



Analysis Of Biogas Potential Based On Land Carrying Capacity And Livestock To Support Household Energy Transition In Cirahab Village, Lumbir Subdistrict, Banyumas Regency

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Abstract

The development of cattle-based biogas is one alternative for supporting rural energy security and reducing dependence on subsidized LPG. This study aims to analyze land carrying capacity, cattle stocking rates, and the potential for LPG subsidy savings in Cirahab Village, Banyumas Regency. The method used was quantitative descriptive analysis with five land-use scenarios (10-50%) of the village's total area of 946 ha. The results of the analysis show that the land's carrying capacity can accommodate 946-4,730 head of cattle, which has the potential to meet the energy needs of 378-1,892 households. Under a 40% land-use scenario, the livestock capacity reaches 3,784 head of cattle with biogas production of approximately 35,119 m³ per month, equivalent to 5,385 3-kg LPG cylinders. Assuming an LPG subsidy of Rp30,000 per cylinder, this program has the potential to save the government approximately Rp161.55 million per month, or Rp1.94 billion per year, in subsidy expenditures. The study's findings indicate that the development of cattle-based biogas has the potential to support community energy self-sufficiency while improving the efficiency of government energy subsidies.

Keywords: biogas, land carrying capacity, cattle, LPG subsidies, renewable energy.





INTRODUCTION

Energy transition is one of the strategic priorities in sustainable development, aimed at reducing dependence on fossil fuels through the use of new and renewable energy sources. In Indonesia, the household sector remains one of the largest energy consumers, particularly for cooking, which is dominated by the use of Liquefied Petroleum Gas (LPG) (Directorate General of New and Renewable Energy and Energy Conservation, 2020). Although the kerosene to LPG conversion program implemented by the government since 2007 has succeeded in improving public access to cleaner energy, dependence on LPG still faces various challenges, including the high burden of government subsidies, fluctuations in global energy prices, and the risk of distribution disruptions, particularly in rural areas. These conditions underscore the importance of developing alternative energy sources derived from local potential to enhance the community's energy resilience and self-reliance.

One renewable energy source with great potential for development in rural areas is biogas (Fitriyah & Wahyudi, 2020). Biogas is the product of the anaerobic decomposition of organic matter primarily livestock waste which produces methane (CH_4) as its main component. Biogas can be used as an alternative fuel to LPG for household cooking, while also providing additional benefits such as reducing environmental pollution caused by livestock waste and producing bioslurry that can be used as organic fertilizer. Thus, the development of biogas not only supports the provision of clean energy (Purnomo, 2012) but also promotes the implementation of a circular economy by converting waste into a valuable resource.

The success of biogas development is greatly influenced by the sustainable availability of raw materials (Sari et al., n.d.). In smallholder livestock systems, biogas production depends on the number of livestock raised, while livestock-rearing capacity is influenced by the region's ability to provide feed sustainably. Therefore, biogas development should not be based solely on the current number of livestock but should also consider the land's carrying capacity as a provider of forage and agricultural waste (Ikanubun et al., 2021). This approach is essential to ensure that increases in livestock populations intended to support biogas production remain within the region's ecological limits and do not place undue pressure on natural resources (Fajri, 2020).

Cirahab Village, Lumbir Subdistrict, Banyumas Regency, is a rural area with an agrarian character, where farming and livestock raising are among the community's primary sources of livelihood. The availability of farmland, backyard plots, and various types of agricultural waste has the potential to serve as a source of forage for cattle. On the other hand, livestock farming produces organic waste in the form of cattle manure, which has largely been utilized





conventionally as livestock manure or has not yet been optimally utilized (Rahman et al., 2019). In fact, if managed using biodigester technology, this waste can become a source of renewable energy capable of reducing the community's dependence on LPG (Hidayat et al., 2020).

Biogas development in Cirahab Village holds great potential, as it is supported by the availability of land resources and a well-established smallholder livestock system. However, to date, it remains unclear whether the available land has the potential to support a sustainable increase in livestock populations, what the optimal number of cattle is that can be raised based on the area's carrying capacity, and to what extent the biogas produced can meet household energy needs (Putri et al., 2020). This information is crucial as a basis for formulating strategies to develop energy-self-sufficient villages based on local resources (Purnomo, 2012).

