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Application of small digester biogas for energy supply in rural areas

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Abstract. Village's self-fulfillment of energy supply is a new concept being developed in Indonesia. Villages are expected to meet their own energy needs without relying on fossil-fuel and other non-renewable energy materials. The concept of village's self-fulfillment of energy here includes two types of provision: the provision of electrical energy and the provision of bio-fuel by utilizing environmentally friendly renewable energy. Biogas is an alternative energy sources produced by anaerobic activities of organic materials such as human and animal feces, or domestic waste in rural communities. In general, rural farmers have 2-4 cows. It is assumed that cows/cattle produces ± 15 kg feces/head/day. A digester with 4m³ capacity potentially produces bio-gas per day that reaches 1.34 m³ equivalent to 6.30 kWh/day. This volume of bio-gas can be used for lamp lighting of 60-100 watts for 8 hours. Other applications that can be utilized are biogas stove. A family of farmer can use 2 stoves to cook 3 food recipes for 8 people and a generator for 1 hour. There is also potential solid mud of 40 kg that produces 8 kg of compost/day and potential sludge fluid as much as 160 liters including bio-urine of 32 liters/day. This paper discusses about the potency of small biogas digester application for village's self-fulfillment of energy supply.

1. Introduction

Energy demand is obtained through global energy supply where its availability is limited or irreversible. Energy consumption during the year 2000 - 2014 is still dominated by fossil fuel (gasoline, diesel fuel, kerosene). The consumption of electricity during 2000 - 2014 in average grew 6.8% per year. This excessive utilization of energy drives energy crisis that systemically give an impact to all aspects.

To date, villages in remote areas have not been reached by the power grid from State Electricity Company or PLN/Perusahaan Listrik Negara or State Electricity Company. According to Bureau Central of Statistics/ BPS (2015), there are about 15.4% or more than 12,000 villages have not been reached by



electricity till end of 2014. A total of 31,387 villages are having only minimum lighting along their main roads.

Several limitations faced to provide electricity for a village are : 1) State Electricity Company requires road access to the village destination for developing its electric network, while in Indonesia, most of villages have no road access; 2) The use of fossil fuel for a generator makes it expensive though most of the villages are poor; 3) Potential renewable energy sources in all rural areas also require an expensive preparation cost plus the lack of knowledge of the technology; 4) Private investors are not interested in funding electricity in rural areas because it is not profitable; 5) Technical issues of extending the distribution including land acquisition and legal certainty; 6) The relatively small allocation of government budget comparing to the total area coverage.

The complexity of energy problems in Indonesia requires a comprehensive national energy management through a clear and measurable National Energy Policy. On that basis, Act no. 30 of 2007 on Energy mandates the drafting of National Energy Policy (KEN) as a guide in national energy management. The basic principles that become the reference in the drafting process of KEN as mentioned in Act no. 30 year 2007 article 1 point 25 are the principle of justice, sustain-ability and environmentally friendly in order to achieve the self-fulfillment and national energy resilience with policy direction of realizing energy security in order to support sustainable development.

Village's self-fulfillment of energy supply is a new concept developed in Indonesia. It means as a village where its people have the capability to meet more than 60% of their energy needs (electricity and fuel) of renewable energy generated through the utilization of local resource potencies.

One of the alternative energy is the utilization of biogas energy. Biogas can be categorized as bioenergy, because the energy comes from biomass. Biomass is a relatively young organic material derived from living things or cultivated products and industrial wastes (agriculture, plantations, forestry, animal husbandry, and fisheries).

The potency of livestock waste as one of raw materials required for biogas production can be found in rural areas where most people have livestock. Waste farms such as feces, urine and cattle feed residue is one source of materials that can be utilized to produce biogas. Biogas is a renewable energy that can be used as an alternative fuel to replace fossil fuels such as kerosene and natural gas. The issues to be discussed are:

1. What is a biogas
2. How is the process of cow feces to become biogas energy as an alternative energy supply in rural areas
3. How to utilize biogas from cow feces as an alternative energy

2. Literature Review

2.1. Biogas

Biogas is a gas fuel (biofuel) and renewable fuel produced by anaerobic digestion or anaerobic fermentation of organic matter with the help of methane bacteria such as *Methanobacterium* sp. The materials that can be used as raw material for biogas production are biodegradable materials such as biomass (non-fossil organic material), dirt, solid waste from rural activities and others. However, biogas is usually made from livestock feces such as cattle, buffalo, goats, horses, and others. The main content of biogas is methane gas (CH₄) with a concentration of 50-80 vol. Gases in biogas that can act as fuel are methane gas (CH₄), Hydrogen gas (H₂), and Carbon monoxide (CO) gas.

