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Empowering Pig Farmers through the Utilization of Manure into Biogas and Bioslurry

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Abstract: Pig manure often creates environmental pollution and social issues for small-scale farmers. This community service activity empowers pig farmers to utilize manure for biogas production as an alternative energy source and as a bioslurry for organic fertilization. We applied socialization and assistance, and constructed dome-type biogas digesters using locally available materials. We analyzed the potential of biogas based on the number of livestock and daily manure production, then connected this to household cooking energy needs. The results indicate that farmers can use the resulting biogas as a substitute for LPG for cooking, reducing their dependence on LPG. Additionally, bioslurry can serve as organic fertilizer, supporting agriculture and household gardens. Socio-economically, this activity enables energy cost savings, improves environmental conditions around pens, and fosters greater social acceptance of pig farming. Overall, transforming livestock manure into biogas and bioslurry provides a sustainable empowerment model for farmers, which communities can replicate.

Keywords: Biogas, Bioslurry, Community Service, Farmer Empowerment, Pig Manure.

Introduction

Agriculture continues to be their main source of income, for the majority of Indonesian rural populations. Because it provides millions of farmers with both food and revenue, rice holds a crucial position as a staple food. But despite its vital function, the rice farming industry confronts significant obstacles that could jeopardize farmers' welfare and production (Quirinno et al., 2024; Sumini et al., 2025).

Sustainable farming sytems were agricultural practices that do not harm, create a balance, and work in harmony with nature, which can be realized through four different systems (Salikin, 2011; Rasyid et al., 2024; Sirajuddin et al., 2025). One of the models that can be used in the implementation of sustainable agriculture is the integrated farming system (Mukhlis et al., 2023; (Mukhlis et al., 2024).

The integrated farming system, or IFS, is an agricultural approach that merges two or more sectors of agriculture (Channabasavanna et al., 2009; Ugwumba et al., 2010; Jaishankar et al., 2014). This system facilitates connections between different products, promoting a cycle of biological recycling (Prajitno, 2009; Changkid, 2013; Thorat et al., 2015). It relies on minimal external inputs (Devendra, 2011; Nurcholis & Supangkat, 2011; Hilimire, 2011) and maximizes resource efficiency (Bosede, 2010; Balemi, 2012; Soputan, 2012). Various methods are implemented to enhance agricultural output, boost productivity, increase farmers' earnings, and promote sustainability (Gupta et al., 2012; Manjunatha et al., 2014; Thorat et al., 2015; Mukhlis et al., 2024; Nurhapsa et al., 2024).

The livestock sector is a key pillar of rural household economies. In North Sulawesi, pig farming is an integral part of tradition and a significant source of income for many families. However, as pig populations grow, waste management becomes a problem. Poorly managed manure pollutes the environment, causes

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odors, spreads disease, and can provoke social conflict (Ully & Wuwur, 2019; Tuhuteru et al., 2023).

Farmers can actually turn the problem of livestock waste into an opportunity if they manage it properly. Pig manure, besides its potential to pollute the environment, contains high organic matter that allows use as an alternative energy source in the form of biogas or as organic fertilizer (bioslurry) to benefit agriculture (Suryatmojo et al., 2024; Nurhapsa et al., 2020). Using biogas not only reduces the community's dependence on fossil-based energy but also adds value through household cost savings and improved environmental quality.

Discussions with the "Cahaya Berkat" pig farming group in Tiwoho Village, Wori District, North Minahasa Regency, showed that their understanding and skills in managing livestock manure are still limited. Most farmers are not yet familiar with biogas production technology or bioslurry utilization, despite showing interest and willingness to participate in training. This indicates a gap between the available resource potential and the community's knowledge and skills in utilizing it.

Therefore, we carried out this community service activity with the following objectives: (1) to improve the understanding and skills of pig farmers in utilizing livestock waste into biogas and bioslurry, (2) to reduce environmental pollution problems caused by livestock manure, and (3) to provide economic added value through the use of alternative energy and organic fertilizers. By adopting a participatory approach, we aim to foster awareness and independence among farmers in managing waste sustainably. Thus, this program addresses not only environmental problems but also supports the welfare improvement of members of the "Cahaya Berkat" pig farming group.

Method

Location and Activity Targets

This community service activity was conducted in Tiwoho Village, Wori District, North Minahasa Regency, involving a group of local farmers who are members of the community. The group consists of 12 members, and the pig population comprises 216 animals, including 83 sows, 4 boars, 120 growers, and 9 starters. Partners were selected based on their willingness to participate, the accessibility of the location, and the potential for a sufficient number of livestock to support biogas production.

