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Implementation of Biogas Systems in Broiler Farms to Improve Biosecurity and Sustainable Economic Value

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Abstract: This study aims to evaluate the application of an integrated biogas system in closed house broiler farms as an effort to improve energy efficiency, biosecurity, and sustainable economic value. The research was carried out at PT Zara Propertifarm Indonesia, Bogor Regency, with a system engineering approach and cost-benefit analysis. The results of the study show that the application of biogas is able to reduce LPG consumption by 50% and save energy costs of up to IDR 1,500,000 per production cycle. In addition, there was an increase in the average weight of chickens from 1.82 kg to 1.97 kg per head and a decrease in the mortality rate from 4.8% to 3%. The fermented waste was successfully processed into solid and liquid fertilizer with laboratory quality according to the SNI 19-7030-2004 standard. Economic analysis shows that the total benefits reach IDR 4,760,000 per 1,000 chickens per cycle. Socially, this activity increased the capacity of 15 MBKM students and 8 partner farmers through biogas system operational training. These findings confirm that the biogas system can be a model of sustainable teaching farms based on renewable energy that supports the transition to low-emission agriculture and a circular economy in the livestock sector.

Keywords: Biogas; Energy efficiency; Sustainable farming.

Introduction

The poultry sector plays a vital role in meeting the increasing demand for animal protein in Indonesia (Fadilah et al., 2025). According to the Central Bureau of Statistics, the broiler chicken population has exceeded 3.1 billion birds, reflecting its strategic role in supporting national food security (BPS, 2022; Kleyn & Ciacciariello, 2022; Puji et al., 2023). This large-scale production supports millions of small and medium-scale farmers and contributes substantially to economic development in rural regions across Indonesia (Nyange et al., 2019). As the demand for broiler meat continues to rise, the sector's contribution to food security and economic stability becomes increasingly significant at the national level.

Alongside its rapid growth, the poultry sector requires an efficient production model supported by effective environmental management and disease prevention strategies (Kostaman et al., 2024). Broiler farming generates substantial quantities of organic waste, especially feces, which pose a risk as a reservoir of pathogens if not managed properly (Yanqoritha, 2023). The integration of renewable energy technologies, such as biogas systems, represents an essential scientific approach to transforming waste into useful energy while simultaneously reducing pathogen loads and greenhouse gas emissions (Putra et al., 2025). This concept aligns with the global discourse on sustainable agriculture and the circular economy, where resource optimization and environmental protection are prioritized (Parmawati et al., 2025).

Despite advancements in vaccination programs and antibiotic use, broiler farms continue to face high mortality rates due to diseases such as Avian Influenza (AI), Newcastle Disease (ND), and Infectious Bursal Disease (IBD) (Ike et al., 2021). These pathogens can thrive in poultry houses due to fecal accumulation and inadequate waste management, especially in open-house systems that are vulnerable to environmental variations (Claude et al., 2021; Ramukhithi et al., 2023). Even though closed-house systems offer better

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environmental control, they still fail to ensure effective waste separation and treatment (Sima et al., 2013; Rabaey et al., 2020). Integrating a biogas system into closed-house operations presents an innovative solution to enhance biosecurity through real-time waste processing while producing renewable energy and organic fertilizer (Sulewski, 2024; Ejedegba, 2024).

Given the growing emphasis on sustainable livestock management and green economy initiatives, the adoption of biogas-based waste treatment systems in broiler farms has become increasingly urgent (Ejedegba, 2024). Implementing this system is expected to improve farm biosecurity, reduce pathogen transmission risks, and strengthen environmental sustainability within broiler production. Therefore, this study aims to develop and evaluate the integration of biogas technology in closed-house broiler farming systems to enhance biosecurity, reduce production costs, and generate greater economic and environmental value. The findings of this study are expected to contribute to the development of sustainable poultry production models that improve farmer resilience and support Indonesia's low-carbon development agenda.