Methane (CH₄) is an important and major component of biogas because of its usefulness and has a high calorific value (Table 1). It is an odorless and colorless properties. If the gas produced from this anaerobic fermentation process can burn, it contains at least 45% of methane gas. For pure gas (100%), it has a calorific value of 8,900 kcal/m³. With high heating value, biogas can be used for cooking purposes, lighting, and the source of prime movers.

Table 1. Main composition of biogas

No.	Gas	Hadi (1981)	Price (1981)
1	Methan (CH ₄)	54-70 %	65-75%
2	Carbon dioksida (CO ₂)	27-35 %	25-30%
3	Nitrogen (N ₂)	0.5-2.0 %	<0.1%
4	Hidrogen (H ₂)	-	<0.1%
5	Carbon monoksida (CO)	0.1 %	-
6	Hidrogen sulfida (H ₂ S)	Low	<0.1%

Source: Hambali (2007)

2.2. Materials Producing Biogas

A small-scale farms or rural household can keep 2-4 cows. Biogas from livestock manure has a nutritional balance, easy to be diluted and biologically processable. The biological processing range between 28-70% of organic matter depends on its feeding condition. The production of fresh livestock feces shown in Table 2.

Table 2. The production of fresh livestock feces per day

No.	Categories	Weight (kg/unit)	Production (kg/day)
1	Beef Cows	400-500	20-29
2	Milk Cows	500-600	30-50
3	Eggs Hen	1.5-2.0	0.10
4	Meat Hen	1.0-1.5	0.06
5	Pig (mature)	80-90	7.00
6	Sheep	30-40	2.00

2.3. Biogas Process

Biogas physically is a gas. The process of its formation requires a tight or closed condition of space in order to be stable. Biogas is formed through several processes that take place in an anaerobic space or without oxygen. This ongoing process also gives ecology advantage because it does not produce odor.

Anaerobic microorganisms

Organic materials ----> CH₄ + CO₂ + H₂ + NH₃

2.4. Biogas Digester

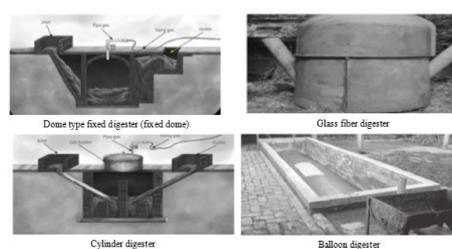


Figure 1. Types of biogas digester

To produce biogas, a biogas generator called a digester is needed. There are several types of digester based on the raw material of manufacture that is dome type fixed digester (fixed dome), cylinder digester, balloon digester, and glass fiber digester (Figure 1).

2.5. The main components of bio-digester

The main components of biogas include digester equipped with an inlet and outlet, gas shelter, and sludge shelter (waste in solid and liquid form) (Wahyuni 2017).



Figure 2. Biogas components

2.6. Bio-digester supporting components

Supporting components of bio-digester are added to produce biogas in large quantities and safe to be used such as installation of biogas pipes, biogas pumps, biogas container bags (Figure 3), manometers, and valves or gas taps (Wahyuni 2017).



Figure 3. Biogas container bags

2.7. Biogas Process

According to Wahyuni (2017), measures of making biogas from waste material of livestock manure.

1. Prepare the raw material of fresh manure (2-3 days)
2. Add water with a ratio of 1: 2 (one part of dirt: two parts water). Mix them well, then insert or wash them into biogas digester

3. Perform filling through the inlet channel continuously until the biogas digester is filled with 60% of its volume capacity. Full digester condition is detected by the presence of a mixture of material out through the outlet discharge at the time of filling
4. After the digester is full, let it stand for 13-20 days. Be sure that the position of the control gas faucet and the spraying gas faucet extending into the stove or application tool are closed. It aims to produce a room in anaerobic conditions to support the fermentation process of microorganisms.
5. On day 14-21, the result of the fermentation process will be visible and usually biogas in the form of methane gas (CH₄) will accumulate at the top of the biogas digester dome and ready for use for cooking or lighting.
6. Filling of biogas materials can then be done daily, about 10% of the digester volume. The remaining processing of biogas material in the form of sludge will automatically come out from the outlet whenever the biogas material is filled. The residues of biogas processing materials are manure/organic fertilizer, both in wet and dry conditions.