Activity Design

The method used is a participatory approach with the following stages: (1) Identification of problems and potential through initial interviews and pre-tests to determine the farmers' level of knowledge about biogas and bioslurry; (2) Socialization and education on the impact of livestock waste and the benefits of utilizing manure as biogas and organic fertilizer; (3) Technical training on the construction and operation of biogas digesters, including the filling process, maintenance, biogas collection, and utilization of bioslurry; (4) Construction of a 2 m diameter and 2 m deep digester unit as a demonstration model; (5) Assistance and monitoring of digester use, including observation of gas production, bioslurry quality, and farmer involvement; (6) Evaluation through post-tests and group discussions to assess changes in farmers' knowledge, attitudes, and participation.

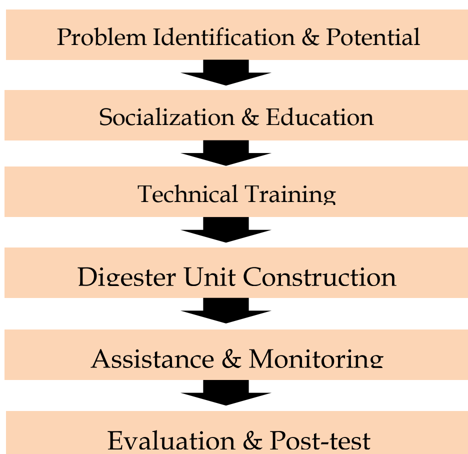
Data Collection Techniques

Data was collected in several ways: (1) Pretest and posttest: to measure changes in farmers' understanding of biogas and bioslurry; (2) Field observations: to record farmer participation in each stage of the activity; (3) Technical records: volume of manure entering the digester, estimated biogas production, and utilization of bioslurry; (4) Focus group discussions (FGD): to explore farmers' motivations, challenges, and expectations regarding the program.

Data Analysis

1. We analyzed quantitative data (pretest–posttest, biogas production, slurry volume) descriptively and comparatively to show improvements in knowledge and technical achievements.
2. We analyzed qualitative data (motivation, participation, obstacles) using a descriptive narrative approach, referring to themes that emerged from the FGD and observations;
3. We used the analysis results as the basis for formulating technical and socioeconomic recommendations to ensure program sustainability.

Method Flowchart Sketch:



Flow Chart Explanation:

1. Identification of Problems & Potential
   Through pre-tests and initial interviews to determine the level of understanding of farmers.
2. Socialization & Education
   Presentation of material on the impact of livestock waste, the benefits of biogas, and bioslurry.
3. Technical Training
   Practical training on the construction, filling, maintenance, and utilization of biogas digesters.
4. Digester Unit Construction
   Field demonstration with a biogas reactor measuring 3 m in diameter and 2 m in depth.
5. Assistance & Monitoring
   Observation of gas production, utilization of bioslurry, and farmer participation.
6. Evaluation & Post-test
   Measuring improvements in farmers' knowledge, attitudes, and skills.

Result and Discussion

Initial Conditions of Partners (Pretest)

The pretest results showed that most pig farmers in Tiwoho Village were unfamiliar with biogas and bioslurry technology. Seventy percent of respondents reported *no knowledge of it*, while only 2% claimed to be aware. This significant knowledge gap emerges even though the potential for pig waste they produce is high. This condition leads to environmental pollution, unpleasant odors, and potential social conflict with the community. Additionally, farmers continue to view livestock manure as waste with no added value, so they still fully bear the costs of household energy and fertilizer.

Most respondents had never heard of biogas, and only a handful knew its benefits. Farmers had almost no technical knowledge of biogas production, so their practical skills remained very low. Nevertheless, most respondents exhibited a positive attitude and high motivation to participate, primarily to reduce odors, mitigate pollution, and lower their household energy costs.

The pretest results showed that more than 70% of respondents were unaware of biogas technology, its benefits, or the process of producing it. However, after we conducted socialization, training, and mentoring, the post-test results showed significant improvement. More than 80% of respondents now understand the benefits of biogas and how to operate a simple digester. This demonstrates that the PKM activity successfully enhanced farmers' knowledge and skills, thereby supporting the sustainable use of biogas technology at both household and group levels.

Figure 1. Implementation of Socialization

Activity Implementation

The PKM activity progressed through participatory stages, beginning with socialization, technical training, and mentoring. During socialization, we raised awareness about the impact of livestock waste and the potential of biogas. We conducted training through hands-on practice in operating digesters, including mixing manure with water, filling the digester, and utilizing biogas for cooking. We then conducted regular mentoring sessions, enabling farmers to manage the digesters independently. The high level of participation and enthusiasm among farmers during activities demonstrates their sense of ownership of the technology introduced.