Method

Time and Place

The research was carried out from May to October 2023 in the livestock area of PT Zara Propertifarm Indonesia, Bogor Regency, West Java Province. This location was chosen purposively because it represents the characteristics of a modern broiler farm with a closed house system, and has the potential to apply integrated biogas technology as an effort to energy efficiency and waste management**.**

Research design

This research uses a system engineering research approach that focuses on design, implementation (Samaras & Horst, 2005), and evaluation of integrated biogas systems in closed house type chicken coops (Tumusiime et al., 2023). The main goal of this research is to create a system that is able to separate chicken manure from the beginning of maintenance to reduce the risk of disease and utilize waste as an alternative energy source. The method applied is an applied experiment design (Krishnaiah & Shahabudeen, 2012), with collaboration between universities, industry, and society (triple helix collaboration) (Etzkowitz & Leydesdorff, 2000:(Ranga & Etzkowitz, 2013).

Population and Research Sample

The research population includes broiler farming units operating with a closed house system under the management of PT Zara Propertifarm Indonesia. The research sample was determined by purposive sampling (Yusuf et al., 2025). Chickens that are considered representative of modern systems based on automation of ventilation and feeding (Poultry, 2022). The subjects of the activity include cage operators, partner breeders, and students of the Independent Learning Independent Campus (MBKM) program who are involved in the implementation process.

The main variables of the study included: (a) the efficiency of waste treatment, (b) the volume and quality of the methane gas produced. Data collected through direct observation (Salahuddin et al., 2024), recording of the content of solid and liquid fertilizers from laboratory tests, and structured interviews (Hastika & Supriatno, 2024). The research materials include fresh chicken manure, water, and starter bacteria (EM4) as inoculants in the biogas fermentation process.

Research procedure

The stages of the research implementation include four main steps of certainty:

1. *Planning and Coordination*:

Conducting a partner needs analysis, preparing the design of the biogas system according to farm conditions, as well as scheduling activities and division of roles between the university team and industrial partners.

2. *Technology Implementation*:

Build a biogas reactor unit to process chicken manure into methane gas. The gas produced is used as an energy source to replace LPG for brooder heating and cage lighting. Fermentation residues (sludge) are processed into solid and liquid organic fertilizer.

3. *Training and Mentoring*:

Carry out training for farmers and MBKM students on the operation and maintenance of biogas systems, as well as the application of cage biosecurity principles. Technical assistance is provided by lecturers and industry practitioners on a regular basis.

4. *Monitoring and Evaluation:*

Observations were made on the stability of the fermentation process, the volume of gas produced, the air quality of the cage, and the response of chickens to environmental changes. The evaluation also includes an analysis of the economic benefits and social impacts of the implementation of an integrated biogas system.

Data Analysis

Quantitative data are analyzed descriptively and inferentially (Tambunan et al., 2021). The efficiency of the system is calculated based on the ratio of waste to methane gas conversion (m^3/kg of waste) and the ratio of energy savings (LPG equivalent) (Chamdimba, 2025). The efficiency of the system is calculated based on the ratio of waste to methane gas conversion (m^3/kg of waste) and the ratio of energy savings (LPG equivalent).

Socio-economic data were analyzed using the (cost-benefit analysis) method (Florio et al., 2025), while farmers' perception of the application of technology is analyzed through the Likert scale (Aditiawan et al., 2025). All data is processed using Microsoft Excel software to generate charts and tables.

Result and Discussion

Implementation of Biogas System in Chicken Farms

The implementation of an integrated biogas system in PT Zara Propertifarm Indonesia's chicken farm has been successfully carried out. Chicken manure waste that had previously accumulated on the floor of the cage was drained into a closed digester reactor, so that the condition of the cage became cleaner and free of ammonia-free. The fermentation process produces methane gas which is used to operate the brooder heater and some of the enclosure's lighting needs. The application of this technology supports energy efficiency while creating a healthier maintenance environment for livestock. The implementation of the biogas system in the chicken coop is presented in full (Figure 1).

