

Economic Feasibility and Sustainability of a Circular Economy of Cow Dung-Based Household Biogas in West Nusa Tenggara

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Abstract

This study aims to analyze the economic feasibility of utilizing cow dung for household biogas and examine its contribution to the implementation of a circular economy and local resource-based economic development in West Nusa Tenggara Province. The study uses a quantitative approach with the Cost-Benefit Analysis (CBA) method through Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP) indicators, supported by empirical validation through limited interviews with household biogas users. The research data is a combination of secondary and primary data. The results show that the household biogas system is economically feasible with an NPV of Rp869,688, an IRR of 12.6%, a BCR of 1.09, and a Payback Period of 6.8 years. The main economic benefits come from savings in LPG use and the use of bio-slurry as organic fertilizer, which is supported by field validation results in the form of reduced household energy expenditure and low operational costs of the biogas system. From a circular economy perspective, the biogas system reflects a closed-loop system pattern through processing livestock waste into renewable energy and utilizing its residue as a productive input. These findings indicate that household biogas is not only feasible as a renewable energy investment, but also contributes to increasing the efficiency of local resource utilization, strengthening the energy security of rural communities, contributing to the efficiency of community expenditure, and supporting sustainable economic development in West Nusa Tenggara Province.

INTRODUCTION

The transition to a sustainable energy system has become a strategic agenda for economic development, particularly in developing countries that still face a high dependence on fossil fuels. Modern economic development is no longer solely oriented toward increasing economic growth, but also focuses on a region's ability to optimize the use of local resources, create added value, strengthen energy security, and maintain environmental sustainability. In this context, the development of locally sourced renewable energy is a crucial instrument in driving the transformation toward a more inclusive and sustainable green economy and circular economy. (International Energy Agency, 2022; Rianawati et al., 2021).

In Indonesia, the household energy sector in rural areas is still dominated by the use of conventional fuels such as Liquefied Petroleum Gas (LPG) and firewood. This dependence on fossil fuels not only increases household vulnerability to energy price fluctuations but also increases pressure on low-income household budgets and slows the transition to a more sustainable energy system. Therefore, developing renewable energy that utilizes the potential of local resources is a crucial strategy to support energy security while strengthening regional economic development,

particularly in rural areas with abundant natural resources and livestock. (International Energy Agency, 2022; Ministry of Energy and Mineral Resources, 2023).

West Nusa Tenggara Province is one of the regions with a strong livestock economic base, characterized by a beef cattle population of around 1.3 million head and spread across various districts/cities. (BPS NTB, 2024) Central Lombok Regency is a livestock center with a cattle population of approximately 144,075. This large livestock population demonstrates the livestock sector's significant potential as a driver of regional economic development. However, the resulting cow manure waste is largely underutilized, thus failing to create added economic value and even potentially causing environmental pollution, particularly water pollution and odor disturbances. (Ahmad Chaidir, 2016). From a development economics perspective, this condition shows that livestock waste is still an economic resource that has not been optimally utilized (underutilized economic resource), even though through technological innovation this waste can be transformed into a productive asset that supports local resource-based economic development. (Nuryanti et al., 2024).

One way to optimize these resources is by utilizing cow dung to produce household biogas. In addition to producing alternative energy that can replace LPG, the biogas system also produces bio-slurry that can be used as organic fertilizer, thereby increasing the efficiency of resource use in the livestock and agricultural sectors. (Kabeyi & Olanrewaju, 2022; Kusmiyati et al., 2023) From a development economics perspective, the benefits of biogas extend beyond household energy savings, contributing to increased added value in the livestock sector, strengthening the energy security of rural communities, reducing agricultural production costs through the use of organic fertilizers, and reducing environmental pollution. The interconnectedness of the livestock, energy, and agriculture sectors reflects local resource-based economic development that supports more inclusive and sustainable economic growth. (Guindo et al., 2023).

Various previous studies have shown that the use of livestock manure-based biogas is generally feasible from both technical and financial perspectives. Biogas can be an alternative energy source that can contribute to reducing dependence on fossil fuels, particularly in developing countries. (Bond & Templeton, 2011; Surendra et al., 2014) From an economic perspective, processing cow dung into biogas is considered feasible based on the Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit-Cost Ratio (BCR) indicators, which meet investment criteria. (Muharja et al., 2024) Meanwhile, from an environmental perspective, the application of Anaerobic Digestion technology can reduce methane emissions while producing organic fertilizer that supports increased agricultural productivity. (Widiarta et al., 2025). In addition, community-based biogas development has also been reported to be able to improve the welfare of livestock farmers through the empowerment of livestock groups. (Abyadul Fitriyah et al., 2021) However, most of these studies still focus on technical, financial, or environmental aspects separately, thus failing to examine the contribution of biogas to regional economic development through optimizing local resources and creating added value across sectors.