Knowledge and Attitude Changes (Posttest)

The posttest results showed a significant increase in knowledge. A total of 55% of respondents fell into the "*know*" category, and another 30% were in the "*somewhat know*" category. This means that more than 80% of respondents understood biogas technology after the activity. A comparison of the pretest and posttest (Table 1, Figure 2) reveals that this activity successfully enhanced the farmers' understanding, transforming their knowledge from minimal to a deeper understanding of the function, benefits, and management of biogas technology. This improvement reflects the success of the PKM program in terms of empowerment, not just technology transfer.

Table 1. Comparison of Farmers' Knowledge about Biogas Before and After the PKM Activity

Knowledge Category	Pretest (%)	Posttest (%)
Don't know	70	5
Somewhat know	20	10
Fairly knowledgeable	8	30
Know	2	55

Following socialization, training, and mentoring activities, there was a notable increase in knowledge. The post-test results showed that the majority of respondents (55%) stated that *they knew*, while the other 30% were categorized as *somewhat knowledgeable*. Thus, more than 80% of respondents understood biogas technology following the PKM activities.

A comparison of farmers' knowledge levels before and after the activities is shown in Table 1, while the changes are visualized in Figure 2. This data shows that the PKM program not only introduced biogas technology but also succeeded in increasing farmers' capacity to understand the principles of sustainable pig manure management.

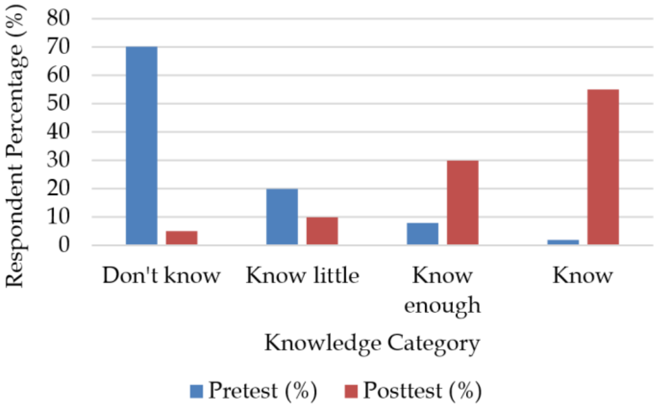


Figure 2. Comparison of pig farmers' knowledge levels about biogas before (pretest) and after (posttest) the socialization, training, and mentoring activities

The PKM activities carried out have successfully enhanced the knowledge and skills of pig farmers in Tiwoho Village in utilizing livestock manure for biogas production. Prior to the activity, the majority of respondents were unaware of the benefits of biogas, both environmentally and economically. However, after socialization, training, and mentoring, there was a significant increase in farmers' understanding, with more than 80% of respondents falling into the categories *of fairly knowledgeable* to *knowledgeable*. This confirms that a participatory approach to technology transfer can create real change in the level of community knowledge, while also demonstrating the success of the empowerment aspect.

The implication of this activity for pig farmers is an increased understanding of integrated livestock waste management, where pig manure is no longer seen as a source of pollution but as a source of alternative energy and organic fertilizer. The application of biogas technology has the potential to reduce household expenses for cooking fuel, improve sanitation in the barn environment, and provide organic fertilizer that can be used for agricultural businesses around the farm. In line with the findings of Abdeshahianet al., (2016) and Surendra et al., (2020), the integration of biogas systems in small to medium-scale pig farms also contributes to improving the sustainability of livestock businesses through efficient resource utilization and reduced environmental impact. Thus, although the capacity of the digester in this activity is still limited, its implementation has strategic value as a first step toward developing a more optimal and sustainable biogas system for pig farmers.

Technical Analysis of Biogas Potential

The results of the activity in a group with a pig population consisting of 83 sows, 4 boars, 120 growers, and 9 starters showed that the total daily manure production reached around 477.1 kg/day. The biogas digester, built in the shape of a dome, has a diameter of 2 m and a depth of 2 m, resulting in a geometric volume of 6.28 m^3. Taking into account a freeboard of 20% for gas accumulation, the effective working volume of the digester is 5.02 m^3. Based on a pig population of 216, total manure production reached 477.1 kg per day, which, after being mixed with water at a ratio of 1:1, produced a slurry volume of approximately 0.95 m^3 per day. These conditions resulted in a hydraulic retention time (HRT) of approximately 5.3 days. This HRT value is much lower than the optimal HRT for anaerobic digestion of pig manure, which is generally in the range of 15–30 days, as reported by Mao et al., (2015) and Li et al., (2019), who stated that a longer HRT has a positive effect on the stability of the fermentation process and methane production. Nevertheless, the development of small-scale digesters with relatively short HRT is still considered relevant in the context of community service because they serve as demonstration units and learning tools for renewable energy technology at the farmer level (Scarlat et al., 2018; Khan et al., 2021).