Various studies on biogas in Indonesia generally focus on estimating biogas production based on existing livestock populations or on the technical aspects of biodigester construction. These approaches provide an overview of available energy potential but do not address the question of a region's optimal capacity to support sustainable biogas development. On the other hand, research on the carrying capacity of livestock land generally only examines a region's ability to provide feed without linking it to energy production potential. As a result, the relationship between land resources, livestock capacity, and household energy needs has not yet been integrated into a single analytical framework.

Given these conditions, an approach is needed that integrates the analysis of land carrying capacity, livestock capacity, and biogas production potential into a single system. This study began by identifying the area of land with the potential to serve as a source of forage and agricultural waste, and then calculating the optimal capacity for cattle that can be raised based on the region's carrying capacity. Next, this optimal livestock population was used to estimate manure production, the resulting biogas potential, and its equivalence to household LPG needs in Cirahab Village. Using this approach, it is possible to determine the region's capacity to support the transition of household energy from LPG to biogas based on local resources (ESDM, 2021).

The results of this study are expected to make a scientific contribution in the form of an analytical model that links land carrying capacity, livestock production capacity, and renewable energy potential at the village level. Furthermore, the findings are expected to serve as a basis for local governments, village governments, and communities in designing sustainable biogas development policies as part of efforts to achieve energy security, increase the value added of the livestock sector, reduce environmental pollution, and strengthen sustainable rural development.





METHOD

Time and Location of the Study

This study was conducted in June 2026, with Cirahab Village, Lumbir Subdistrict, Banyumas Regency, Central Java Province, as the subject of the study. Cirahab Village was selected because it is an agricultural area with potential for cattle farming and the use of biomass as a renewable energy source. The study did not collect primary data in the field but instead utilized various secondary data obtained from government agencies and relevant scientific publications (Ardiansyah et al., 2022).

Data Collection Methods

Data collection was conducted using the documentation method by compiling various secondary data relevant to the research objectives. The documents used included official statistical publications, government reports, regulations, and scientific articles discussing the use of livestock waste as a renewable energy source. All data were then verified, classified, and organized according to the needs of the research analysis (Abrar, 2024).

Data Analysis Techniques

This study employed quantitative descriptive analysis. The analysis was conducted in several stages, namely:

1. Analysis of the general conditions of Cirahab Village based on data on demographics, land use, and livestock population;
2. Analysis of land carrying capacity in providing forage for livestock;
3. Estimation of the maximum cattle capacity based on land carrying capacity;
4. Estimation of livestock manure production as a feedstock for biogas;
5. Calculation of biogas production potential using conversion factors published in various studies;
6. Conversion of biogas volume to household LPG equivalents; and
7. Estimation of potential savings in government LPG subsidies based on energy substitution results.

All calculation results were then analyzed descriptively and compared with various previous studies to evaluate the potential for implementing a household biogas program in Cirahab Village.



RESULTS AND DISCUSSION

General Conditions of Cirahab Village, Banyumas Regency

Cirahab Village is one of the villages in Lumbir Subdistrict, Banyumas Regency, Central Java Province. According to the 2025 Lumbir Subdistrict in Figures report, Cirahab Village covers an area of approximately 9.46 km² with a population of 5,474 people, consisting of 2,796 men and 2,678 women, as well as 1,933 households (KK). Administratively, Cirahab Village consists of 6 hamlets, 6 neighborhood units (RW), and 35 neighborhood groups (RT). These geographical and demographic conditions indicate that Cirahab Village is a rural area dominated by agricultural and livestock activities.

The livestock sector is one of the key potentials supporting the development of renewable energy in Cirahab Village. According to 2024 data from the Banyumas Regency Fisheries and Livestock Service, the beef cattle population in Cirahab Village stands at 43 head, ranking the village sixth out of ten villages in Lumbir Subdistrict. Although not the highest, the presence of cattle serves as a potential source of biomass that can be utilized as feedstock for biogas. Therefore, this study not only considers the existing cattle population but also analyzes land carrying capacity to estimate livestock capacity and the potential for household biogas development.

LPG Use by Residents of Cirahab Village

Liquefied Petroleum Gas (LPG) is the primary energy source for households in Indonesia for cooking. Government policies encouraging the switch from kerosene to LPG have increased the use of subsidized 3-kg LPG cylinders, resulting in a rising trend in household LPG consumption. This increase in consumption has led to a rise in the government's energy subsidy burden, making it necessary to develop alternative energy sources that utilize local potential, one of which is biogas derived from livestock waste.