The circular economy approach offers a more comprehensive perspective on livestock waste utilization. This concept emphasizes efficient resource use through material reuse, waste reduction, and sustainable value creation. (Geissdoerfer et al., 2017) In the context of household biogas, cow dung, which initially had no economic value, is processed into renewable energy, while the residue is reused as organic fertilizer. This cycle not only provides economic benefits through energy savings and reduced agricultural production costs, but also strengthens environmental

sustainability and improves community well-being through the optimization of local resources.(Fitri & Hamdi, 2024).

Although various studies have demonstrated the technical and financial feasibility of developing household biogas, studies integrating economic feasibility analysis with a circular economy perspective and linking it to regional economic development are still relatively limited, particularly in areas with a livestock-based economy, such as West Nusa Tenggara Province. Most studies still position biogas as an alternative energy technology at the household level, while its contribution to increasing the added value of the livestock sector, strengthening energy security in rural communities, and developing a local resource-based economy has not been comprehensively discussed.

Therefore, this study aims to analyze the economic feasibility of utilizing cow dung-based household biogas using the Cost-Benefit Analysis (CBA) approach through the Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP) indicators, and evaluate its contribution in supporting the implementation of a circular economy in West Nusa Tenggara Province. Different from previous studies, this study not only evaluates the feasibility of household biogas investment, but also positions biogas as a local resource-based economic development strategy that contributes to increasing the added value of the livestock sector, strengthening community energy security, and providing empirical evidence for the formulation of sustainable economic development policies in West Nusa Tenggara Province.

METHODS

Types and Approaches of Research

This research uses a quantitative approach with descriptive-analytical methods. The focus of this study is to evaluate the economic feasibility of household biogas investments through a Cost-Benefit Analysis (CBA) and to examine its contribution to sustainable development from a circular economy perspective. The analysis was conducted using simulations based on secondary data, reinforced by limited empirical validation with household biogas users.

Data Collection Sources and Techniques

The data used in this study consisted of secondary data and limited primary data. Secondary data were obtained from the Central Statistics Agency (BPS), reports from household biogas programs such as the Indonesia Domestic Biogas Program (IDBP), reports from related agencies, and relevant previous research. Primary data were obtained through limited interviews with household biogas users, which aimed to validate assumptions regarding investment costs, operational and maintenance costs, and benefits derived from biogas utilization. Therefore, the primary data in this study were not used as a basis for statistical analysis, but rather as empirical validation of the assumptions used in the CBA analysis.

Unit of Analysis and Research Location

The unit of analysis in this study is a cow dung-based household biogas system. The research location focused on West Nusa Tenggara Province, specifically Central Lombok Regency, as one of the centers for cattle farming and household biogas users.

Table 1. Beef Cattle Population and Biogas-Using Households in West Nusa Tenggara Province in 2024

Regency/City	Beef Cattle Population (Head)	Biogas User Households
Mataram City	1,075	10
Bima City	27,698	34
West Lombok Regency	95,205	617
East Lombok Regency	143,658	1,034
Central Lombok Regency	144,075	1,079
North Lombok Regency	67,396	1,476
West Sumbawa Regency	90,761	495
Sumbawa Regency	307,552	668
Dompu Regency	188,160	461
Bima Regency	239,714	258

Source: BPS West Nusa Tenggara Province (2024) and Data on Households Using Biogas in NTB Province (2024).

Based on Table 1, Central Lombok Regency has a relatively high cattle population of 144,075, with 1,079 households using biogas. This indicates adequate raw material availability and the implementation of household biogas at the community level. The location was selected not only based on the cattle population size but also on the high number of households using biogas, making this area representative for validating the economic benefits and sustainability of household biogas systems in West Nusa Tenggara Province.

1. Economic Feasibility Analysis Techniques for Household Biogas Systems

The economic feasibility analysis was conducted using a Cost-Benefit Analysis (CBA) approach based on Discounted Cash Flow to evaluate the benefits and costs of the investment over the life of the biogas installation. Indicators used included Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP). This approach was chosen because it can illustrate investment feasibility through present value, making it more appropriate for evaluating renewable energy investments that provide long-term benefits.

a) Net Present Value (NPV)

NPV is used to measure the difference between the present value of benefits and the present value of costs over the life of a biogas installation. An investment is considered feasible if the NPV is positive.

