Financial Aspects of Biogas Production from Livestock Waste to Meet Household Energy Needs

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ABSTRACT

The livestock sector has significant potential to contribute to methane emissions, which are the second largest after CO2, accounting for 13% of total emissions. One solution to control methane emissions is the use of biogas reactors. This study aims to assess the financial aspects of biogas production from livestock waste to meet household energy needs and to determine its financial feasibility. The research employs a qualitative approach that emphasizes flexibility, direct interaction with research subjects, and sensitive interpretation of data context. Data collection was conducted through a literature review by examining and analyzing literature related to the research topic. The literature study results indicate that constructing biogas reactors using cow dung has viable potential for development, especially as a replacement for LPG. However, replacing wood fuel depends highly on the local price of firewood. This study recommends that, for the development of biogas from cattle farm waste to replace firewood, interest subsidies or other assistance are needed to make the development feasible. Additionally, to encourage public interest in developing biogas reactors for cattle farm waste, financial incentives in the form of interest subsidies through program loans are necessary. Developing biogas reactors from cattle farm waste for household energy needs is economically viable, especially as a substitute for LPG, but requires additional support such as interest subsidies to replace firewood. Financial incentives are essential to attract public interest in developing these biogas reactors.

Keywords: Biogas, Cost Analysis, Methane Emissions.

INTRODUCTION

The increase in global average temperatures since the mid-20th century has been caused by increased concentrations of greenhouse gases (GHGs) due to human activities (Chen et al., 2024; B. Li et al., 2024). Indonesia is allegedly the fourth most polluting country in the world (as one of the largest GHG-producing countries). Energy use is one of the contributing sectors to CO_2 emissions. Until 2011, fossil energy consumed up to 96.21 percent of the total national energy

(Nawalany et al., 2023). Energy issues are also accompanied by the energy crisis and the commitment of the Government of Indonesia through Presidential Regulation No. 61 of 2011 related to GHG emission reduction, where Indonesia is committed to reducing GHG emissions by 26 percent with its efforts and reaching 41 percent if it receives international assistance in 2020 from business as usual (BAU) conditions (Fekete et al., 2021; Lima et al., 2020; Satola et al., 2021).

The energy crisis is also a serious concern for the government. Indonesia, as a tropical country, produces a lot of biogas and biomass, including bioenergy, which is a renewable energy source. Bioenergy can provide a sustainable source of energy (sustainable). With the right approach to the use of technology, biogas and biomass waste can be utilized with high use-value and high economic value (a valuable resource) (S. Li et al., 2022). Efforts to improve the environment by implementing waste-to-energy technology require support to accelerate its development. In the waste-to-energy development program, there are at least two indicators of success, namely (1) reducing emissions from waste-to-energy utilization activities and (2) obtaining alternative energy instead of fossil fuels for the community as a result of waste-to-energy utilization activities.

Energy production is the largest contributor to CO_2 emissions. When LULUCF-related emissions are excluded, CO2 emissions account for 85 percent of total emissions (Kusmiyati et al., 2023). The remaining 15 percent is derived from agriculture, industry, and waste. Until 2011, energy was dominated by petroleum, natural gas, and coal. Oil accounted for 46.93 percent of the total energy supply, coal accounted for 26.93 percent, and gas accounted for 21.90 percent (Bhatti et al., 2024).

The livestock sector is one of the sectors that have the potential to contribute to methane emissions. Methane is the second-largest emission after CO_2, accounting for 13% of total emissions (Hamatani et al., 2023). With this consideration, methane emissions and the livestock sector's largest source of methane emissions need serious attention. Fresh manure (KTS) production potential as a raw material for biogas cow waste reached 88,714.88 thousand tons in 2010. The production potential of the KTS can produce biogas equivalent to kerosene production of 4.43 billion liters per year. Then, the potential of organic fertilizers produced reached 35.48 billion tons per year.

A biogas reactor is one solution to control methane emissions (González-Arias et al., 2024). Livestock manure that has the potential to produce methane will be isolated in the reactor and accommodate methane production (Minardi et al., 2023; Ude et al., 2024). Methane gas contained in biogas, as a result of biogas reactors, is a fuel that can replace the use of kerosene and LPG for household and business purposes. Energy conversion with biogas as an alternative fuel will suppress methane emissions, greatly contributing to global warming (Al Zahra et al., 2024).

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A biogas reactor's function is to convert animal waste, human waste, and other organic matter into biogas. Biogas consumption on a household scale, among others, is used as an alternative fuel for heating and electric generators (Issahaku et al., 2024; Strubbe et al., 2024; Wiloso et al., 2024). Based on the length of development and application of biogas technology around the world, this technology is well established and proven to produce non-fuel energy that is also environmentally friendly. For the community and businesses, especially micro and small businesses, biogas production is very profitable (Ahmad & Jabeen, 2023; Fekete et al., 2021).