According to data from the Banyumas Regency Central Statistics Agency, Cirahab Village has 1,933 households. In this study, it is assumed that each household uses an average of four 3-kg LPG cylinders per month. Based on this assumption, total LPG consumption in Cirahab Village is estimated at 7,732 3-kg cylinders per month, equivalent to 23,196 kg of LPG per month. Annually, this demand amounts to 92,784 3-kg cylinders, or approximately 278.35 metric tons of LPG.

This high level of LPG consumption indicates households' heavy reliance on fossil fuels for cooking. This situation presents a significant opportunity for the development of alternative energy in the form of biogas derived from cattle manure (Lubis, 2020). Partially substituting LPG

with biogas has the potential to lower household expenses, reduce consumption of subsidized LPG, and ease the burden of energy subsidies borne by the government. The following table shows estimated LPG demand:

Table. Estimated Household LPG Consumption in Cirahab Village

No	Description	Value
1.	Number of households	1.933 households
2.	LPG consumption per household	4 3kg cylinders per month
3.	Total LPG cylinders per month	7.732 cylinders
4.	Total LPG per month	23.196 kg
5.	Total LPG cylinders per year	92.784 cylinders
6.	Total LPG per year	278.352 kg (278,35 ton)

Potential of Land for Cattle Farming

Cirahab Village is a rural area covering approximately 9.46 km²; the region is dominated by agricultural land use, including both paddy fields and dryland. These conditions present significant opportunities for the development of cattle farming due to the availability of forage sources derived from agricultural byproducts, such as rice straw, corn leaves, natural grasses, and other forage crops. The agricultural system, which remains agrarian in nature, allows for integration between the agricultural and livestock sectors, enabling crop residues to be utilized as livestock feed, while livestock manure can be returned to the land as organic fertilizer. This concept aligns with the principles of circular agriculture, which promotes efficient resource use and reduces waste (FAO, 2020).

An analysis of land carrying capacity is necessary to determine the region's ability to sustainably provide feed for the cattle population. Carrying capacity is calculated based on the area of forage-producing land, biomass productivity, livestock dry matter requirements, and the level of land utilization. The greater the available forage production relative to livestock needs, the higher Cirahab Village's capacity to support an increase in the cattle population without placing pressure on land resources.

In addition to supporting livestock production, the availability of forage land is also a key factor

in ensuring a continuous supply of cattle manure as a raw material for biogas. Therefore, land carrying capacity analysis not only serves to determine the capacity for livestock development but also provides the basis for calculating the potential for renewable energy that can be generated through biogas technology.

The village of Cirahab has a total area of 9.46 km², equivalent to 946 hectares (ha). However, not all of this area can be utilized as forage land, as part of it is used for residential areas, public facilities, roads, rivers, and other land uses. Therefore, this study employs five land-use scenarios: 10%, 20%, 30%, 40%, and 50% of the total area.

The area of potential land is calculated using the following equation:

$$L_p = L_t \times P$$

Description:

- L_p = potential land area (ha)
- L_t = village area (ha)
- P = percentage of land in use

Table 2. Ratio of land area in use

No	Percentage of Lan	Land Area (ha)
1	10%	94,6
2	20%	189,2
3	30%	283,8
4	40%	378,4
5	50%	473,0

Estimated Number of Livestock That Can Be Raised in Cirahab Village

The success of a household biogas program is heavily influenced by the amount of livestock manure available each day. An adult cow typically produces about 10–20 kg of fresh manure per day, while a household biogas digester with a capacity of 4–6 m³ generally requires about 20–30 kg of fresh manure per day. Thus, this feedstock requirement can be met by approximately 2–3 adult cows to meet the cooking energy needs of a single household (Sofyan & Adi, 2024).

The number of cows that can be raised is calculated based on the assumption that 0.1 ha of forage land is needed per cow. The equation used is:

$$J_s = \frac{L_p}{0,1}$$

Description:

- J_s = number of cattle (heads)
- L_p = forage land area (ha)

T Table 3. Number of Livestock That Can Be Raised

Land Percentage	Land Area (ha)	Number of Cows (head)
10%	94,6	946
20%	189,2	1.892
30%	283,8	2.838
40%	378,4	3.784
50%	473,0	4.730

Estimated Number of Households Using Biogas

In this study, it is assumed that the biogas feedstock requirements for one household are met by 2.5 cows (Ulva et al., 2022). The number of households that can be served is calculated using the following equation:

$$J_{KK} = \frac{J_s}{2,5}$$

Description:

- J_{KK} = number of households
- J_s = number of cows (heads)

Tabel 4. Jumlah Rumah Tnagga Pengguna Biogas

No	Land Percentage	number of cows (heads)	Number of household
	10%	946	378
	20%	1.892	757
	30%	2.838	1.135
	40%	3.784	1.514
	50%	4.730	1.892

Assuming that the government subsidy for each 3-kg LPG cylinder is Rp30,000, the potential savings for the government can be calculated using the following equation.

