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Biogas Potential from the Treatment of Solid Waste of Dairy Cattle: Case Study at Bangka Botanical Garden Pangkalpinang

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Abstract

Bangka Botanical Garden is an integrated cattle farm treating cattle solid waste as an energy source to produce biogas as fuel for gas stoves. At present, they make use of 132 kg of cattle waste from 5 cows and produce only 1 m^3 of gas per day. This paper will discuss energy need, economic and environmental aspects of using cattle waste to produce biogas and the use of biogas to satisfy the need for electricity in the BBG farm. This study is descriptive in character. The data were collected through observation, measurement and interviews with informants. The biogas obtained could be used to provide lighting in the pens amounting to 60-100 W for 50 hours, as automotive fuel for a 1 HP engine for 17 hours, producing 39 kWh of electricity sufficient to cook three dishes for 40-48 servings. Producing 39.48 kWh of electricity per day, the generator could supply electricity in BBG farm using 35 light bulbs of 25 W each, switched on 12 hours per day. Thus, the electricity needed for lighting was 10 kWh per day. The milking machine needed 0.55 W per milking, or 1.1 W per day of two milking. The rest of the energy could be used to run water pumps, mowers and welding machines. The BBG farm needs to increase the efficiency of digester use by employing the inactive digester and improve the electricity installation for lighting.

Keywords: Biogas; Cattle; Energy; Potential

Introduction

Human beings need energy for their activity, and so does economy. Energy can be obtained from renewable natural sources and nonrenewable mineral sources, which takes a very long time to reproduce. Energy consumption in Indonesia has increased from time to time. Elinur et al. [1] stated that Indonesian crude oil reserves would be exhausted in 23 years, gas reserves in 59 years, and coal in 82 years.

According to the Mineral Resources Data and Information Center of the Ministry of Energy and Mineral Resources [1] unwise use of energy not only would exhaust the mineral resources but would also cause environmental pollution, through excessive emission of CO_2 and other green house effects. CO_2 emission, according to the Basic Scenario or Business as Usual (BAU) would increase to 1000 million tons in 2020 and would increase further to 2129 million tons in 2030. According to the scenario, the mitigation of CO_2 emission could reduce this to 706 million tons in 2020 and to 1219 million tons in 2030. The sources of CO_2 emission are coal (50.1%), natural gas (26%), and mineral fuel (23.9%). The industrial sector is the biggest contributor of CO_2 emission, followed by homes, transportation, commerce and farming, construction and mining.

Energy diversification is one of the solutions to the energy crisis threat in this country. Conservation could be done through energy saving and developing renewable energy sources, which of course, should be supported by government policies, which are environment-conscious. One of the renewable energy sources is biogas. Biogas can be produced from animal waste, tofu industry waste, organic waste from homes and traditional markets. Biogas has the potential to become an alternative renewable energy source in Indonesia, experiencing energy crisis, marked by the increasing scarcity and price of mineral fuel, resulting in high cost of electricity power production. Wahyuni [3] stated that biogas could create fire sparks with the power of 6400-6600 kcal/m^3. The energy content of 1 m^3 biogas equals that of 0.62 liter paraffin, 0.46 liter LPG, 0.52 liter diesel fuel, 0.08 liter gasoline, and 3.5 kg wood. Hanif's study [4] found that one cow could produce 25 kg waste. Thus, 411 animals could produce 10,275 kg waste with dry material content of 2,055 kg, which could produce 82.2 m^3 of biogas per day. 1 m^3 biogas could produce 4.7 kWh of electricity. Therefore, 441 cattle have the potential to produce 386.6 kWh of electricity per day. According to Hardianto et al. [5] there are three advantages of treating cattle waste to produce biogas, namely: 1) biogas can be used as alternative fuel instead of oil fuel or wood with a high heat quality, 2) the fluid sludge can be used as fertilizer, and 3) the solid sludge can be used as mixture of animal feed. According to Arifin et al. [6] in Saung Balong Pesantren (Islamic Boarding School), they had made a biogas pilot plant that produced 7 m^3 of gas per day. The gas was used for the Pesantren's daily need, for cooking and lighting, and used to run a pure biogas generator producing 1,000-10,000 W (10 kW) using dual fuel system and had made biogas enrichment though absorption and putting biogas in tanks. The electricity produced by the biogas installation in Saung Balong Al-Barakah could reduce dependence on the electricity supplied by the state electricity industry (PLN).

