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STUDY OF THE POTENTIAL AND FEASIBILITY OF UTILIZING BIOGAS ENERGY AS POWER PLANT AT PT. BTSB JEMBER

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ABSTRACT

The limitations and scarcity of energy sources derived from fossil fuels necessitate the need for solutions to utilize alternative and renewable energy sources, such as biogas. PT. BTSB (Biro Teknik Sinar Baru) is one of the companies in Jember Regency that has begun using biogas energy. However, the use of biogas is currently limited to cooking purposes. Despite being utilized solely for cooking, biogas can also be harnessed as a source of electrical energy. Therefore, this study conducts an analysis to determine the potential of biogas at PT. BTSB that can be utilized as a source of electrical energy. With the availability of electrical energy from biogas, it is hoped that it can reduce air pollution and decrease electricity expenses, thereby enhancing profits at PT. BTSB Jember. The first step in this research involves collecting data from PT. BTSB Jember regarding biogas, including: the number of cows, the target volume of biogas, temperature in the digester tank, pressure in the digester tank, and methane (CH4) content in biogas. Based on this data, further calculations will be performed for mol of biogas, volume of biogas, electrical energy and power, conversion and production of energy and electrical power, and the cost of energy production. According to the research findings, it is revealed that PT. BTSB produces an average of 5.15 m³ of biogas per day and has a potential of 57.53 kWh of electrical energy per day. With a cost of approximately Rp. 23,274,117 per day for each kWh, electricity from PT. BTSB's biogas is proven to be cost-effective. Thus, the biogas energy at PT. BTSB has the potential to be used as a biogas power plant.

Keywords: *Biogas, Power plant, Electrical energy, Air pollution*

1. INTRODUCTION

The definition of energy resilience according to the International Energy Agency (IEA) is a continuous availability of energy at an affordable price [1]. Additionally, a country is considered to have energy resilience if it has a 90-day supply of energy for import needs. Energy resilience is deemed crucial as energy plays a vital role in the production of goods and services [2]. Any disruptions that hinder the availability of energy supplies, such as primary fuel sources like coal, gas, oil, or electricity, can decrease the economic productivity of a region. If the magnitude of the disruption reaches a national level, it can cause deviations from set economic growth targets [3].

Currently, Fossil still remain the primary energy source to meet the electricity needs of the citizens in Indonesia [4]. This results in energy sources from fossil gradually depleting over time as they are classified as non-renewable electricity sources [5]. Furthermore, energy sources from fossil can also contribute to global warming [6]. The limitations and scarcity of energy derived from non-renewable sources like fossil fuels prompt us to seek alternative energy development that is abundant and environmentally friendly [7]. One of the renewable energy sources that can be used as an alternative electricity energy sources is biogas [8].

Biogas is a mixture of several gases resulting from the anaerobic fermentation of organic materials, with methane (CH_4) and carbon dioxide (CO_2) being the dominant gases. Methane (CH_4), the main component of biogas, is a useful fuel due to its high calorific value [9]. Biogas emerges as a recovery solution to transform waste into energy. Generated from the organic matter found in animal manure, such as from cows, chickens, ducks, goats, pigs, and others, biogas is produced through the anaerobic decomposition or fermentation of organic materials. Biogas itself is a gas obtained from the anaerobic breakdown of organic matter [10]. The production of biogas occurs through a digester apparatus under anaerobic conditions, where microorganisms optimize the decomposition process. There are three stages in the biogas formation process, which are hydrolysis, acidification, and methanogenic. Generally, a complete Biogas Power Plant system is composed of an anaerobic digester, feedstock, biogas conditioning (which purifies the methane content in biogas), Engine Generator, Heat Recovery Use, Exhaust Heat Recovery, and Engine Heat Recovery [11].

Biogas has been mostly utilized as a fuel for cooking purposes, but it can also be utilized as a source of electricity [12]. The potential of biogas energy to be converted into electricity can be implemented by utilizing power generation technologies such as gas turbines, microturbines, or otto cycle engines. The selection of these technologies is influenced by factors such as the generated biogas potential, biogas pressure, methane gas concentration, load requirements, and the availability of funds [13]. For the conversion, 1 kg of methane gas is equivalent to 6.13 x 10^7 J, 1 kWh is equivalent to 3.6 x 10^7 J, and 1 m^3 of methane gas is equivalent to 11.17 kWh [14].