Subsidy Savings Formula

$$PS = T \times S$$

With:

- PS = Subsidy savings (Rp)
- T = Number of 3-kg LPG cylinders that can be replaced
- S = Subsidy per 3-kg LPG cylinder (Rp30,000)
- Meanwhile, annual savings are calculated as:

$$PS_t = PS_b \times 12$$

dengan:

- PS_t = Annual subsidy savings
- PS_b = Monthly subsidy savings

Table 5. Potential Government Savings

Land Use	LPG Cylinders Replaced (cylinders/month)	Government Savings (Rp/month)	Government Savings (Rp/year)
10%	1.344	Rp 40.320.000	Rp 483.840.000
20%	2.692	Rp 80.760.000	Rp 969.120.000
30%	4.037	Rp 121.110.000	Rp 1.453.320.000
40%	5.385	Rp 161.550.000	Rp 1.938.600.000
50%	6.729	Rp 201.870.000	Rp 2.422.440.000

DISCUSSION

Based on the analysis results, the use of cow manure-based biogas in Cirahab Village has the potential to generate significant savings in the government's LPG subsidy budget. Under a 10% land utilization scenario, biogas production is estimated to replace approximately 1,344 3-kg LPG cylinders each month, potentially saving the government Rp40.32 million in subsidies per month, or about Rp483.84 million per year.

If the proportion of land utilized increases to 40%, the livestock capacity is estimated to reach 3,784 head of cattle, which could meet the biogas needs of approximately 1,514 households.

This biogas production is equivalent to replacing approximately 5,385 3-kg LPG cylinders each month, resulting in potential government subsidy savings of around Rp161.55 million per month or Rp1.94 billion per year.

Meanwhile, under an optimistic scenario with 50% land utilization, the potential subsidy savings increase to approximately 6,729 3-kg LPG cylinders per month, with an economic value of about Rp201.87 million per month or approximately Rp2.42 billion per year. These results indicate that the development of household biogas not only enhances the community's energy self-reliance but also makes a tangible contribution to the efficiency of government spending by reducing the need for LPG subsidies.

Table 6. Analysis of the Potential for Land Use for Cattle Biogas and Its Equivalence to a 3-kg LPG Cylinder.

Land Use	Land Area (ha)	Number of Cows	Number of Households	Biogas (m ³ /month)	LPG Equivalent (kg/month)	3 kg LPG Cylinders/month
10%	94,6	946	378	8.768	4.033	1.344
20%	189,2	1.892	757	17.559	8.077	2.692
30%	283,8	2.838	1.135	26.327	12.111	4.037
40%	378,4	3.784	1.514	35.119	16.155	5.385
50%	473,0	4.730	1.892	43.887	20.188	6.729

CONCLUSION

Based on the results of the analysis, Cirahab Village has significant potential to develop cattle farming as a source of raw materials for household biogas. With a total area of 946 ha and a forage land utilization scenario of 10-50%, the land's carrying capacity is estimated to support 946-4,730 head of cattle, which could meet the cooking energy needs of approximately 378–1,892 households.

Under a 40% land utilization scenario considered the most realistic Cirahab Village is estimated to be able to support the raising of 3,784 head of cattle and produce 35,119 m³ of biogas per month, equivalent to 5,385 3-kg LPG cylinders per month. Assuming an LPG subsidy of Rp30,000 per cylinder, implementing the biogas program under this scenario has the potential to save the government Rp161,550,000 in subsidy costs per month, or approximately Rp1,938,600,000 per year.

The results of this study indicate that the development of cattle-based biogas is a viable

alternative to support rural energy security, reduce dependence on subsidized LPG, and improve the efficiency of local resource utilization through the integration of the agriculture, livestock, and renewable energy sectors. Therefore, this program has the potential to become a strategy for sustainable village development while also supporting the national energy transition policy.

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