General formula for NPV

$$NPV = \sum_{t=1}^n \frac{B_t - C_t}{(1+r)^t} - I_0$$

Information:

- B_t = benefits in year t
- C_t = costs in year t
- r = discount rate
- n = technical age of the project
- I_0 = initial investment

Criteria:

- $NPV > 0 \rightarrow$ feasible
- $NPV < 0 \rightarrow$ not feasible

b) Internal Rate of Return (IRR)

The IRR is the discount rate that results in a zero NPV. Mathematically, a biogas investment is considered economically feasible if the IRR is greater than the discount rate used.

Basic IRR formula

$$0 = \sum_{t=1}^n \frac{B_t - C_t}{(1 + IRR)^t} - I_0$$

Criteria:

- $IRR > r \rightarrow$ feasible
- $IRR < r \rightarrow$ not feasible

c) Benefit-Cost Ratio (BCR)

The BCR is used to compare the present value of benefits with the present value of costs over the life of the installation. The BCR formula is written as follows:

$$BCR = \frac{PV \text{ Manfaat}}{I_0 + PV \text{ Biaya O\&M}}$$

Criteria:

- $BCR > 1 \rightarrow$ feasible
- $BCR < 1 \rightarrow$ not feasible

d) Payback Period (PP)

Payback Period The PP is used to determine the time required for the initial investment to be covered by net cash flow. The calculation is performed by observing the accumulated annual net benefits until the initial investment value is reached. An investment is considered attractive if the capital recovery period is relatively short compared to the installation's technical life. The PP calculates the time required to recoup the initial investment.

$$PP = \frac{I_0}{Arus \text{ Kas Bersih Tahunan}}$$

Information:

- I_0 = initial investment
- $B_t - C_t$ = annual net cash flow

e) Cost-Benefit Analysis (CBA) Summary

Methodologically, the CBA in this study uses the Discounted Cash Flow approach. Based on the calculation results:

- $NPV > 0$ indicates the project increases wealth.
- $IRR > r$ ($12.6\% > 10\%$) indicates the project is profitable compared to the benchmark interest rate.
- $BCR > 1$ indicates benefits outweigh costs.

2. Analysis of the Benefits and Sustainability of the Circular Economy

In addition to the economic aspect, this study also assesses the contribution of household biogas systems within a circular economy framework through a descriptive approach focusing on social and environmental aspects. The method used to analyze benefits and sustainability is field validation of Cost-Benefit Analysis calculations. The social aspect is measured through labor absorption indicators arising from the construction, operation, and maintenance of household biogas installations. The environmental aspect is analyzed through the potential reduction of water pollution due to the processing of cow dung that was previously discharged directly into the environment. This approach is used to provide a comprehensive overview of the benefits of household biogas systems not only as an economic investment but also as part of sustainable development efforts based on a circular economy in rural areas.

RESULTS AND DISCUSSION

1. Economic Feasibility of Household Biogas Systems

The economic feasibility analysis of a cow dung-based household biogas system in West Nusa Tenggara Province was conducted using a Cost-Benefit Analysis (CBA) approach, assuming constant cash flows over the project's 15-year lifespan and a 10% discount rate. The technical and economic parameters used in the analysis are presented in Table 2.

Table 2. Technical Parameters and Economic Assumptions

Component	Mark	Unit
Digester capacity	6	m ³
Initial Investment	7,500,000	Rp
Annual O&M Cost	300,000	Rp/year
Benefits of LPG	900,000	Rp/year
Benefits of Slurry	500,000	Rp/year
Total Benefit	1,400,000	Rp/year
Net Benefit	1,100,000	Rp/year
Technical Age	15	Year
Discount Technique	10	%

Source:Primary data processed 2026

The initial investment value refers to the 2023 Indonesia Domestic Biogas Program (IDBP) cost standard for a 6 m³ digester capacity. The installation's technical life is set at 15 years, referring to previous studies demonstrating the long-term durability of household digester construction. Operational and maintenance costs are assumed to be IDR 300,000 per year based on field interviews, which indicate that household biogas installations in West Nusa Tenggara Province require relatively few repair costs during the first five years of operation. This value is used as an estimate to accommodate minor maintenance needs. In terms of benefits, LPG savings are calculated at IDR 900,000 per year, derived from an average savings of IDR 75,000 per month based on actual household usage after switching to biogas.(Wresta et al., 2015).

