from integrated agricultural waste and to analyze the potential of biogas as an alternative fuel so that it can be applied in household life.

2. Methodology

2.1. Location and Time of Research

The study was conducted in March 2017 until December 2017. All research activities were carried out at PT SWEN IT, Ciomas District, Bogor Regency, West Java.

2.2. Tools

The tools used in developing biogas include filler tubs and reservoirs, digester, PVC pipe with a diameter of 4 inches, plastic tube with diameter ¾ inch, bucket, wood stirrer, dipper, gas tap, knee (½ inch and L draft), paralon clamps, plastic tube clamps, paralon glue, glass fiber controller, and cement, sand and bricks. The resulting biogas is stored using a biogas container with a capacity of 1 m^3 made of tapered plastic. In addition, LPG stoves, biogas stoves and kerosene stoves are used for biogas fuel testing. Other tools used are pan, measuring cup, stopwatch, camera, and stationery.

2.3. Materials

The main materials used in making biogas are livestock manure in integrated farming systems, namely cow dung, sheep dung, and chicken manure in fresh conditions and water. The materials used in biogas testing include biogas, LPG, kerosene, water, and matches.

2.4. Work procedures

2.4.1. Making gas from manure of integrated farming systems

The following are steps to make biogas from livestock manure.

a. Preparing raw material of fresh livestock manure (2-3 days).
b. Add water with a ratio of 1: 2 (one part dirt: two parts water). Stir until it is evenly mixed, then enter or flow it into the biogas digester.
c. Charging it through the inlet channel continuously until the biogas digester is full or filled with about 60% of the digester volume capacity. The full condition of the digester can be known by the mixture of material coming out through the outlet drain when charging.
d. After the digester is full, leave it for 13-20 days and ensure the position of control gas faucet and the outlet of discharged gas to the stove or application tool are closed. This aims to produce a space in anaerobic conditions to support the microorganism fermentation process.
e. After 14-21 days, the results of fermentation process will be seen and in general, the biogas in the form of methane gas (CH4) will accumulate in the top of the dome of biogas digester and be ready to use for cooking or lighting.
f. Biogas collected in the dome can be flowed directly to kitchen or put it into a 1 m^3 biogas bag to be applied to biogas-fueled stoves, lights and generators
g. A good quality of fire can be seen from its blue and not smoky flame. This shows clean fuel parameters.
h. During its use, the amount of biogas in the digester will decrease daily. Therefore, it is necessary to refill it by using fresh cow manure mixed with water every day with the aim of stabilizing biogas

production.

2.4.2. Water Boiling Test

Biogas testing as an alternative fuel to substitute fossil fuels is done by boiling 10 liters of water using LPG stoves, kerosene stoves, and biogas stoves. Stages carried out in biogas testing as an alternative fuel to substitute fossil fuels include the following steps

a. Preparing LPG stoves, kerosene stoves and biogas stoves.
b. Preparing three large pots of water each containing 10 liters of water and placed them on the three provided stoves
c. Turn on LPG stoves, kerosene stoves, and gas stoves at the same time and execute a calculation of the duration required of boiling water by using a stopwatch.

3. Results and Discussion

3.1. Integrated Farming System and Potential Waste Produced

Integrated farming system (IFS) is a system that combines several agricultural businesses such as farming, horticulture, livestock, fisheries, forestry, poultry farming, and anything that can be maintained and can provide benefits to farmers [5]. Integrated farming systems are based on the concept of biological recycling between agricultural, fishery and livestock businesses. Plant-based farming provides by-products in the form of feed for fisheries and livestock farming. Vice versa, fisheries and livestock businesses provide by-products in the form of fertilizers for plant farming. Fisheries businesses produce feed for livestock, while livestock businesses produce products for agriculture and feed for fisheries. The components of the integrated farming system carried out at PT SWEN are shown in Table 1.

Table 1: Components of an integrated farming system

Type of Business Conducted	Types of Commodity Cultivated
Agriculture	Organic vegetables (kale, chili, eggplant, long beans, tomatoes, mustard greens, pakcoy, and lettuce), oyster mushrooms and corn.
Livestock	Cows, sheep and chickens
Fishery	Catfish

According to [9], beef-cow business produces by-products which are waste or waste from cow products. Cow manure can be used as organic fertilizer (liquid or solid organic fertilizer) which could also be used for agricultural and biogas activities.