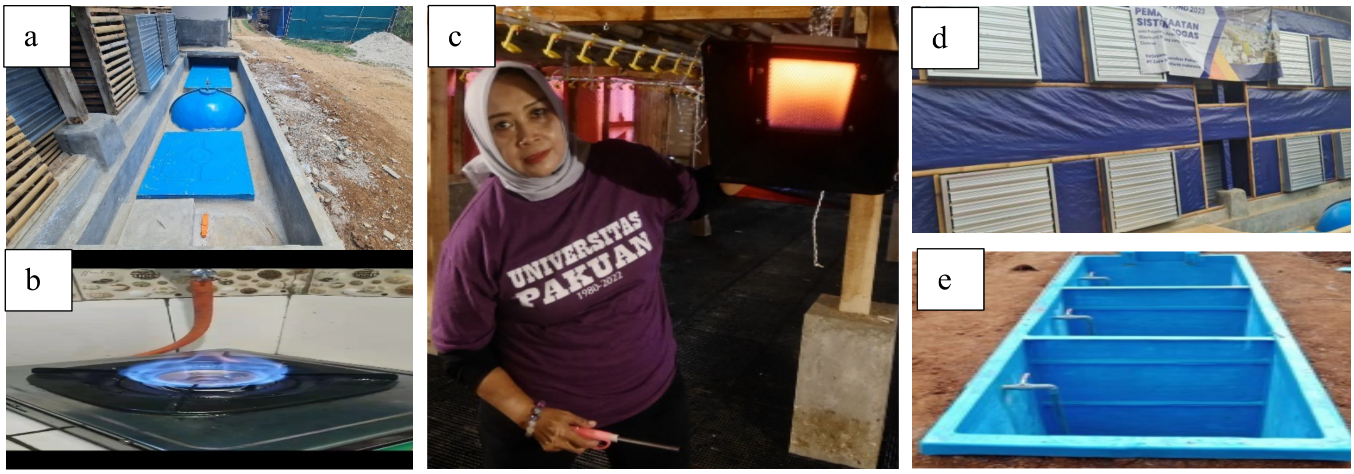

Figure 1. Implementation of the biogas system in chicken farming

***Information:** a. Biodigester 5m3; b. Biogas stove; c. Biogas brooder; d. Blower; e. Biogas bioslurry fermentation tank

The application of biogas systems in closed house type chicken farms has significantly changed energy efficiency and operational costs, as shown in (Table 1). Before the implementation of biogas, farmers used an average of four 12 kg LPG cylinders per month, with energy costs reaching Rp940,600 per month. Once the biogas system is operational, the LPG requirement decreases to two cylinders per month, reducing energy costs by up to 50%. In addition, the average temperature of the cage increased from 29.2°C to 30.1°C, indicating more stable environmental conditions and suitable for the growth of chickens.

The decrease in LPG consumption and energy costs shows that the biogas system is capable of becoming an efficient alternative source of renewable energy for chicken farms. The methane gas produced from the fermentation of fecal waste provides a sustainable energy supply for heating needs (brooders), thereby reducing dependence on commercial LPG. Increased cage temperature stability also plays an important role in maintaining the thermal comfort of broiler chickens, especially in the early stages of growth. According to (Deago et al., 2023), temperature stability between 30–32°C in the first week greatly affects the In addition to energy efficiency, the 50% cost savings show the real economic potential of the implementation of a biogas system. This result is in line with the findings of (Hamzehkolaei & Amjady, 2020) that the use of biogas in poultry farms can reduce operational costs by up to 45–55% compared to conventional energy sources. This efficiency also has a positive impact on business sustainability because it reduces carbon emissions and minimizes organic waste. Thus, the implementation of a biogas system not only improves energy efficiency, but also supports environmentally friendly and sustainable farming practices.

