Study of Biogas Energy Potential from Pig Waste of Pelambian Hamlet, Salusopai Village, North Toraja District

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Abstract: National energy sources still rely on non-renewable fossil-based raw materials, so new breakthroughs are needed to develop renewable energy such as biogas. This study was carried out in Pelambian Hamlet. Salusopai Village. North Toraja Regency with the aims to analyze the potential and benefits of biogas energy development from pig waste and formulate its development strategy in Pelambian Hamlet. Data collection was carried out through questionnaires to the residents of Pelambian Hamlet. Salusopai Village to find out the information of livestock and energy needs. The development of biogas energy can used to replace the fossil fuels and the substitution of LPG energy into biogas has benefits the economic ad environment which reduces the impact of pollution from pig waste and produces fertilizer from waste that has gone through the fermentation process. The calculation of biogas energy potential is based on the dry matter content of pig manure. The obtained result demonstrated the biogas energy potential is 9.17 m3/day or equivalent to 4.22 kg LPG/day. The strategy to develop biogas energy from pig waste is to build biogas installations, optimize the use of slurry as fertilizer, build concrete fixed-dome digesters, optimize existing pigs, maximize absorption of DAK in accordance with existing regulations, conduct socialization and training in making biogas installations, making and strengthening a group of pig farmers in Pelambian Hamlet.

Keywords: Biogas Energy, Fixed-dome digesters, Pig Waste, Renewable energy

I. INTRODUCTION

Increasing energy needs must be balanced with adequate energy supply. The source of national energy highly relies on the non-renewable resources which may run out one day. Therefore, new breakthroughs are needed to develop renewable energy such as biomass, biogas, solar, and wind. Based on Wahyuni (2013), one of the largest greenhouse gas emitters came from the livestock sector, which was 18%. Farm waste can also cause water pollution when entering water bodies [1]. The waste produced can become a complementary local energy source [2, 3]. Therefore, efforts are needed to treat these wastes so that they are more useful and reduce environmental pollution, including through biogas technology with the concept of zero waste [4].Biogas is a mixture of gas produced by methanogenic bacteria that occurs in materials that can be naturally removed under anaerobic conditions [5]. In general, biogas consists of methane gas (CH4) 50 to 70%, carbon dioxide (CO2) gas 30 to 40%, hydrogen (H2) 5 to 10%, and other gases in small amounts [6]. The calorific value of 1 m^3 of biogas is equivalent to 0.6-0.8 liters of kerosene, 0.52 liters of diesel. According to Suriawiria (2005) in Hanif (2010) work, 1 m^3 of biogas is equivalent to 4.7 kWh of electrical energy [7]. The comparison of biogas with other fuels is shown in Table 1.

According to United Nation (1984) in Wahyuni (2015) [6] and the Indonesian Ministry of Agriculture (2008) [8], the production of pig waste with a weight of 90 kg is approximately 7 kg/day or 7.77% of body weight, with a dry matter content of around 9%. Meanwhile, according to LGED (2006) in Simeon (2009), pigs weighing 50 kg have a production of 0.5 kg/day of waste or 10% of body weight with 20% dry matter content [9].

Table. 1 Comparison of biogas with other fuels [6]

Information	Other fuels	
1 m^3 of Biogas	0.46 kg of LPG	0.80 liters of gasoline
	0.62 liters of kerosene	1.50 m3 of gas box
	0.52 liters of diesel oil	3.50 kg of firewood

Based on data from the North Toraja District Animal Husbandry Office in 2014, the number of pig population in North Toraja was 298,895. With a large population of pigs, there will also be a lot of pig waste generation which will certainly pollute the environment if it is not managed properly. Besides that, the power generation system using biogas generated from the waste of pig farm also been study [10]. Therefore this study identified the benefits gained from the development of biogas energy from pig waste and determines the potential amount of biogas energy that can be generated from pig waste in Pelambian Hamlet, Salusopai Village.