The cow farm business unit is the main means to support biogas production. Besides producing waste that can be used for biogas raw materials, cow farms also have a high selling value so they can be more profitable for farmers. In the integrated farming system, there are 3 cows in an enlargement period. Laying hen farming is a livestock business that is used in integrated farming systems at the research site. Laying hens used are 60 arabic chickens. Bedises the main daily results of eggs, these chicken farms produce chicken manure that potential to make biogas. According to [8], chicken manure should be seen as a by-product and not as livestock waste. One method that can be used is processing the manure into fertilizer or use it in the form of biogas. Other types of livestock combined in this system are sheep farms. The sheep raised are 10 wool-producing sheeps. The sheeps are producing sheep dung that can be used as biogas, and the fur -harvested every three months – are used as raw material for handicrafts, as well as the sale of sheeps. Integrated organic farming is done by using natural fertilizers in the form of solid fertilizers derived from processed manure used as raw material for biogas and the use of liquid fertilizer from livestock urine. The excess of organic farming can be used to feed the animals. In addition, in this integrated farming system, 2000 catfish are maintained. Catfish maintenance is carried out by feeding them regularly on a daily basis with a mixture of factory-made pellets and organic pellets made from the residual of cow dung waste. This shows that the waste produced from integrated farming systems can be used as a by-product and can be utilized further so that it can increase the profits obtained by the manager.

3.2. Biogas production from livestock manure in an integrated farming system

Biogas is a combustible material which is a combination of several gases (Table 2). Biogas consists of a large portion of methane (CH4) and carbon dioxide (CO2) gas and it is formed from the decomposition of organic compounds by anaerobic bacteria in the absence of oxygen. The gas formed is a waste product from decomposing microbial respiration and the gas composition depends on the decomposed substance. If the decomposed substances are dominated by carbohydrates such as glucose and other simple sugars and polymers such as cellulose and hemicellulose, methane gas production will be low. Whereas if the fat content is high, the production of methane will also be high [3].

Table 2: biogas composition

Gas	Concentration (%)
Metana (CH_4)	55 – 70
Karbon dioksida (CO_2)	30 – 45
Hidrogen sulfida (H_2S)	1 – 2
Hidrogen (H_2)	1 – 2
Amonia (NH_2)	1 – 2
Karbon monoksida (CO)	Low
Nitrogen (N_2)	Low
Oksigen (O_2)	Low

Source: [3]

Basically, raw material for making biogas comes from the substrate of organic matter or the rest of microorganisms for both those that have undergone decomposition or the fresh one. Most of raw materials that can be used for making biogas are residual waste of human activities, such as livestock waste, agricultural waste, industrial waste, water waste, and organic waste. The raw material used in making biogas in this study is livestock waste in the form of cow dung, chicken manure, and sheep dung.

Bacteria involved in anaerobic processes require several elements equal to the needs of living organisms such as food sources and optimum environmental conditions. Anaerobic bacteria consume carbon about 30 times faster than nitrogen. The relationship between the amount of carbon and nitrogen is expressed as a ratio (C/N), the optimum ratio for anaerobic digesters ranges from 20-30. If C/N is too low, nitrogen will be consumed quickly by methanogenic bacteria to meet their growth needs and only a few react with carbon, as a result the gas produced is low. Conversely if C/N is too high, nitrogen will be released and accumulate in the form of ammonia (NH4) which can increase pH. If the pH is higher than 8.5 it will show a negative effect on the population of methanogenic bacteria [4]. Based on Table 3, the applied and best farm waste from integrated farming to be used as raw material for biogas is cow dung with a C/N ratio of 24.

Table 3: Carbon and Nitrogen Ratios (C/N) from some organic ingredients

Organic ingredients	Ratio C/N
Duck manure	8
Human waste	8
Chicken manure	10
Goat manure	12
Pig manure	18
Sheep manure	19
Cow/buffalo manure	24
Water hyacinth	25
Elephant manure	43
Corn stalks	60
Rice straw	70
Wheat straw	90
Sawdust	>200

Source: [4]

Biogas production is carried out in the biogas digester. The size of the digester is adjusted to the amount of raw material entered every day. The raw material put into the digester undergoes a fermentation period of 30-40 days. The processing site must also be able to accommodate 40% of the gas produced within 24 hours. Table 4 shows the capacity of the digester based on the number of inputs of organic matter per day, and the maximum gas that can be preserved. In this study the capacity of the digester used was 4 m^3 capacity.

Table 4: Size of digester and quantity of material needed per day

Digester capacity (m^3)	Number of material required (kg)	Number of cows	Amount of water needed per day (liter)	Gas production per day (m3)
4	20	2 – 5	40	2 – 3
5	25	3 – 7	50	3
6.4	30	7 – 10	60	3.4
7	35	8 – 15	70	3 – 5
11	55	15 – 25	110	6 – 7
17	85	25 – 50	170	8 – 10

Source: PT SWEN Inovasi Transfer, 2009

A digester with the capacity of 4 m^3 or 4000 liters can be filled with 60% of livestock manure and water and 40% gas with a comparison of livestock manure and water is 1 kg of manure and 2 liters of water. The fermentation process lasts for 40 days, so it takes as much as 40 liters of water and 20 kg of manure every day. The production of fresh livestock manure per day is presented in Table 5.