Table 1. Comparison of Energy and Operational Costs Before and After Biogas Implementation

Parameter	Before biogas	After biogas	Percentage savings (%)
Consumption of 12 Kg LPG Cylinder (cylinder/month)	4	2	50
Energy costs (Rp/month)	940600	470300	50
Average cage temperature (°C)	29,2	30,1	Stabil

Improved Biosecurity of the Cage

The implementation of the biogas system has a direct effect on improving biosecurity in livestock areas. Chicken feces that were previously a source of disease spread are now managed behind closed doors in digesters, so that the risk of contamination of pathogens such as Avian Influenza and Newcastle Disease can be minimized. The results of the observations show in Table 2. that the average mortality of chickens decreased from 4.8% to 3.0%, while the average weight increased from 1.82 kg to 1.97 kg per head after the implementation of the biogas system. The decrease in mortality is thought to be related to improved cage air quality and reduced ammonia exposure, as feces are directly drained into a closed digester. According to (Chen et al., 2017), the high ammonia content in the cage's air (>20 ppm) can decrease the immunity of chickens and increase susceptibility to respiratory diseases. In addition, the temperature and humidity of the cage that are more stable due to the use of biogas for heating also affect the growth performance of chickens.

These results support the research of (Emam et al., 2023) who reported that ideal microclimatic conditions (29–31°C) are able to increase feed efficiency and daily weight gain of broiler chickens. In terms of biosecurity, the biogas system plays an important role in breaking the chain of disease transmission because cage waste no longer accumulates in the production area. This is in line with the findings of Haryanto et al. (2023) that a closed waste management system can reduce the incidence of poultry diseases by up to 40% (Abdisa Serbessa et al., 2023). Thus, the application of biogas is not only environmentally friendly, but also increases productivity and animal welfare in a sustainable manner.

Table 2. Comparison of Mortality and Average Weight of Chickens Before and After the Implementation of the Biogas System

Maintenance cycle	Mortality before biogas (%)	Mortalitas after biogas (%)	Average weight before biogas (kg/head)	Average weight after biogas (kg/head)
Siklus 1	4.5	3.2	1.82	1.95
Siklus 2	4.8	3	1.8	1.97
Siklus 3	5	2.8	1.85	2
Average	4.8	3	1.82	1.97

The results (Figure 2), show the design of the chicken coop mat designed with an improved biosecurity system. The structure of this base uses a main frame of galvanized metal or aluminum material that is stainless and strong load-supporting. On top of the frame is installed a grating plate made of plastic or fiberglass that functions as a cage floor.

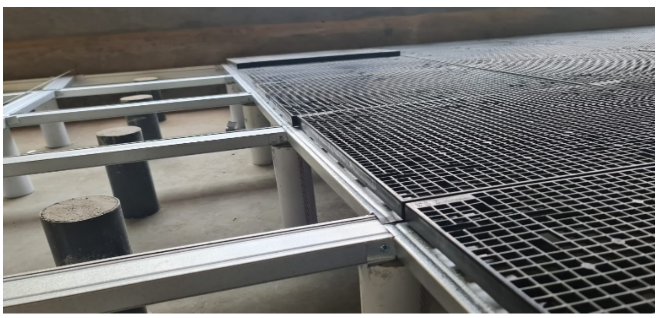

Figure 2. Alasa chicken coop

The grid design allows chicken droppings to fall directly down, so that the area where the chicken stands remains clean and dry. This condition is essential to reduce the risk of bacterial, fungal, and parasitic infections that usually develop in humid environments. In addition, this system also facilitates the cleaning process because dirt does not accumulate on the floor surface. With a combination of strong truss structure, anti-corrosion materials, and ventilation of the grille, this design significantly improves the biosecurity of the cage, maintains the health of chickens, and supports the efficiency of maintenance and sanitation of the environment.