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II. RESEARCH METHODS

The study was conducted for 2 months (April to June 2016) in Pelambian Hamlet, Salusopai Village, Salu District, NorthToraja Regency. The secondary data such as number of pigs is obtained from the database of North Toraja District government agencies. The primary data are collected from the questionnaires and interviews regarding the farm conditions and energy needs. Besides that, the primary data collection was also carried out to find out the dry matter from the manure of adult pigs and child pig. The samples of pig manure were taken for 3 consecutive days from 3 different farms with a variety of adult pigswhich are 1, 3, and 5 adult pigs and one farm for 2 child pigs. The sample is then dried for 7 days under the sun then weighed.

Data Processing and Data Analysis

1. Calculation of pig manure production. The pigs are classified into 2 types, which are adult pigs and (young) pigs. Adult pigs are pigs that are more than 6 months old and (young) pigs are pigs that are less than 6 months old. Assuming the weight of an adult pig is 90 kg/head and the weight of a child pig is 30 kg/head. From the literature it is assumed that pig manure is 7.77% of the body weight of pigs [6]. So, Pig manure = 7.77% x type of pig (kg / day)
2. Calculation of biogas energy production potential. Biogas potential (m^3) = amount of dry material (kg.BK) x production rate (m^3/kg.BK). The rate of biogas production is determined to be 0.30 m^3/kg.BK (at temperature 25°C)
3. Conversion of biogas energy to LPG in accordance with biogas energy equality in Table 1.
4. Calculation of biogas digester needs is adjusted to the amount of raw materialin the form of pig manure and water. It is assumed that the ratio between livestock manure and water is 1: 1,while for fermentation time (HRT) is assumed to be 50 days. The digester model used in the calculation is the fixed-dome.
5. Environmental analysis is carried out descriptively using secondary data from literature studies and field data.
6. Economic analysis is carried out to determine the economic benefits of biogas development by calculating the difference between the investment costs of building a biogas installation and the benefits of energy substitution. It is assumed that the age of the digester is 15 years and the cost component is considered fixed.
7. SWOT analysis is used to find out the strengths, weaknesses, opportunities and threats that form the basis for formulating strategies that can be carried out for the development of biogas from pigs waste in Pelambian Hamlet. Salusopai Village.

III. RESULTS AND DISCUSSION

General information of Animal Agriculture in Pelambian Hamlet,Salusopai Village

From the survey, there are 21 independent farmersin Pelambian Hamlet with total pigs of 79 units (35 is adult pigs and 44 is child pig). Pigsties in Pelambian Hamlet were built with bamboo floor but some made with cement floors. Some of the pigsties are located behind their house and some is located on the bank of Sopai River with the purpose for easy maintenance and manage. Unpleasant odour was reported due to the accumulated waste near the pig farm. The pigs are feed twice a day (morning and evening) with vegetable, bran or corn. They plant the vegetable by themself while, the bran and corn are bought from market. Before food is given, the pigsty must first be cleaned with water and the livestock waste will directly enter the river. The number of pigs inPelambian Hamlet tends to remain constant, even though there are pigs that are sold or used for traditional feast, the farmers will buy more pigs to maintain.

Biogas Energy Potential from Pig Livestock Waste in North Toraja Regency

Based on data from the Livestock Service Office of North Toraja Regency, the population of swine livestock in North Toraja Regency in 2015 was 299.819 units. Where the rough calculations shows the total potential of biogas energy from pig waste that is able to be produced with the total population is 56.665.79 m^3/day equivalent to 11.097.05 kWh or 11.09 MW.Unite all this waste into one processing is very difficult and requires high operational costs as they are independent farmers. Thus, develop a village or household scale potential of biogas energy is considered.

Biogas Energy Potential from Pig Livestock Waste in Pelambian Hamlet. Salusopai Village. North Toraja District

From result demonstrated the average dry matter content in adult pig manure is 0.59 kg/day, while the dry matter content in child pig manure is 0.225 kg/day. The total potential of biogas energy that can be produced is around 9.17 m^3/day or 274.95 m^3/month equivalents to 126.48 kg LPG/month. Based on the results of a survey conducted not all pig owners are interested in building a biogas installation. 6 out of 21 respondents are not interested in building a biogas installation. With these considerations, the development of biogas energy should be done on a household scale. There are 15 respondents who had the desire to build a biogas installation but only 7 respondents had the potential to fulfil the needs from the utilization of their pig waste, namely Bernaliku, Yansen. Lamba, DamarisLapu, YosephaDama, DelviKondobone and Monica.