The conversion of biogas as an alternative fuel is a way to replace fossil fuels such as kerosene and LPG. Biogas feed is also a waste that is utilized along with anaerobic biological processes in the reactor. Dregs or waste from biogas reactors also have the economic potential to be used as raw materials for organic fertilizers. The biogas reactor is one of the practical solutions of appropriate energy technology that is easy and inexpensive to implement for the community, including remote communities. Operation and maintenance are also very easy and do not require human resources with special skills. For construction, there are many human resources in Indonesia who are trained and ready to apply various biogas reactor technologies.

METHODS

The method used in this research is qualitative. The qualitative approach emphasizes flexibility, direct interaction with research subjects, and sensitive interpretation of the context of the data obtained (Mertens, 2023). The literature study data collection technique involves reviewing and analyzing literature, including books, written materials, and references related to the research topic (Jailani, 2023). After the data is collected, the analysis process is carried out through three main stages. The first stage was data reduction, where the collected data was organized and sorted to identify key patterns or findings. Deleting irrelevant data and grouping data into specific categories is part of this stage. After the data reduction stage, proceed with data presentation. At this stage, the data that has been sorted and organized is presented using various methods, such as tables, graphs, or narratives. Data presentation aims to facilitate understanding and interpretation of research results. The last stage is conclusion drawing. The results of data analysis are evaluated to identify key findings and emerging patterns. Conclusions are drawn based on the interpretation of the analysis results, and the implications of the findings can be elaborated.

RESULTS AND DISCUSSION

Basic Assumptions

For the development of biogas reactors for animal husbandry waste and cow dung, the assumption made in this analysis consists of various sizes of biogas reactors, namely 6 m^3 and 10 m^3. In detail, the following assumptions are used:

Table 1. Basic Assumptions Calculation Of Financial Analysis And Cost Benefit Analysis Of Biogas Reactor Development Of Cattle Farm Waste

Assumptions	Unit	6 m^3	10 m^3
Initial investment	Rp	8.000.000	12.000.000
Investment period	Year	5	5
Economic life	Year	20	20
Number of cows	Tail	6 – 8	10 – 12
Utilized waste	Kg	60	100
Biogas produced	m^3 Biogas	1,8	3
Biogas to LPG	Kg/m^3/day	0,46	0,46
LPG equivalent	Kg	0,828	1,38
Biogas to firewood	Kg/m^3/day	3,5	3,5
Firewood equivalent	Kg	6,3	10,5
LPG gas price	Rp/kg	6.000	6.000
LPG gas subsidy	Rp/kg	6.855	6.855
Firewood prices	Rp/kg	600	600
LPG gas	Kg/day/RT	0,465	0,465
Firewood	Kg/day/RT	3,185	3,185
Number of households	RT	2	3
Save LPG (volume)	Kg/year	302	504
Save LPG (Rp)	Rp/year	1.813.320	3.022.200
Save firewood (volume)	Kg/year	2.300	3.833
Save firewood (Rp)	Rp/year	1.379.700	2.299.500
Loan interest rate to industry/group*)	Percent	13,5	13,5
Interest subsidy*)	Percent	0	0
Interest received by the bank	Percent	13,5	13,5
LPS guarantee interest	Percent	7,5	7,5
Additional interest	Percent	6	6
Carbon dioxide from LPG	Kg CO_2/kg LPG	3	3
Carbon dioxide from firewood	Kg CO_2/kg firewood	1,52	1,52
Carbon dioxide from LPG saved	Ton CO_2/year	0,91	1,51
Carbon dioxide from firewood saved	Ton CO_2/year	3,50	5,84

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The resulting fertilizer	Kg/month	15	25
Fertilizer prices	Rp/kg	2.500	2.500
Income from fertilizer	Rp/year	450.000	750.000
Discount rate for IRR (interest rate)	Percent	12	12
Depreciation	Percent/year	5	5
Remaining in 20 years (from 20 years of economic life)	Percent in the fifth year	0	0
Wake-up time until ready to use	Day	15	15
Assumption of pollution avoidance: cost EUR 19/Ton and Exchange Rate: 1 EUR: Rp 16.500	Rp/Ton	313.500	313.500

Analysis of Financial Feasibility

In order to find a comprehensive indicator as a basis for acceptance or rejection of a project, several investment criteria need to be considered. The investment criteria that will be used in this financial analysis are net present value (NPV) and internal rate of return (IRR). NPV is the difference between the present value of the flow of benefits and the flow of costs. On the other hand, IRR describes the rate of return of a net investment. In project evaluation, an NPV greater than or equal to zero and an IRR greater than the discount rate are required for a project to be financially viable.