Waste Processing into Organic Products

The results of laboratory tests on 17 quality parameters of organic solid fertilizers from fermentation of biogas waste showed that all parameters were in the normal category (Table 3). This indicates that the fermentation process that takes place in the biogas system is able to produce organic fertilizers with physical, chemical, and biological characteristics that meet national quality standards. The C-organic content and C/N ratio which are in the normal range indicate that the decomposition process of organic matter is optimal. A balanced C/N ratio is important to support the availability of nitrogen nutrients for plants and prevent soil acidification. Normal pH values indicate that the fertilizer has a neutral to slightly alkaline reaction, in accordance with the criteria of good organic fertilizer according to SNI 19-7030-2004, which is a pH between 6.0–8.0. In addition, test results for heavy metal elements such as arsenic (As), mercury (Hg), lead (Pb), and cadmium (Cd) show safe values and do not exceed the set threshold. This is important because heavy metals in high concentrations can degrade soil fertility and harm human health through the food chain (Angon et al., 2024). These findings prove that chicken biogas waste can be processed into environmentally safe organic fertilizer (Angon et al., 2024).

Table 3. Laboratory Test Parameters of Organic Solid Fertilizer Fermented Biogas

Parameter	Testing
C-Organik	Normal
Rasio C/N	Normal
Foreign Objects	Normal
Moisture Rate	Normal
Arsen (As)	Normal
Mercury (Hg)	Normal
Lead (Pb)	Normal
Cadium (Cd)	Normal
pH	Normal
Sodium (Na)	Normal
Diphosphorus Pentaxide (P_2O_5)	Normal
Dipotassium Oxide (K_2O)	Normal
Escherichia coli	Normal
Salmonella sp.	Normal
Iron (Fe)	Normal
Eat (Mn)	Normal
Zinc (Zn)	Normal

Microbiological aspects, parameters of Escherichia coli and Salmonella sp. shows a negative (normal) result, indicating the absence of harmful pathogen contamination. These conditions indicate that the anaerobic fermentation process and high temperature in the biogas digester are effective in suppressing the activity of pathogenic microorganisms (Lin et al., 2016)

Quality of Organic Liquid Fertilizer from Biogas Fermentation

The results of laboratory analysis showed that all test parameters on organic liquid fertilizer from fermented biogas waste were in the normal category (Table 4).

Table 4. Laboratory Test Parameters of Organic Solid Fertilizer Fermented Biogas

Parameter	Testing
C-Organik	Normal
Foreign Objects	Normal
Arsen (As)	Normal
Mercury (Hg)	Normal
Lead (Pb)	Normal
Cadium (Cd)	Normal
pH	Normal
Escherichia coli	Normal
Salmonella sp.	Normal
Iron (Fe)	Normal
Eat (Mn)	Normal
Copper (Cu)	Normal
Zinc (Zn)	Normal
Boron (B)	Normal

This indicates that the anaerobic fermentation process of chicken farm waste does not only produce energy in the form of biogas (Alengebawy et al., 2024). It will, but also a by-product in the form of liquid fertilizer that is feasible and safe to use as a source of plant nutrients. Normal C-organic content indicates that the organic matter in the liquid fertilizer has decomposed well, so that carbon elements are available to support the microbial activity of the soil. In addition, normal pH results indicate that the fertilizer has neutral to slightly alkaline properties, corresponding to the ideal range for the availability of macro and micronutrients in the soil.

The heavy metal parameters (As, Hg, Pb, Cd) show safe values and do not exceed the SNI threshold 19-7030-2004, which means that the liquid fertilizer does not pose a toxic risk to plants or the environment. The content of microelements such as Fe, Mn, Cu, Zn, and B is also in the normal range. It functions as an essential element for plant physiological processes, for example the formation of chlorophyll, enzymes, and growth hormones (Farooq et al., 2025). In terms of microbiology, tests for Escherichia coli and Salmonella sp. shows a negative (normal) result, indicating that the fermentation process has successfully suppressed the population of pathogenic bacteria.