3. Results and Discussions

3.1. Biogas energy conversion and electricity

A cow with a weight of 450 kg produces a waste of 25 kg/day of feces. The number of cows owned by the people in rural areas on average are 2-4 cows. So the production of cow feces per day is $2 \times 25 = 50$ kg/day. The content of dry matter (BK) for cow feces is 20%, then the total dry matter content is: $50 \times 0.20 = 10$ kg. BK. So the potency of biogas of 2 cows is $10 \times 0.04 = 0.4$ m³/day. The potency of electrical energy generated from feces of 2 cows owned by villagers on average is $0.4 \text{ m}^3 \times 4.7 \text{ Kwh} = 1.88$ Kwh/day. The potency of gases generated from different types of feces and conversion of biogas into the energy are presented in Table 3 and Table 4.

Table 3. The potency of gases generated from different types of feces

No.	Types of feces	Dry materials (BK)	Gas produced (m ³)
1	Cows or buffalo	20	0.023-0.040
2	Pig	9	0.040-0.059
3	Hen	28	0.065-0.116
4	Human	11	0.020-0.028

Table 4. Conversion of biogas into other energy

No.	Utilization	Energy 1m ³ biogas
1	Lighting	Lamp of 60-100 watt for 6 hours
2	Cooking	Cooking 3 recipes of food for 5-6 people
3	Horse Power	Running a motorcycle 1 hp for 2 hours
4	Electricity	4.7 Kwh electric energy

3.2. Conversion of biogas to other substitution of energy

The biogas produced is used as an alternative energy substitution for personal needs. In this activity, income estimation is derived from liquid petroleum gas (LPG) expenditure which can be saved through the use of biogas generated and based on biogas energy equivalence on LPG. A cow produces 25 kg of feces/day. 1 kg of feces is equivalent to 0.06 m³ of gas. If a household in rural areas has 2 cows, then $0.06 \text{ m}^3 \times 50 \text{ kg} = 3 \text{ m}^3$ gas. In 30 days (one month), 2 cows produce gas equivalent to 90 m³. For conversion, 1 m³ biogas is equivalent to 0.46 kg LPG gas. Then 90 m³ biogas is equivalent to 41.4 kg LPG. The highest retail price of LPG at this time is IDR150,000.00/12 kg (12 kg LPG contains 26.2 liter) or equal to IDR5,700.00/liter. The LPG energy content is 49.51 MJ/kg, while the biogas (70% methane) is 35 MJ / kg, so the biogas energy equivalence is 70% to LPG energy. Biogas production of

2.4 Nm³/day or 72 Nm³/month, the usage of LPG which can be saved in one year is IDR2,297,872.00 or about IDR191,490.00/month. Conversion with kerosene for 1 m³ biogas is equivalent to 0.62 liter. Biogas production for a month from 2 cows by 90 m³ is also equivalent to about 55.8 liters of kerosene.

3.3. Side results of biogas

The material from livestock digestion is used as raw material for composting with the use of effective microorganism (EM). This compost is sold IDR400.00/kg or IDR20,000.00/sack. It is assumed that the compost from digestive waste is 40% of the weight of the input feces per day. If 2 cows produce 40 kg/day of feces, the compost produced per year is equivalent to 3650 kg. With the sale price mentioned above, then the additional income per year from the sale of compost in average is IDR1,460,000.00/year or about IDR121,667.00/month. Summary of income estimated from bio gas development activities derived from the feces of 2 cows is in Table 5.

The potency of urine. A cow with a weight of ± 300 kg produces urine 8-12 liters per day, while ± 250 kg cows produce urine 7.5-9 liters per day (Adijaya *et al.* 2008). Cow's urine can be used as organic fertilizer (Maurer *et al.* 2006). Cow's urine is converted into liquid fertilizer known as biourine through a fermentation process involving the role of microorganisms. The amount of biourine produced reaches 40 liters x IDR700.00 (price) x 30 days then the income from biourine reaches IDR840,000.00/month.

Table 5. Revenue from the development of biogas with the capacity of digester of 2 cows

Revenue	Total	Price per unit	Total revenue per year
Saving LPG	876 Nm ³ /tahun	IDR3,220.00/Nm ³	IDR 2,820,720.00
Selling compost	3650 kg/year	IDR400.00/kg	IDR 1,460,000.00
Biourine	14,400liter/tahun	IDR700.00/liter	IDR10,080,000.00
Total revenue per year			IDR14,360,720.00



Figure 4. Biogas application

4. Conclusions

Biogas is gas fuel and renewable fuel from organic matter and resulted by anaerobic fermentation. Manures which produce by two cows can result on average is 0.4 m³ biogas/ day and equivalent to electrical energy equal to 1.88 Kwh/ hari. Biogas can used as alternative energy to substitute the use of LPG. In addition, biogas produced side result such as compost and biourine.

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