The Profitability Index (PI) and Return on Investment (ROI) are other financial indicators that can also be used. The Profitability Index (PI) is intended to calculate the ratio between the value of net cash flows that will come and the value of investments that are now. If PI > 1, then the investment is worth running, and if PI 1, then the investment is not worth running. ROI is the ratio of net profit to cost. ROI is used to compare the return on investment between investments that are difficult to compare using monetary value. A positive ROI indicates that the investment is worth making.

In the development of a cattle waste biogas reactor, there are two initial conditions that determine the calculation results, namely the condition of the development of a cattle waste biogas reactor to replace one of: i) the use of LPG gas, or ii) the use of firewood.

From the calculation of various financial indicators used, it can be shown that the development of biogas reactors for cattle waste will be feasible for all sizes (6 m^3 and 10 m^3) if biogas products from cattle waste are used to substitute LPG gas that have been used by households of farmers for their daily needs at home. Meanwhile, if the biogas product from cow farm waste is

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only used to substitute firewood that has been used by households, the financial feasibility depends on the amount of interest that must be borne by the debtor and the size of the biogas reactor for cow farm waste that is built. The smaller the interest rate to be borne by the debtor and the larger the size of the reactor, the more financially feasible it is for the development of biogas from cow farm waste.

From the existing financial indicators, biogas from cattle waste is financially feasible to be used to substitute the use of firewood if the debtor only bears an interest expense of a maximum of 7 percent for a size of 10 m^3, while for a size of 6 m^3, based on NPV, IRR, and PI indicators, it is not financially feasible, but ROI is feasible. When viewed in general terms for all measures of biogas from cow dung waste, financial feasibility is largely determined by utilizing biogas products produced and by-products, namely fertilizers.

Table 2. Financial Analysis Results of Biogas Reactor Development Financing Of Cattle Farm Waste Based On Npv Calculation Results (In Million Rp)

Interest Rate on Debt	LPG to Biogas NPV (Rp. Million)		NPV from Firewood to Biogas (Rp. Million)	
	Size 6 m^3	Size 10 m^3	Size 6 m^3	Size 10 m^3
0,0%	3,05	7,38	(0,17)	2,01
1,0%	2,87	7,11	(0,35)	1,73
2,0%	2,68	6,83	(0,54)	1,46
3,0%	2,50	6,55	(0,73)	1,18
4,0%	2,31	6,27	(0,91)	0,90
5,0%	2,12	5,99	(1,10)	0,62
6,0%	1,94	5,71	(1,29)	0,34
7,0%	1,75	5,43	(1,47)	0,06
8,0%	1,57	5,15	(1,66)	(0,22)
9,0%	1,38	4,87	(1,84)	(0,50)
10,0%	1,19	4,59	(2,03)	(0,78)
11,0%	1,01	4,31	(2,22)	(1,06)
12,0%	0,82	4,04	(2,40)	(1,34)

Table 3. Results Of Financial Analysis Of Biogas Reactor Development Financing Of Cattle Farm Waste Based On Irr Calculation Results (In Percent)

Interest Rate on Debt	IRR from LPG to Biogas		IRR from Firewood to Biogas	
	Size 6 m^3	Size 10 m^3	Size 6 m^3	Size 10 m^3

0,0%	16,17%	18,70%	11,77%	13,84%
1,0%	15,88%	18,38%	11,51%	13,57%
2,0%	15,59%	18,07%	11,27%	13,30%
3,0%	15,31%	17,76%	11,02%	13,04%
4,0%	15,03%	17,46%	10,79%	12,79%
5,0%	14,76%	17,17%	10,55%	12,54%
6,0%	14,49%	16,88%	10,33%	12,29%
7,0%	14,23%	16,59%	10,10%	12,05%
8,0%	13,97%	16,32%	9,88%	11,81%
9,0%	13,72%	16,04%	9,67%	11,58%
10,0%	13,48%	15,78%	9,45%	11,35%
11,0%	13,24%	15,51%	9,25%	11,13%
12,0%	13,00%	15,26%	9,04%	10,91%

Table 4. Results Of Financial Analysis Of Biogas Reactor Construction Financing Of Cattle Farm Waste Based On Roi Calculation Results (In Percent)

Interest Rate on Debt	ROI from LPG to Biogas		ROI from Firewood to Biogas	
	Size 6 m^3	Size 10 m^3	Size 6 m^3	Size 10 m^3
0,0%	182,33%	213,70%	128,24%	153,60%
1,0%	178,15%	209,06%	124,86%	149,85%
2,0%	174,10%	204,56%	121,59%	146,21%
3,0%	170,17%	200,19%	118,41%	142,68%
4,0%	166,34%	195,94%	115,32%	139,24%
5,0%	162,63%	191,81%	112,31%	135,90%
6,0%	159,01%	187,79%	109,39%	132,66%
7,0%	155,50%	183,89%	106,55%	129,50%
8,0%	152,08%	180,08%	103,78%	126,42%
9,0%	148,75%	176,38%	101,09%	123,43%
10,0%	145,50%	172,78%	98,47%	120,52%
11,0%	142,34%	169,27%	95,91%	117,68%
12,0%	139,26%	165,84%	93,42%	114,91%