Romadhona et al (2020) conducted research related to biogas utilization as an alternative source of electric power At BBPTU HPT Baturraden. In this study, researchers examined biogas originating from the feces of FH (Holstein Friesian) Dairy Cows. The results of this research show that in a day, 232 cows produce 6,960 kg of wet feces, which are used for biogas to form 125.28 m^3 of biogas which can produce 8070.12 Watts. The electrical energy produced is still only used for lighting [15]. Other research was conducted by Sukron and Iskendar (2020). In this research carried out utilization of biogas energy for power plant electricity in Tuwang Village, Karanganyar District Demak District. Based on the experimental results, energy can be estimated the biogas produced from livestock in Tuwang Village every day is 40.42 MJ [16].

One of the companies in the Jember regency that has utilized biogas as a source of energy is PT. BTSB (Biro Teknik Sinar Baru). Therefore, the use of biogas is currently limited to cooking purposes. As one of the companies focusing on projects related to mechanical, electrical, and plumbing works and supported by experienced experts, PT. BTSB is currently concentrating on projects related to the utilization of new and renewable energy (EBT). Therefore, the development of alternative energy as new and renewable energy (EBT) becomes a suitable solution to reduce dependence on fossil energy and create a sustainable environment. At the local level, the energy that can be developed in the Jember Regency, specifically at PT BTSB, is biogas derived from livestock manure, particularly Limousin cattle. PT. BTSB has the potential to utilize biogas energy not only as a substitute for LPG or for cooking purposes but also to convert it into electricity for use as a Biogas Power Plant (PLT Biogas). Based on the description provided earlier, the objective of this research is to discuss the potential utilization of biogas energy as a Biogas Power Plant (PLT Biogas) in the Jember Regency area, particularly at PT. BTSB Jember. The hope is that the results of this research can assist in addressing the existing problems.

2. RESEARCH METHODOLOGY

This research was carried out using data obtained from PT BTSB Jember which was then processed to determine the potential and feasibility of biogas produced at PT BTSB as a power plant. To convert biogas energy into electricity, a gas engine or similar power generator is needed. In this study, the analyzed generator is a gas engine, as gas engines have been used as a reference in previous biogas utilization studies. The Figure 1 is a research flowchart used in this research:

Table 1. Composition of Biogas in the Anaerobic Process

Component	Percentage of Volume (%)	mol	Molecular Weight (g/mol)	Molecular Weight of the Mixture (g/mol)
CH_4	65	0.65	16	10.4
CO_2	30	0.3	44	13.2
N_2	0.3	0.003	28	10.084
H_2	2.6	0.042	2	0.052
H_2S	2	0.02	34	0.68
O_2	0.1	0.001	32	0,32
Total	100	1		24.448

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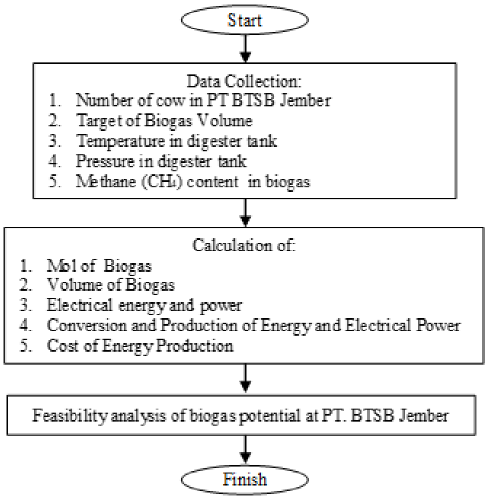

Figure 1. Research flowchart

The first step taken in this research was to collect data from PT BTSB Jember regarding biogas which includes: number of cows, target of biogas volume, temperature in digester tank, pressure in digester tank, and methane (CH_4) content in biogas. Based on this data, further calculations will be performed for mol of biogas, volume of biogas, electrical energy and power, conversion and production of energy and electrical power, and cost of energy production. Based on existing references, the following is a table of biogas composition from the anaerobic process:

Once the gas pressure and temperature in the digester tank are known, the next step is to determine the mol of biogas present using equations (1) and (2) below:

$$mB = TB/MWM \tag{1}$$

in where:
mB = mol of Biogas (mol)
TB = Target of Biogas (liter)
MWM = Molecular Weight of the Mixture (24,448 g/mol based on reference)

$$n = \frac{CH_4}{100} x9800 \tag{2}$$

in where:
n = mol of Biogas used for volume calculation (mol)
CH_4 = methane content (% mol)
9800 = mol Biogas from theoretical calculation (mol)

The next step is to determine the volume of biogas from the pressure, temperature, and mol of biogas using equation (3):

$$V = \frac{nRT}{P} \tag{3}$$

in where:
P = Gas Pressure (atm)
V = Gas Volume (liters)
n = mol of Biogas (mol)
R = Universal gas constant (0.0821 L.atm/mol.K)
T = Temperature (K)