Table 5: Production of fresh livestock manure per head per day

Type of livestock	Livestock Weight (kg / head)	Manure Production (kg / day)
Beef cattle	400 – 500	20 – 29
Dairy cows	500 – 600	30 – 50
Laying hens	1.5 – 2.0	0.10
Broiler	1.0 – 1.5	0.06
Adult pig	80 – 90	7.00
Sheep	30 – 40	2.00

Source: United Nation 1978

According to the Chengdu Biogas Research Institute (1989), every kilogram of dung of cows or buffalos can produce 0.023 - 0.040 m3 of gas. This shows that 20 kg of manure that enters the digester per day can produce biogas as much as 0.46 - 0.8 m3 per day, equivalent to 460 - 800 liters. Based on previous research, the daily production of biogas from a cow ranges from 600-1000 liters per day. 2 cows kept for enlargement process can produce biogas as much as 1200 - 2000 liters per day so that biogas production can meet fuel needs for household scale since generally, the average energy required for cooking of a family is 2000 liters of biogas.

3.3. Utilization of Biogas as an Alternative Fuel

The technology of organic material fermentation is one of the simple energy diversification efforts that is easy to be developed in Indonesia. In addition, it can also be used as an electrical energy producer because it has a large enough calory value. The ability of biogas as an energy source depends on the amount of methane gas. Every 1 m^3 of methane is equivalent to 10 kWh. This value is equivalent to 0.6 liters of oil fuel. As a power plant, the energy produced by biogas is equivalent to 60-100 watts of light for 6 hours of lighting [1].

Table 6 shows the application of 1 m^3 of biogas to the length of time of a biogas stove work on and a biogas-fueled electric generator, both for gas that goes through the refining process with and without desulfulizer. The biogas stove can work non-stop for 59 minutes with a 1 m^3 biogas bag, while for an electric generator it can turn on for 49 minutes for unpurified and 40 minutes for purified biogas. Purified biogas using desulfulizer is very necessary for electric generators because H2S is corrosive that can cause rust on the engine. In addition to this potential, biogas is used for several equipment such as water pumps, rice cookers, ovens, water heaters, heaters, irons, and tractors / plows.

One of the use of biogas as an alternative fuel is the use of biogas stoves for cooking activities. A biogas stove has a similar way of working as LPG gas stoves. The difference is the energy sources. The advantage of a biogas stove is producing an evenly blue flame, with similar heat generated as LPG gas-fired stoves, and the gas produced by biogas stove is harmless, non-toxic and does not produce soot. Based on the research by [2], gas produced from anaerobic or biogas processes contains 45% methane gas. In general, the burned methane gas will produce a blue color flame that is not easily extinguished.

Table 6: Storage Bag Filling Time and Application

Type	Unpurified	Unpurified	Purified	Purified*
Stuffing Time	15 min 20 s	10 min 38 s	39 min 05 s	32 min 42 s
Generator	45 min 41 s (260V)		40 min 28 s (260V)	
Stove	59 min 44s		59 min	

*Biogas stored in the bag. Biogas before use can purified by desulfurizer.

Table 6 shows that a stove with biogas fuel can boil 10 liters of water in 40.35 minutes.

Table 7: Comparison of the duration of boiling water by using kerosene, LPG and biogas fuel

Fuel	The average boiling time is 10 liters of water (minutes)
Biogas	40.35
Kerosene	59.14
LPG	30

The time needed to boil 10 liters of water on this biogas stove is faster than kerosene stoves but slower than using LPG gas stoves. The difference of speed in boiling water can be influenced by the differences of the flame color, where kerosene produces yellow flame while LPG and biogas produce blue flame. According [7], the yellow color of the flame is caused by the presence of soot radiation. Soot, as a result of carbon radiation, give a little chance of fuel and air, acting as oxidizers, to meet. Less heat then being produced.

Figure 1: Biogas Utilization by farmers with communal systems in Bangka Regency

Based on this research, it can be seen that biogas can be used as an alternative fuel by utilizing waste from livestock or integrated farming.

The use of biogas as an alternative fuel for cooking delivers many advantages. Besides more efficient than using kerosene, it can save family expenditure for buying fossil fuels. It avoids fuel shortages, and people who use the biogas participate in mitigating greenhouse gases. It also reduces the negative impact of livestock activities.

Figure 1 above shows that beef cattle breeders in Bangka Regency have used biogas. They use biogas bag with a capacity of 1 m^3. Every time they come to feed cattle in the stalls, they go home carrying a bag of biogas for cooking needs every day.

4. Conclusion

Based on the analysis, the results show that integrated agricultural waste in the form of livestock manure can produce biogas and by-products in the form of organic fertilizers that can be utilized by farmers as input for production activities and for sale. Manure from one cow can produce biogas around 600-1000 liters per day. The use of biogas as an alternative fuel, such as the use of biogas stoves, can save money to buy fossil fuels. It avoid scarcity of fossil fuels. People who use biogas participate in mitigating greenhouse gases. It can also reduce the negative impact of livestock activities. Using biogas in a group scale is more efficient by "come with the grasses, go home with the biogas".

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