Table 5. Results Of Financial Analysis Financing The Construction Of Biogas Reactor Cattle Farm Waste Based On The Calculation Of Pi (Profitability Index)

Interest Rate on Debt	PI from LPG to Biogas		PI from Firewood to Biogas	
	Size 6 m³	Size 10 m³	Size 6 m³	Size 10 m³
0,0%	1,38	1,62	0,98	1,17
1,0%	1,36	1,59	0,96	1,14
2,0%	1,34	1,57	0,93	1,12
3,0%	1,31	1,55	0,91	1,10
4,0%	1,29	1,52	0,89	1,07
5,0%	1,27	1,50	0,86	1,05
6,0%	1,24	1,48	0,84	1,03
7,0%	1,22	1,45	0,82	1,00
8,0%	1,20	1,43	0,79	0,98
9,0%	1,17	1,41	0,77	0,96
10,0%	1,15	1,38	0,75	0,94
11,0%	1,15	1,38	0,72	0,91
12,0%	1,10	1,34	0,70	0,89

Analysis of cost-benefit

Cost and benefit analysis is the process of identifying, measuring, and comparing the costs and social benefits generated by a project or investment activity. The starting point of the need for cost and benefit analysis in project analysis is the inability of a single financial analysis to capture the overall gains and losses felt by the community as a result of a project or investment (Singgih & Yusmiati, 2018). Indicators used in financial analysis can be misleading when used as indicators of social welfare because most public projects produce goods that cannot be freely traded on the market, such as waste management, pollution disposal, or health care improvements.

One method of cost and benefit analysis that is commonly used is the benefit-cost ratio (BCR). This benefit-cost ratio (BCR) is basically the comparison between the present value of the valuation of the benefits received by the community against the costs that the community must bear from the implementation of a project. A project is considered feasible to be implemented if the B/C ratio is greater than one, where the benefit valuation is greater than the cost valuation.

Based on the experience possessed by the owners of biogas reactors for cattle farm waste, the useful life of biogas reactors for cattle farm waste can last up to 20 years. In the analysis of costs and benefits for the development of biogas reactors from cattle farm waste, the loan to be granted has an assumed payback period of five years.

Table 6. Cost And Benefit Analysis Of Biogas Reactor Development Of Cattle Farm Waste Assuming Benefits Of 20 Years And 5 Years Loan

Indicators	Size 6 m^3	Size 10 m^3
Initial fee (Rp)	8.000.000	12.000.000
Loan term (years)	5	5
Bank interest rates	13,5%	13,5%
Debtor's interest expense	0,0%	0,0%
Interest subsidy	13,5%	13,5%
a. Switching from LPG to biogas		
- Cost value (C) (Rp)	17.832.229	26.491.200
- Benefit value (B) (Rp)	43.992.374	71.710.490
- Net benefit value (Rp)	26.160.145	45.219.289
B / C ratio (BCR)	2,47	2,71
Eligibility (if BCR>1)	Eligible	Eligible
Reduced CO_2 emissions (tons)	18	30
b. Switching from firewood to biogas		
- Cost value (C) (Rp)	17.660.800	26.491.200
- Benefit value (B) (Rp)	31.420.653	50.757.622
- Net benefit value (Rp)	13.759.853	24.266.421
B / C ratio (BCR)	1,78	1,92
Eligibility (if BCR>1)	Eligible	Eligible
Reduced CO_2 emissions (tons)	70	117

Discussion

Based on the calculation of cost and benefit analysis for all sizes of cow farm waste biogas reactor, the BCR value produced shows that the development is economically feasible to run because the value is greater than 1, both for those who previously used LPG gas and firewood as fuel for household purposes. In the calculation of this cost and benefit analysis, the amount of the debtor's interest expense and interest subsidy expense does not affect the economic feasibility because it is only a transfer of dependents between the interest expense borne by the debtor and the interest subsidy expense by the government.

CONCLUSION

The results of this literature study concluded that the construction of biogas reactors using cow dung has a viable potential to be developed (especially for the replacement of LPG gas, while the replacement of wood fuel is highly dependent on the price of firewood in the area). The results of this study recommend that for biogas from cow farm waste to replace firewood (which is highly dependent on the price of firewood), interest subsidies or other assistance are needed to finance its development to become feasible. However, incentives in the form of interest subsidies through program loans are still needed to encourage the public to be interested in developing a biogas reactor for cattle farm waste.

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