The BBG farm is a farm inside the Integrated Farming Area (KUTBBG), owned or organized by *Yayasan Bangka Go Green* (Bangka Go Green Institute), located on the coast of Pantai Pasir Padi, Pangkalpinang, the Province of Bangka Belitung Islands. The BBG farm covers an area of 312 ha in the middle of the Ketapang Industrial and Harbor Area. KUTBBG is located in Bukit Intan Sub-Ditrict, the Kelurahan (Village) of Temberan. The daily activity of BBG is growing dairy and beef cattle, using the government supplied electricity

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produced by the state electricity industry (PLN). The electric energy is used to run the water pumps, milking machines, lighting, workshop/welding, and mowers/choppers. Meanwhile, for cooking the BBG farm has used the biogas produced through cattle waste treatment.

The main problem faced by the farmers was that the electricity was often off. This frequent turning-off of electricity has negative consequences, as it disturbs the farmers' activity and has a bad effect on the electrical appliances. The switching off electricity also damages the electronic appliances. The BBG farm has two biogas installations, but only one unit is active, because the other unit is too far from the pens. The active biogas installation supplies energy for the farmers' cooking stoves. Every day the farmers only use 2 wheelbarrows or 132 kg of cattle waste.

Weight measurement of dairy cattle was done using 42 sample cattle and measurement was successful from 17 cattle, because the rest are too aggressive. Chest measurement was done using a chest measurement tape, because the farm does not have a cattle scale. According to the *Schoor formula*, Cattle weight (kg) = (chest measurement (cm) + 22)^2: 100. Based on the results of measurements of bust 17 dairy cows gained weight average dairy farm in Bangka Botanical Garden is 432.07 kg / head as shown in Table 1.

The integrated farm area of Bangka Botanical Garden (KUTBBG) Pangkalpinang integrates plantation, fishery and animal husbandry. The initial concept of the KUTBBG planning applied the zero-waste system, where the animal waste was only used as fertilizer, while the leaves from the plantation were used for animal feed. Some of the animal waste was later processed to make compost and some to produce biogas for daily need of gas for cooking stoves. With 2 digester units and the ample availability of waste from the dairy cattle, the use of the animal waste potential had not been to the maximum. The problem was that one unit of the biogas installation was too far from the dairy cattle pens. If the digester in BBG farm were used efficiently, the dependence on the state supplied electricity could be reduced, thus saving electricity and fuel. Electricity needed in the BBG farm was 875 W, for 35 light bulbs of 25 W, 0.55 W for milking machine, for 1 AC Unit, for 1 mower/chopper, 1800 W for water pump, and for workshop/welding. This article will discuss the energy use problem, the economy and environmental advantage of using cattle waste to produce biogas and the use of biogas to supply the electricity need of the BBG farm.

No	CM (cm)	BW (kg)
1	188	441.00
2	180.5	410.06
3	187.5	438.90
4	164	345.96
5	203	506.25
6	186	432.64
7	175	388.09
8	190	449.44
9	172	376.36
10	181	412.09
11	178	400.00
12	194	466.56
13	188	441.00
14	202	501.76
15	197	479.61
16	196	475.24
17	173	380.25
Average weight (kg)		432.07

Table 1: Cattle Weight Measurement Result (*Source: Primary Data Measurement Result*, 2013).