Meanwhile, the economic value of the slurry is assumed to be IDR 500,000 per year as an estimate for the utilization of biogas residue as organic fertilizer. A 10% discount rate is used to represent the time value of money in evaluating renewable energy investments in Indonesia and refers to previous studies that used a similar discount rate as the basis for calculating the present value of investment benefits and costs.(Afriani & Poletti, 2026; NewClimate Institute & IESR, 2024).Based on these parameters, annual cash flow and present value calculations are carried out, which are presented in Table 2.

Table 3. Cash Flow Projections and Present Value

Year	Benefit (Rp)	Cost	Net Benefit (Rp)	Discount Factor	Present Value (Rp)
0	0	7,500,000	- 7,500,000	1.00	-7,500,000
1	1,400,000	300,000	1,100,000	0.909	1,000,000
2	1,400,000	300,000	1,100,000	0.826	909,091
3	1,400,000	300,000	1,100,000	0.751	826,446
4	1,400,000	300,000	1,100,000	0.683	751,315
5	1,400,000	300,000	1,100,000	0.621	683,013
6	1,400,000	300,000	1,100,000	0.564	620,921
7	1,400,000	300,000	1,100,000	0.513	564,474
8	1,400,000	300,000	1,100,000	0.467	513,158
9	1,400,000	300,000	1,100,000	0.424	466,507
10	1,400,000	300,000	1,100,000	0.386	424,098
11	1,400,000	300,000	1,100,000	0.350	385,543
12	1,400,000	300,000	1,100,000	0.319	350,494
13	1,400,000	300,000	1,100,000	0.290	318,631
14	1,400,000	300,000	1,100,000	0.263	289,665
15	1,400,000	300,000	1,100,000	0.239	263,332

Source:Primary data processed 2026

Total: Total PV Net Benefit (Years 1-15) Rp8,369,688

Initial Investment Rp7,500,000

NPV Rp.869,688

Table 3 shows that the household biogas system generates an annual net cash flow of Rp1,100,000 derived from the total annual benefits of Rp1,400,000 minus the operation and maintenance costs of Rp300,000. The present value of the net benefits decreases each year due to the influence of a 10% discount factor, which reflects the time value of money.

The accumulated net cash flow value over 15 years reached Rp 8,369,688. After deducting the initial investment of Rp 7,500,000, the Net Present Value (NPV) was obtained at Rp 869,688. A positive NPV value indicates that the investment in the household biogas system is still economically feasible and can provide net benefits over the project's technical life.

Table 4. Summary of Cost-Benefit Analysis Results

Indicator	Mark	Criteria	Information
NPV	Rp.869,688	> 0	Worthy
IRR	12.6%	> 10%	Worthy
BCR	1.09	> 1	Worthy

Indicator	Mark	Criteria	Information
PP	6.8 years	<15 years	Worthy

Source: Primary data processed 2026

Based on Table 4, all economic feasibility indicators show results that meet the investment criteria. The Net Present Value (NPV) of Rp. 869,688 (greater than zero) indicates that the investment is feasible and capable of generating net economic benefits over the project's technical life. The Internal Rate of Return (IRR) of 12.6%, which is higher than the 10% discount rate, indicates that the investment return is reasonable because it is still above the cost of capital. The Benefit-Cost Ratio (BCR) of 1.09 indicates that every rupiah of cost generates benefits of Rp. 1.09. In addition, the payback period of 6.8 years is still shorter than the installation's technical life of 15 years, so there is a sufficiently long remaining operating period to generate additional economic benefits.(Abdo et al., 2024).

Research results mfound that the use of cow dung as an energy source provides economic benefits that can cover investment costs in the long term.(Wresta et al., 2015). Similar findings were also reported by(Nandiyanto et al., 2018), which shows that a biogas system for livestock farming is feasible to develop because it produces greater economic benefits compared to the costs incurred during the operational life of the installation. These results indicate that although household LPG savings are relatively limited, a biogas system remains feasible if operating and maintenance costs are at a low level, as found in empirical conditions in the field.(Geddafa et al., 2023; Meilinda Suriani Harefa et al., 2024).