Anaerobic temperatures and conditions during fermentation lead to the inactivation of harmful microorganisms, so the resulting liquid fertilizer is safe for plants and does not pollute the environment. This result proves that organic liquid fertilizer from biogas fermentation has good quality, safety, and environmental friendliness. This product can be used as a liquid complementary fertilizer (PPC) in sustainable agricultural systems, supporting the efficiency of the utilization of livestock waste, and reducing dependence on inorganic fertilizers (Ayenew et al., 2025).

The results of organic fertilizer products can be seen in (Figure 3) showing the final results of the process of processing chicken manure into organic fertilizer. This process is part of an environmentally friendly livestock waste utilization system. Chicken manure produced from the cage is collected, then through a fermentation or decomposition process using microbial activators to accelerate the decay of organic matter. After the fermentation process is complete, the fertilizer is dried until the moisture content is low to make it more resistant to storage.

Figure 3. Yield of fertilizer products

The image shows that the mature organic fertilizer is deep black with a crumb texture, indicating that the decomposition process is going perfectly. The fertilizer is then packaged in white plastic sacks for easy storage and distribution. This fertilizer product has economic value because it can be reused to fertilize agricultural land around farms. In addition to reducing environmental pollution, this system also supports the circular economic principle in the livestock sector by converting waste into useful resources.

Economic benefits

The application of the biogas system on broiler farms has been proven to provide significant economic benefits. Based on the cost-benefit analysis, energy costs per production cycle decreased from IDR 3,000,000 to IDR 1,500,000, resulting in savings of 50%. In addition to energy efficiency, there was an increase in the average weight of chickens from 1.82 kg to 1.97 kg with an additional economic value of IDR 3,000,000 per 1,000 heads, as well as a decrease in the mortality rate from 4.8% to 3%, which provided an additional benefit of around IDR 260,000 per cycle. Fermented waste processed into organic fertilizer also generates a new selling value of IDR 500,000 per cycle. In total, the net economic benefits of implementing the biogas system reach around IDR 5,260,000 per 1,000 chickens per production cycle. The results of the research on the economic benefits are presented in full (Table 5).

Table 5. Estimation of Economic Benefits of Implementing Biogas Systems per Production Cycle

Component	Before biogas (Rp)	After biogas (Rp)	Difference / benefit (Rp)
Energy cost per cycle (gas/LPG)	3.000.000	1.500.000	+1.500.000
Increase in chicken weight (per 1000 heads Rp 20,000/kg)	36.400.000	39.400.000	+3.000.000
Reduction in mortality (1000 heads, chicken price Rp 35,000/head)	965	1.225.000	260
Selling value of organic waste fertilizer	0	500	500
		Total	4.760.000

The use of biogas as an alternative energy source has been proven to be able to keep the temperature of the cage stable, thereby reducing thermal stress and increasing chicken growth. These results are consistent with the research of (Bórawski et al., 2024), which states that the use of biogas in the livestock sector can reduce operational costs by 40–60% and improve production performance. In addition, the use of biogas residues as organic fertilizers supports the principle of the circular economy and increases business added value (Usykova et al., 2025). Thus, the biogas system provides integrated economic and ecological benefits in sustainable livestock management.

Social and educational impact

Biogas system implementation activities have a positive impact on increasing the capacity of human resources and the social environment. A total of 15 MBKM students and 8 partner farmers were involved in training activities and technical assistance. Students gain hands-on experience in the planning, installation, and evaluation of biogas systems, while farmers gain new knowledge about energy efficiency and waste management. In addition, the surrounding community also benefits from the availability of organic fertilizers and a cleaner environment. This increase in competence strengthens the triple helix (academic–industry–community) collaboration as explained by (Usykova et al., 2025), who emphasize the importance of cross-sector cooperation in accelerating the adoption of green technology in the livestock sector. The social impact can also be seen from changes in farmers' behavior towards cage cleanliness and environmental awareness. Thus, these activities are not only oriented towards technical results, but also contribute to human capacity building and sustainable vocational education.