Study Method

The study was done at the farming complex as part of the Integrated Farming Area of Bangka Botanical Garden. The cattle population was 223, consisting of dairy cows, bulls and calves. We studied only 42 cattle, because they live in one pen, close to the biogas installation. Observing every step in raising the cattle. Secondary data were obtained through literature study and documents related to the Integrated Farming Area of BBG (KUTBBG). The pen janitors acting as informants consist of 4 persons from the dairy section, 2 persons from the bull section, and 6 from the calf section, and 1 nutritionist and 2 grass cutters, 2 persons from the composting section, 1 person from the biogas section. Biogas potential analysis was done by multiplying dairy cow waste mass and dry material content and converted to the amount of gas obtained (m^3) so that we got the daily biogas volume from 42 dairy cows.

Environment aspect analysis was done by calculating greenhouse gas emission formula quoted from the Indonesian Ministry of Environment, that is:

GG Emission = Ai × EF_i

GG Emission = Greenhouse gas emission (CO_2, CH_4, N_2O)

Ai = type i material consumption, or the amount of i product.

EF_i = Emission Factor of i type material or i product.

The treatment of 1 ton CO_2 of greenhouse gas emission based on Kyoto Protocol requires 30 Euros. By using biogas, the BBG farm could help reduce the amount of greenhouse gas emission.

Results and Discussion

Biogas potential as energy source

Farming Mechanization Development Center in Serpong has studied the biogas use obtained from cattle waste for lighting and cooking stoves. Biogas is feasible technically and economically to use as energy source. The feasibility of biogas use in electricity generators has also been studied [7].

The BBG farm owns 223 heads of cattle, consisting of dairy cows, bulls and calves. As the cattle waste was not only treated in digester to produce biogas, but also composted to become fertilizer, so far the digester with a capacity of 4 m^3 has been using only 2 wheelbarrows or 132 kg of dairy cattle waste to produce gas. The produced gas was used only as fuel for cooking stoves and not as fuel for electric generator for lighting or other appliances using electricity. According the informant from the biogas section, biogas had been used to supply energy for generating electricity for lighting in the pens before the blockage and damage in the digester, resulting from the hard material in the feces, containing heavy copra residue that could not be removed and thus precipitated at the bottom of the digester. Up to now the digester has not been used any more to produce gas for lighting in the pens.

The number of dairy cows in the BBG farm is 42, weighing 450-500 kg. With the number of cattle in the farm, it has the potential to produce enough biogas as a source of energy to provide electricity and satisfy the fuel need in the husbandry section. Cattle waste is the most efficient material to produce biogas, because each 10-20 kg of waste per day can yield 2 m^3 of biogas. As the energy contained in 1 m^3 biogas is

2000-4000 Kkal, it is sufficient to provide cooking fuel need of a family (4-5 persons) for 3 hours [8].

From the chest measurement, we could roughly determine the weight of the dairy cows in the BBG farm is between 400 and 500 kg. According to Riliandi [9] a mature dairy cow can produce 25 kg of feces per day. Similar statements were made by Wiryosoehanto, Soedono and Solihat that a lactating dairy cow weighing 450 kg could produce around 25 kg of urine and feces per day. Therefore, we could assume that each dairy cow in the BBG farm produced 25 kg of waste per day.

Each dairy cow weighing 450 kg has the potential to produce 25 kg of feces and urine per day. According to the Farming Mechanization Development Center, Ministry of Agriculture's Research and Development Department (2008) quoted by Hanif [4] that 25-30 kg of cattle waste contained 20% dry material and biogas produced is 0.023 – 0.040 m^3/kg of dry material. With the number of dairy cows in the BBG farm, 42 heads, the farm has the potential to produce 1,050 kg per day.

The total dry material content of cattle waste is 20% of the wet waste, 210 kgDW. According to the United Nations (1984) as quoted by Widodo [10], 1 kg of cow or buffalo waste can produce 0.023 – 0.040 m^3 of biogas. Thus, the BBG farm's total potential to produce biogas from cattle waste is 8.4 m^3 per day as shown in Table 2.

Environment aspect analysis

Indonesia is assumed to be the third largest contributor of greenhouse gas emission in the world, after China and the United States. In 2006, FAO produced a report titled "*Livestock's Long Shadow*" with the conclusion that animal husbandry was one of the main causes of global warming. The animal husbandry's contribution to global warming was 18%, bigger than that of transportation, which contributed 13.1% [11]. Meanwhile, world's husbandry contributed 37% methane and 65% dinitrogen oxide (IPCC 2001) [12].