Once the average value of the observed biogas volume is known, the next step is to determine the potential electrical energy and power generated using equation (4):

$$EP = VB\ x\ FK \tag{4}$$

in where:
EP = Generated Electrical Energy Potential (kWh/day)
VB = Observed Biogas Volume (m^3)

FK = Conversion Factor (11.17 kWh based on reference)

To determine the power potential generated, the daily generated energy potential that has been determined must divided by 24 using equation (5)

$$P = \frac{EP}{24} \tag{5}$$

in where:
P = Power Potential Generated (MW)
EP = Generated Electrical Energy Potential (kWh/day)

The next step is to convert these potentials into the analyzed power generation technology, namely a 100 kW gas engine, using equation (6):

$$EL = EP\ x\ CF\ x\ \eta \tag{6}$$

in where:
EP = Generated Electrical Energy Potential (kWh/day)
EL = Electrical Energy Generated (kWh/day)
CF = Capacity Factor (0,8 based on reference)
η = Electrical Efficiency (35% based on reference)

The power generated from the analyzed power generation technology can then be determined using equation (7):

$$PEL = \frac{EL}{24} \tag{7}$$

in where:
PEL = Generated Power (kW)
EL = Electrical Energy Generated (kWh/day)

3. RESULT AND DISCUSSION

3.1 Filling Feces into the Digester Tank

There are 6 cows at PT. BTSB, each of which can produce 24-25 liters of feces per day. Therefore, the total daily feces produced is 150 liters/day. Next, we need to understand the stages of filling or inputting the feces into the digester tank to be converted into biogas energy, as indicated in the Table 2.

In the filling process, the cow feces, which has been mixed with water in a ratio of 2:1, are introduced into the digester tank, approximately 25% of the total volume of the digester tank. The digester tank's volume used in this study is 5000 liters, so for the filling, it is at least filled with approximately 1250 liters.

3.2 Data of temperature, pressure, and methane content in biogas at PT BTSB

Before calculating the volume of existing biogas, it is necessary to first determine the values of temperature, pressure, methane gas (ppm), and CH4 (% mol) at PT BTSB Jember, as shown in the following Table 3.

Table 2. Filling Feces into the Digester Tank

Days	Mixed Composition	Cow Feces (liters)	Water (liters)	Total Mixed
1	2:1	150	75	225
2	2:1	150	75	450
3	2:1	150	75	675
4	2:1	150	75	900
5	2:1	150	75	1125
6	2:1	150	75	1350

Table 3. Data of temperature, pressure, and methane content in biogas at PT BTSB

Days	Temperature (°C)	P (atm)	CH_4 (PPM)	CH_4 (% mol)
1	30	0.009	373.2	3.73
2	30	0.009	372.3	3.72
3	32	0.009	458.3	4.58
4	33	0.009	458.3	4.58
5	33	3.4	586.2	5.8
6	34	3.4	586.2	5.8
7	34	4.7	681.3	6.8
8	35	4.7	681.3	6.8
9	34	7.2	1528.24	15.28
10	35	7.2	1528.24	15.28
11	33	5.7	1306.81	13.06
12	34	5.7	1306.81	13.06
13	32	3.8	1136.63	11.36
14	31	3.8	1136.95	11.36

3.3 Volume of Biogas

The Average MWM (Molecular Weight of the Mixture) based on Table 1 is 24. 448 mol and the target of biogas (TB) at the PT BTSB is 240 kg, so the mB is:

$$mB = \frac{TB}{MWM} = \frac{240\ kg}{24.448\ g/mol} = 9.8\ kmol = 9800\ mol$$

Based on Table 3, because the pressure values from the first day to the fourth day are too low (less than 1), the calculation of mol and biogas volume starts from the fifth day.
Based on the Table 3, at the fifth day:
P = 3 atm
C = temperature = 33^o C = 33 + 273 K = 306 K
R = universal gas constant (0.0821 L.atm/mol.K)
CH_4 (%) = 5.8
so the mol of biogas in the fifth day is:

$$n = \frac{CH_4}{100} x\ 9800 = \frac{5.8}{100} x\ 9800 = 568{,}4\ mol$$

and volume of biogas is:

$$V = \frac{nRT}{P} = \frac{568{,}4\ x\ 0.0821\ x\ 306}{3{,}4} = 4199.9\ liters = 4.1\ m^3$$

With the same formula, the results of the biogas volume from the 6th day to the 14th day are obtained.