Calculation of Digester Needs

The digester model used in this calculation is a fixed-dome. The advantage of fixed-dome digester is that it can last up to 30 years. Another advantage of fixed-dome digester is the temperature in the digester which is not easy to change because it is built underground. So that gas production can be constant. After calculation, the volume of digester needs is obtained as in Table 2.

In general, pigsties are close to the breeder's house with the intention of being easy to maintain and manage. So that to make a communal scale biogas, it is necessary to socialize and joint understanding by the farmers to make one village or group scale farm.

By developing a communal scale biogas installation, the biogas produced can be maximizedas well as waste from the farm can be managed optimally and provide comfort in the surrounding environment.

Table. 2 List of household and communal scale biogas digester requirements

Name	Amount of Potential Dirt	Digester Needs (m^3)		
Household scale				
Bernaliku	47.4	5.92	≈	6
Yansen	35	4.37	≈	4
Lamba	28	3.5	≈	3.5
Damaris L.	21	2.62	≈	2.5
Yosepha D.	21	2.62	≈	2.5
Delvi K.	29.52	3.69	≈	3.5
Monica	14.76	1.84	≈	2
Communal scale				
Only those who are interested	281.02	35.12	≈	35
All livestock combined	330.36	41.29	≈	40

Benefits of Biogas Energy Development from Pig Livestock Waste

The biogas energy equality that can be produces from pig waste in Pelambian Hamlet. Salusopai Village compared to other energy is shown in Table 3. If the biogas installation is developed communally for interested farmers, then the need for LPG to cook from the 15 interested farmers is 3 kg/day.

Likewise, if all pigs are combined into one, the energy produced will be able to meet the needs of LPG from 21 farmers, namely 4.1 kg/day. In addition to providing benefits in the form of energy, biogas development also provides benefits for decreasing environmental pollution and economic benefits from energy substitution results.

Table. 3 Equality of energy values based on dry matter from the results of the study

Name	Biogas (m3)	LPG (kg)	firewood (kg)	electricity (kWh)	LPG needs (kg / day)
Household scale					
Bernaliku	1.38	0.64	4.84	0.27	0.3
Yansen	0.89	0.41	3.10	0.17	0.4
Lamba'	0.71	0.33	2.48	0.14	0.3
Damaris L.	0.66	0.30	2.32	0.13	0.2
Yosepha D.	0.66	0.30	2.32	0.13	0.3
Delvi K.	0.89	0.41	3.13	0.18	0.2
Monica	0.45	0.21	1.56	0.09	0.1
Communal scale					
Only those who are interested	7.71	3.55	27.00	1.51	3
All livestock combined	9.17	4.22	32.08	1.79	4.1

Environmental Analysis

According to a 2008 United Nations report in Herawati (2012) [11], the livestock sector contributes 18% of greenhouse gases in the form of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), which are larger than all modes of transportation in the world which is 13.5%. According to the Ministry of Environment of the Republic of Indonesia (2009), basically the GHG emission calculation uses the basic formula as follows:

$$GHG\,emission = \sum_i A_i \times EF_i \qquad (1)$$

Where:
GHG Emissions = Emissions of a greenhouse gas (CO2, CH4, N2O)
Ai = Type i material consumption or number of products i
EFi = Emission Factor from type i or product i

The CH_4 emission factor from pig fermentation process is 1 kg CH_4/head a Year, and pig manure is 7 kg CH_4/head a Year.

While the emission factor from LPG consumption is 63,100 Kg/TJ which according to Sudarno (2015) [12], the value of LPG fuel is 46.110 kJ/kg or 0.000046110 TJ/kg. Besides that, the number of pigs in Pelambian Hamlet is 79 units. Then the amount of emissions from pigs is 632 CH_4/year equivalents to 13,272 CO_2/year. LPG needs for Pelambian Hamlet residents are 2160 kg LPG/year, so the emissions from LPG consumption of Pelambian Hamlet residents is 6,284.60 kg CO_2/year. By developing a biogas installation, methane gas (CH_4) from pig waste will be collected in the digester, which can be used as alternative energy such as LPG substitutes. Therefore, the development of biogas installations on farms will play a role in reducing greenhouse gas emissions, although the amount is very small if not developed on a large scale.