Evaluation and sustainability

The results of the study show that the application of the biogas system in broiler farms has a positive impact on energy efficiency, increased productivity, and waste management. The use of biogas is able to reduce LPG consumption by 50% (Table 1) and save energy costs of up to IDR 1,500,000 per production cycle (Table 5). In addition, there was an increase in the average weight of chickens from 1.82 kg to 1.97 kg per head as well as a decrease in the mortality rate from 4.8% to 3%, as occurred in (Table 2). This condition confirms that biogas technology not only reduces operational costs, but also significantly increases the biological performance of livestock and farmers' income.

In the economic aspect, the results of the cost-benefit analysis show that the total benefits reach IDR 4,760,000 per cycle (Table 5), coming from energy efficiency, increasing crop weight, reducing mortality rates, and additional selling value of fermented organic fertilizers. A positive benefit-cost ratio indicates that the biogas system is feasible and profitable to be implemented sustainably on a small to medium-scale farm. The social aspect also showed positive results. The involvement of 15 MBKM students and 8 partner breeders in training, installation, and technical assistance activities has increased the capacity of human resources and strengthened collaboration between academics, industry, and the community.

This participatory approach encourages changes in farmers' behavior towards waste management and cage cleanliness, while fostering awareness of the importance of implementing green technology in modern farming. Environmental systems, the application of biogas systems play an important role in reducing methane emissions, reducing land pollution, and converting livestock waste into energy sources and organic fertilizers with economic value (Brahmi et al., 2024). A more stable cage temperature after the application of biogas also contributes to improved broiler welfare, which has implications for feed efficiency and production quality (Bashiru & Oseni, 2025).

The sustainability of the program is determined by three main factors: (1) the availability of raw materials for livestock waste in a sustainable manner, (2) increasing the technical capacity of farmers in managing the biogas system, and (3) institutional support in the form of training, financing, and renewable energy incentives. The Matching Fund program is considered successful in creating a sustainable teaching farm model based on renewable energy, which integrates production, environmental, and socio-economic aspects. The biogas technology developed has high potential to be replicated in various regions with different business scales. Therefore, it is necessary to strengthen the institution of farmers and the development of biogas-based green startups is expected to be a new direction for downstream university research. Thus, biogas systems can be an innovative model in the transition to low-emission, energy-efficient, and economically competitive agriculture.

Conclusion

The application of an integrated biogas system in broiler farms has proven to be effective in improving energy efficiency, livestock productivity, and sustainable waste management. The use of biogas is able to reduce LPG consumption by up to 50%, reduce energy costs by IDR 1,500,000 per cycle, and increase the average weight of chickens from 1.82 kg to 1.97 kg per head with a reduction in mortality rate from 4.8% to 3%. The fermented waste has been successfully processed into solid and liquid fertilizer that meets national quality standards (SNI 19-7030-2004) and has economic value. Economically, the cost-benefit analysis shows that the total benefits reach Rp4,760,000 per 1,000 chickens per cycle, making biogas a viable and profitable technology to be adopted by small- to medium-scale farms. From the social aspect, this program strengthens collaboration between academics, industry, and the community through technical training and mentoring of MBKM students and partner breeders. Thus, the biogas system not only supports energy efficiency and emission reduction, but also has the potential to become a sustainable teaching farm model based on renewable energy that can be replicated in various regions of Indonesia.

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Author Contributions
Conceptualization, S.W., D.J., and R.H.; methodology, R.H.; validation, S.W., D.J., and R.H.; formal analysis, R.H.; investigation, R.H.; resources, S.W. and D.J.; data curation, R.H.; writing—preparation of original draft, R.H.; writing—review and editing, S.W. and D.J.; supervision, S.W. and D.J.; project administration, R.H.; S.W. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”

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