Based on Table 2, the biogas produced has the potential to meet 16–32% of household cooking energy needs, thus serving as a partial substitute for LPG, which can reduce LPG consumption. Although it does not completely replace LPG, the use of biogas plays an effective role as a partial substitute energy source in reducing pig farmers' dependence on LPG, reducing household energy expenditure, and increasing energy independence based on livestock waste, as reported in various studies on household biogas in developing countries (Surendra et al., 2020; Khan et al., 2021). This impact aligns with the findings of Damayanti et al., (2020), who suggest that community-based biogas utilization can reduce household expenses while enhancing the welfare of farmers.

Figure 3. Stages of Biogas Digester Construction: Before, During, and After

Utilization of Bioslurry as Organic Fertilizer

In addition to producing biogas, the anaerobic digestion process in the digester also generates a residue in the form of bioslurry, which has the potential to be used as an organic fertilizer. Bioslurry is the end result of livestock manure fermentation that has undergone organic material stabilization, making it easier for plants to absorb nutrients and reducing the level of pathogens compared to fresh manure (Abdeshahian et al., 2016). In this community service activity, the bioslurry produced is intended to be used as liquid and solid organic fertilizer for food crops and horticulture around the yard. The use of bioslurry offers direct benefits to pig farmers, including reduced dependence on inorganic fertilizers, lower agricultural production costs, and support for an integrated livestock-based agricultural system. In line with the findings of Monlau et al., (2015) and Surendra et al., (2020), the use of bioslurry from small-scale biogas installations not only increases the efficiency of livestock waste utilization but also contributes to improving soil quality and environmental sustainability. Thus, the existence of bioslurry reinforces the concept of zero waste in the application of biogas technology, increasing the economic added value of pig farm waste management systems.

Social and Economic Implications of the Biogas Program

The application of pig waste-based biogas technology in this community service activity has real socio-economic implications for farming households. The use of biogas as an alternative energy source for cooking contributes to reducing household expenditure on LPG purchases, thereby increasing daily energy cost efficiency. In addition, the processing of livestock waste into biogas and bioslurry also reduces environmental pollution around the pens, reduces unpleasant odors, and improves social comfort in the residential environment. This condition has a positive impact on social acceptance of pig farming, which was previously often considered to cause environmental disturbances. In line with the findings of Damayanti et al., (2020) and Surendra et al., (2020), community-based biogas programs serve not only as a renewable energy solution but also promote the welfare of farmers through cost savings, increased waste value, and strengthened household energy independence.

Sustainability of the Community Service Program

The sustainability of biogas programs is largely determined by technical, social, and institutional aspects. From a technical perspective, the use of simple digesters made from local materials and their ease of operation allow farmers to perform maintenance independently, without relying on complex technology. From a social perspective, the active involvement of farmers in the planning and construction stages, as well as in the utilization of biogas and bioslurry, increases their sense of ownership, which is a crucial factor in the sustainability of the program. Additionally, the potential use of bioslurry as an organic fertilizer opens up opportunities for integrating livestock and agricultural businesses, thereby strengthening the local economic cycle. To maintain long-term sustainability, continued assistance, strengthening of farmers' knowledge capacity, and institutional support from village governments or livestock groups are needed. This approach aligns with the principles of sustainable development, where biogas technology is not only focused on energy provision but also on enhancing welfare, environmental sustainability, and community independence in a sustainable manner (Khan et al., 2021).

Conclusion

Community service activities, including the development and design of pig manure-based biogas digesters, demonstrate significant potential in supporting the use of livestock waste as a source of renewable energy on a household scale. Technically, the biogas produced can function as a partial substitute for energy sources used for cooking needs, thereby contributing to a reduction in household LPG consumption among farmers. Additionally, the use of bioslurry as an organic fertilizer adds value to livestock waste while supporting more environmentally friendly farming practices. From a socio-economic perspective, this program contributes to energy cost savings, improved environmental quality around the pens, and increased social acceptance of pig farming. The success of the initial implementation phase demonstrates that simple biogas technology, when combined with guidance and the active involvement of farmers, has the potential to be sustainable and replicable as a model for community-based waste management and energy independence.

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