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Based on the results of the interviews, making manure into compost is only done in the dry season and at the same time farmers need compost fertilizer, so that livestock manure tends to be left which in turn flows into the river. Waste or dirt from pigs is also a source of water contamination. Waste from pigs has a pungent odor and is favoured by insects which can cause diseases such as flies. The development of biogas from pig waste can overcome the water pollution as the pig waste will decompose in the digester. Besides that, the fermentation results in the form of slurry do not smell anymore and can be used as compost fertilizer.

Economic Analysis

Economic analysis was carried out on 2 respondents who needed 4 m^3 and 6 m^3 digester sizes. From the calculations, the capital required to build a 4$m^3$and 6 m^3biogas installations is Rp. 7,600,000.and Rp. 8,570,000 respectively. From the survey result, Yansen's family costs Rp. 88,000 per month to buy 4 3 kg LPG tubes and Bernaliku's family costs Rp. 66,000 every month to buy 3 3 kg LPG tubes. Therefore payback period for both them are 7 years and 2 months as well as 10 years and 9 months as the fixed-dome type digester can last up to maximum 30 years. Thus, this is economically feasible to build a house-scale biogas installation.

SWOT Analysis

Based on information obtained from interviews and direct observations in Pelambian Hamlet, and farmers who have used pig waste as biogas energy in North Toraja District, the internal and external strategic factors are identified. These strategic factors were then analyzed with a SWOT analysis matrix and produced four strategies, namely the SO strategy, WO strategy, ST strategy and WT strategy as shown in Table 4.

Table. 4 SWOT matrix for biogas development

Internal factors / External Factors	**Strength (S)** 1. There are 74 pigs 2. There are farmers who are interested biogas installation 3. Biogas is renewable energy 4. Reducing environmental pollution 5. Economic benefits	**Weakness (W)** 1. Lack of socialization 2. Limited capital 3. Limited HR experience 4. Lack of awareness to protect the environment 5. Cages of separate pigs
Opportunity (O) 1. Change other energy sources 2. Develop digester technology 3. Support from the government 4. Fermented dirt used as fertilizer	**Strategy (S-O)** 1. Building biogas installations (S1, S2, S3, S4, S5: O1, O3). 2. Optimizing the use of slurry as fertilizer (S1, S2, S4, S5: O2, O4)	**Strategy (W-O)** 1. Maximizing the absorption of DAK in accordance with existing regulations (W1, W2: O1, O2, O3)
Threat (T) 1. Decreasing livestock population if available traditional feast 2. Reactor leakage	**Strategy (S-T)** 1. Building digesters of concrete fixed-dome types (S1, S2, S3, S4, S5: T2) 2. Optimizing existing pig livestock (S1: T1)	**Strategy (W-T)** 1. Conducting socialization and training in making biogas installations (W1, W3, W4: T2) 2. Make and strengthen farmer groups (W5: T1)

IV. CONCLUSION

1. Based on the data of pig population in North Toraja Regency in 2015, which were 299,819 tails, the potential of biogas energy that could be produced was 56,665.79 m3 / day equivalent to 11,097.05 kWh or 11.09 MW. While the total biogas energy potential of pigs in Pelambian Hamlet, Salusopai Village, North Toraja Regency is 9.17 m3 / day equivalent to 4.22 kg of LPG / day.
2. Benefits of developing biogas energy from pig waste, namely (1) The production of alternative energy sources, (2) Economic benefits from substitution of LPG energy into biogas, (3) Reducing environmental pollution from pig waste, (4) Pig waste those that have gone through a fermentation process can be processed as compost.
3. Strategies that can be implemented to develop biogas installations from pig waste, namely (1) Building biogas installations, (2) Optimizing the use of slurry as fertilizer, (3) Building concrete fixed-dome type digesters, (3) Optimizing existing pigs, (4) Maximizing the absorption of DAK in accordance with existing regulations, (5) Conducting socialization and training in making biogas installations, (6) Making and strengthening farmer groups.

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