Methane emission factor from dairy cow's digestion fermentation is 61 kg per head. We thus know that the BBG farm contributes 13,603 kg of methane emission or 340,075 kg CO_2e gas emission per year. If the waste produced by 42 cows were optimally used to produce biogas the methane emission reduction would be 2,562 kg of reducing CO_2e emission of 64,050 kg per year.

The treatment of 1 ton CO_2e emission following the GHG emission based on the standard Kyoto Protocol costs 30 Euros, when 1 Euro = Rp 12,000 (June 2013), the cost for 1 ton CO_2e emission treatment was Rp 360,000. Thus, if the dairy cow waste in the BBG were optimally used to produce biogas, there would be a cost saving in treating CO_2e emission amounting to Rp 23,058,000 per year.

	BBG Dairy Farm
Gas production benchmark per kg of waste (m^3)	0.023 – 0.04
Cattle waste dry material content *)	20%
Daily dry waste (kg/day)	210
Daily biogas potential (m^3/day)	8.4

Source: Processed primary data (2013) *): United Nations (1984) in Widodo (2004)

Table 2: Biogas Potential (m^3/day) in Dairy Cow Solid Waste (Feces) in BBG Farm.

	BBG Dairy Cattle Farm
Daily biogas potential (m^3/day)	8.4
Pen lighting (60 - 100 watt light bulb)(hour)	50
Energy source to run 1 HP engine (hour)	17
Electricity (kWh/day)	39
Cooking 3 dishes for 5 – 6 persons (servings)	40 - 48 servings

Source: Processed Study Data (2013)t

Table 3: Energy Conversion Based on Cattle Waste Potential (m3 Biogas) in Dairy Cattle Farming Activities in BBG Farm.

Biogas use management

The calorie content of biogas makes it feasible for use in everyday activities, such as drying, lighting, and work requiring heat, like welding. As a fuel to run engines, biogas should be cleaned from the corrosive H_2S gas. There need to be some modification in the carburetor to make it feasible to use as engine fuel. The engines run by biogas fuel could be used in electric generators, water pumps and the like [13].

According to Suriawiria energy from 1 m^3 of biogas could be used to provide energy for a 60-100 W light bulb for 6 hours, for cooking 3 dishes for 5-6 persons, and could run a 1 HP motor for 2 hours. It is known that 1 m^3 of gas can be converted to 4.7 kWh of electricity [4,14].

Biogas produced from 42 dairy cows in the BBG farm could replace electric energy source to provide 60-100 W lighting for the pen for 50 hours, as fuel to move a 1 HP engine for 17 hours, producing 39 kWh of electricity and cooking 3 dishes for 40-48 servings. By producing 39.48 kWh/day, the BBG farm could use the biogas as electric energy source, with 35 light bulbs of 25 W for 12 hours/day. Lighting need is 10 kWh/day. The milking machine needs 0.55 W, thus 1.1 W for two daily milkings. The rest of the energy could be used to run the water pump, the mower/chopper and welders.

Conclusion and Suggestions

Processing dairy cow waste to produce biogas is feasible and highly recommended in the BBG farm, because besides reducing the negative environment impact, it could increase profit and save fuel and electric energy. The biogas potential produced from 42 dairy cows is 8.4 m^3/day. The biogas could be used to provide 60-100 W lighting in the pen for 50 hours, to run a 1 HP engine for 17 hours, producing 39 kWh of electricity and to cook 3 dishes for 40-48 servings. At present the BBG farm use only 132 kg of animal waste, using waste from only 5 cows, producing only 1 m^3 of gas per day. Therefore, there should be more efficient use of the existing digester, use more digesters, maximize the use of waste from 42 heads of dairy cattle, reinstall the electric installation to provide energy for 35 light bulbs of 25 W in the BBG farm complex, reuse the other digester by moving it closer to the cattle pens.

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