2. Analysis of the Benefits and Sustainability of the Circular Economy

Empirical Validation and Relevance to Economic Development

The results of the quantitative analysis are supported by empirical conditions in the field. Based on interviews with household biogas users, it was found that before using biogas, households spent approximately IDR 75,000 per month on LPG. After switching to biogas, these expenses were significantly reduced, resulting in savings of approximately IDR 900,000 per year. This finding indicates that the economic benefits assumed in the analysis have a good level of agreement with actual conditions in the field. The consistency between the calculation results and the empirical conditions indicates that the assumptions used in the study have a sufficient level of validity.(Pfau et al., 2017). Furthermore, the low operational costs reported by users indicate that the biogas system is relatively efficient for long-term implementation. This finding further strengthens the feasibility analysis, which indicates that household biogas investment is feasible.

From a development economics perspective, these savings not only reflect household spending efficiencies but also demonstrate increased economic capacity in rural communities. Reduced energy expenditure allows households to allocate resources to other productive needs, thereby contributing to improved household well-being and economic resilience. Furthermore, reduced dependence on LPG strengthens community energy security, particularly in rural areas vulnerable to price fluctuations and limited conventional energy distribution.

Contribution to Household Economic Efficiency and Energy Security

The primary economic benefit of a household biogas system comes from energy cost savings. Using biogas as an alternative energy source allows livestock households to reduce their dependence on LPG and other conventional fuels.(Zhuniart Ayu Perdanasari, 2018)These savings

provide direct benefits in the form of increased household spending efficiency while strengthening energy security at the local level. (Kabeyi & Olanrewaju, 2022).

From a development economics perspective, energy efficiency extends beyond cost reduction. The savings achieved by households can improve their ability to meet basic needs and engage in other productive economic activities. Thus, biogas utilization contributes to increasing the economic resilience of rural households by reducing their vulnerability to rising conventional energy prices. In addition to energy savings, the use of bioslurry as an organic fertilizer provides additional economic benefits by partially substituting chemical fertilizers. Although its economic value is relatively limited compared to the benefits of LPG savings, bioslurry still contributes to increasing resource utilization efficiency at the household level. (Savitri et al., 2024).

Furthermore, the use of bio-slurry reflects the creation of added value from previously underutilized livestock waste. In the context of local resource-based economic development, this demonstrates increased resource efficiency, where a single production process can generate diverse economic benefits. This integration between the livestock, energy, and agricultural sectors strengthens intersectoral linkages, a crucial characteristic of regional economic development.

Social Contribution to Strengthening the Local Economy

From a social perspective, household biogas systems contribute by creating additional economic activities related to the construction, management, and maintenance of biogas installations. These activities have the potential to absorb labor at both the household and local levels, particularly during the installation construction and maintenance phases. Although their contribution to labor absorption is relatively limited, the presence of biogas systems still has a positive impact on improving the welfare of livestock households. (Nandiyanto et al., 2018).

In addition to providing direct economic benefits, biogas utilization also increases the capacity of communities to manage local resources more productively. The use of livestock waste as an alternative energy source shifts public perception of waste, previously considered worthless, into a resource with economic and environmental benefits. There are also indications of a demonstration effect, where the success of biogas users encourages interest in adopting similar technologies in other communities. This phenomenon demonstrates that biogas development not only impacts user households but also has the potential to expand the diffusion of innovation at the community level. In the long term, this can support the strengthening of community-based local economic development through the utilization of resources available in rural areas.

Environmental Contribution in Supporting Sustainable Development

From an environmental perspective, the use of cow dung for biogas contributes to the reduction of water pollution and organic waste. Processing cow dung through a biogas digester reduces the practice of discharging livestock waste directly into the environment, which previously had the potential to pollute water bodies and cause health problems. In this study, environmental benefits were assessed qualitatively through the potential reduction in water pollution resulting from more controlled cow dung management. This approach was used due to the limited data on environmental economic valuation specific to the household scale. Nevertheless, observations indicate a change in waste management patterns following the implementation of the biogas system.

Before biogas, cow manure was generally dumped directly into the environment or left to pile up around the barn. After biogas implementation, the waste is processed into energy, while the

residue is used as organic fertilizer for agricultural land. In fact, some users have begun developing the use of bio-slurry as a fertilizer product with potential sales value, opening up additional economic opportunities in the future. These findings align with research.(Shaibur et al., 2025)which states that managing cow dung through a biogas system not only produces renewable energy but also bio-slurry that can improve soil fertility and support sustainable agricultural practices. From a development economics perspective, improving environmental quality is a crucial prerequisite for sustainable development because good environmental quality will support the sustainability of community economic activities, particularly in the agricultural and livestock sectors, which are highly dependent on natural resources.