Table 4. Volume of Biogas from 5th day until 14th day

Days	Volume of Biogas (m^3)
5	4.1
6	4.2
7	3.5
8	3.5
9	5.2
10	5.2
11	5.6
12	5.6
13	7.3
14	7.3
Total	51.5
Average	5.15

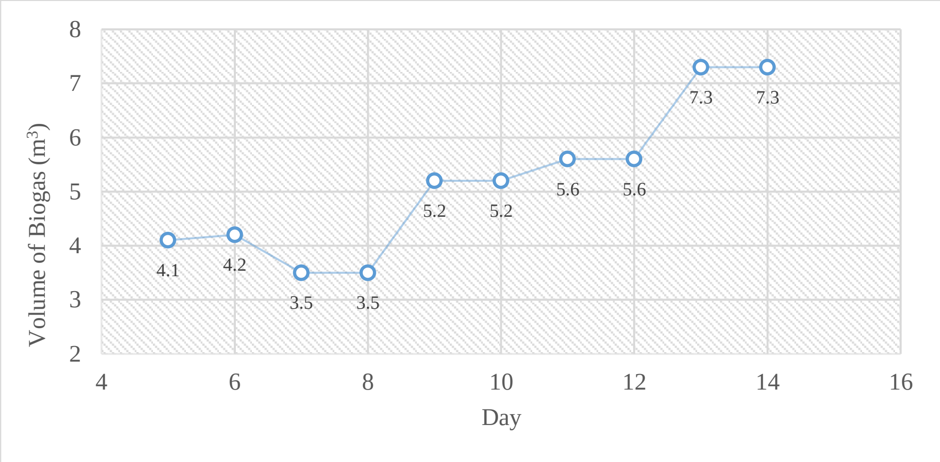

Figure 2. Graph of Biogas Volume from 5th day until 14th day

Table 4 and Figure 2 show that volume of biogas varies from 5th day to 14th day. There are increases and decreases in biogas production during this period. It can be observed that biogas production starts to increase on day 9 and reaches its peak on day 13 before experiencing a decrease. This may be due to a more efficient fermentation process. The average biogas production per day during this period is 5.15 m^3. The volume of biogas in production can fluctuate, and one of the reasons can be attributed to unstable temperature. Inconsistent temperature can affect the activity of microorganisms, thereby influencing biogas production.

3.4 Potential of Energy and Electrical Power

Based on the biogas volume values in Table 4, the potential electrical energy generated can be calculated using equation (4):

$EP = VB\ X\ FK = 5.15\ x\ 11{,}17\ kWh/day\ = 57.53\ kWh/day$

and the potential of generated power can be calculated using equation (5):

$$P = \frac{EP}{24} = \frac{102.65\ kWh/day}{24} = 2{,}4\ kW$$

3.5 Conversion and Production of Energy and Electrical Power

Converting electrical energy derived from biogas energy requires a transformation of the existing energy in biogas, such as potential energy being converted into mechanical energy, and then this mechanical energy is converted into electrical energy.

In considering the choice of conversion technology, there are several parameters to be considered, including technical parameters consisting of the efficiency level of conversion technology and the production of electrical energy, as well as the availability of products/goods in the market. As explained in the previous chapters, this study uses gas engine power generation technology, as gas engines meet the requirements of the existing parameters.

Based on the potential values of generated power and adjusted with the conversion calculation using equation (6), the conversion and production of electrical energy generated is:

$$\begin{aligned} EL &= EP\ x\ CF\ x\ \eta \\ &= 57.53\ kWh/day\ x\ 0.8\ x\ 35\% \\ &= 16.11\ kWh/day \end{aligned}$$

Furthermore, power that generated by biogas is:

$$P = \frac{EL}{24} = \frac{16.11}{24} = 0{,}7\ kW$$

3.6 Cost of Energy Production

If we calculate the cost incurred from the production of generated electrical energy, the calculation is as follows:

Given the electricity tariff for Group R-1/TR for a power capacity of 1,300 VA, Rp. 1,444.70 per kWh. So:

$Cost = 16.11\ x\ Rp\ \ 1{,}444.70/day$

$Cost = Rp\ 23{,}274.117/day$

Thus, based on the existing cost calculation, the utilization of biogas energy into electrical energy, which is then used as a biogas power plant, will save approximately Rp. 23,274,117/day in electricity costs or if accumulated over one month, it will save approximately Rp. 698,223.51.

4. CONCLUSION

PT. BTSB produces 150 liters of feces per day by 6 cows. This feces production yields an average of 5.15 m^3 of biogas per day, with a potential of 57.53 kWh of electrical energy per day. If applied using gas engine technology, this potential generates 16.11 kWh of electricity per day. This electrical energy potential can meet the needs of small industries and households, with a minimum power requirement of 2200 watts/2.2 kWh for small industries and 1300 Watts/1.3 kWh for households. With a cost of around rp. 23,274,117 per day for each kWh, electricity from PT. BTSB's biogas proves to be cost-effective. Thus, the biogas energy at PT. BTSB has the potential to be used as a power plant.

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