Biogas in the Perspective of Circular Economy and Regional Development

Overall, the cow dung-based household biogas system in West Nusa Tenggara Province reflects the principles of a circular economy through a closed-loop resource utilization system. Previously waste cow dung is processed into renewable energy, while the residue is reused as organic fertilizer.(Shaibur et al., 2025).This pattern shows that waste is no longer seen as residue that must be disposed of, but rather as an economic resource that can be reused to produce added value.(Hak et al., 2023)The integration of economic, social, and environmental benefits demonstrates that biogas systems serve not only as an alternative energy source but also as a mechanism for increasing resource efficiency and reducing waste. The interconnectedness of the livestock, energy, and agricultural sectors creates a more productive and sustainable economic cycle, thus supporting the implementation of a circular economy at the household and rural community levels.(Surendra et al., 2014).

The findings of this study also have broader implications for regional economic development. For West Nusa Tenggara Province, which has a large beef cattle population, the development of household biogas has the potential to become a local resource-based development strategy. Optimizing livestock waste into renewable energy not only increases the added value of the livestock sector but also strengthens community energy security, reduces environmental burdens, and opens up opportunities for new economic activities that support sustainable regional development. Thus, household biogas can be viewed not only as an alternative energy technology but also as a local economic development instrument capable of simultaneously integrating economic, social, and environmental objectives. These findings strengthen the argument that community-based biogas development can be a strategy in supporting the transformation towards a green economy and sustainable development in West Nusa Tenggara Province.

3. Research Limitations

This study has several limitations that should be considered when interpreting the results. First, the economic feasibility analysis assumes constant cash flows throughout the project's lifecycle, thus failing to consider potential future changes in energy prices, operational costs, or the economic value of bioslurry. Second, the economic benefit estimates are based on interviews with a limited number of respondents, so the representativeness of the results across a wider region requires further study. Third, the environmental benefits in this study are still analyzed qualitatively and have not been converted into economic values due to limited environmental valuation data at the household level. We recommend that future research develop sensitivity analyses to changing economic conditions, expand the scope and number of respondents, and integrate environmental economic valuation approaches and economic impact analyses at the regional level. These developments are expected to provide a more comprehensive picture of the contribution of

household biogas to local resource-based economic development and the implementation of a circular economy.

CONCLUSION

This study shows that the utilization of cow dung for household biogas in West Nusa Tenggara Province remains economically feasible and relevant within a circular economy framework. The Cost-Benefit Analysis (CBA) results indicate a Net Present Value (NPV) of Rp869,688, an Internal Rate of Return (IRR) of 12.6%, a Benefit-Cost Ratio (BCR) of 1.09, and a Payback Period of 6.8 years. All of these indicators meet the investment feasibility criteria, indicating that the biogas system is still capable of providing net economic benefits to user households even with more conservative assumptions. Furthermore, the empirical validation results show consistency between the calculation assumptions and actual conditions in the field, particularly in terms of relatively limited but stable savings in household energy costs. This reinforces that the biogas system is not only theoretically feasible but also applicable in a rural context with modest energy consumption characteristics. From a development economics perspective, the results of this study indicate that the utilization of livestock waste as renewable energy can create added value from local resources that have previously been underutilized. Biogas systems not only improve the economic efficiency of livestock households but also strengthen the energy security of rural communities, promote linkages between the livestock, energy, and agricultural sectors, and support more inclusive and sustainable local economic development. Therefore, household biogas development can be viewed as a local resource-based development strategy that supports the transition to a green economy and a circular economy in West Nusa Tenggara Province.

POLICY IMPLICATIONS

Based on the research results, several policy implications can be considered to support the development of cow dung-based household biogas in West Nusa Tenggara Province. First, the local government, along with relevant agencies, needs to expand support for household biogas development by providing financing schemes or initial investment assistance. This step is crucial considering that the cost of building installations remains a major obstacle to the adoption of biogas technology at the household level. Second, a sustainable mentoring program is needed for communities, not only in the operation and maintenance of biogas installations, but also in optimizing the use of bio-slurry as an economically valuable organic fertilizer. This approach is expected to increase the sustainability of biogas use while opening up opportunities for business development based on biogas by-products. Third, household biogas development needs to be integrated into regional development policies through a circular economy approach that connects the livestock, energy, and agricultural sectors. This integration has the potential to increase the efficiency of local resource utilization, strengthen the energy security of rural communities, and create added value that supports sustainable regional economic development.

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