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# Implementation of biogas-based green energy for waste management optimization in TPST 3R Gadingkulon

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**ABSTRACT**

TPST 3R Gadingkulon in Malang Regency manages approximately 500–800 kg of waste per day, with around 70% consisting of organic waste. However, the management of organic waste has not been optimized, resulting in environmental problems and dependence on fossil energy. This community service program aims to implement a green energy system through biogas technology and improve community awareness regarding sustainable waste management. The method used employs a participatory approach consisting of field observation, training, installation of biodigester systems, and continuous assistance. Activities carried out including waste sorting training, implementation of organic waste processing into biogas and organic fertilizer, and evaluation using pre-test and post-test methods. The results show that the biogas system has been successfully implemented and is able to convert organic waste into renewable energy and useful products. In addition, an increase in community knowledge and participation in waste management has also been observed. Taken together, this program contributes to reducing environmental pollution, lowering operational energy costs, and increasing the economic value of waste.



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## 1. INTRODUCTION

TPST 3R Gadingkulon is a waste management facility in which processes are based on the principles of reduce, reuse, and recycle (3R), located in Gadingkulon Village, Dau District, Malang Regency, East Java. According to a 2022 report by Portal Berita Radius, TPST 3R Gadingkulon serves approximately 1,700 households, including around 1,200 households from Gadingkulon Village and 500 households from residential areas within the TPST's service area (Radius, 2022).

Given this service coverage, the potential volume of household waste generated in the Gadingkulon area is estimated to be substantial. Based on an average household waste generation rate of 0.4–0.5 kg per person per day, the total waste generated within the service area is estimated at approximately 2–3.5 tons per day. Of this amount, organic waste is estimated to account for approximately 50–60%, resulting in an available organic waste potential of approximately 1–2 tons per day.

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Prior to the implementation of the community service program, a portion of the organic waste generated at TPST 3R Gadingkulon had not been optimally utilized and remained at risk of accumulating significantly. This condition served as the baseline for the implementation of organic waste treatment technology using a biogas reactor. The reactor had an effective capacity of 550 liters and was cylindrical in shape, measuring approximately 1.5 meters in length and 1 meter in diameter.

The reactor was used to process organic waste into biogas, which could be utilized as an alternative energy source, particularly to support lighting needs in the TPST 3R Gadingkulon area. In addition to biogas, the treatment process also produced a residue in the form of slurry, which has the potential to be utilized as an organic fertilizer material. The implementation of this technology was expected to reduce the accumulation of organic waste while increasing its utilization value by converting it into energy and fertilizer material.

The effectiveness of the biogas reactor was evaluated by comparing conditions before and after the implementation of the community service program. The observed parameters included the amount of organic waste fed into the reactor, the volume of biogas produced, the duration of biogas utilization for lighting, the amount of treatment residue generated, and the reduction in untreated organic waste. These measurements were used to demonstrate changes in the capacity and effectiveness of organic waste management at TPST 3R Gadingkulon.


**Figure 1**. TPST 3R Gadingkulon

Furthermore, the level of public knowledge and awareness regarding waste management remains relatively low. This condition is reflected in the continued occurrence of improper waste disposal and waste burning practices in open areas, which may contribute to environmental pollution, unpleasant odors towards surrounding neighborhood, and adverse risks on public health. Concurrently, the KSM TPST 3R Gadingkulon partner still faces limitations in waste treatment equipment and technologies, resulting in suboptimal management of organic waste, with some waste still at risk of accumulating or ultimately being disposed of at the landfill (TPA). Limitations in technology, human resources, and operational capacity remain challenges in strengthening community-based waste management (Putra et al., 2025).

Based on these issues, the community service program is conducting assistance in implementing a biogas system as an appropriate technology for the KSM TPST 3R Gadingkulon partner. The biogas system was selected for its potential in processing organic waste into a useful alternative energy source, while at the same time also producing residues that can be utilized as organic fertilizer. The implementation of this system is intended to reduce the accumulation of organic waste and to strengthen the partner's capacity regarding sorting waste, processing organic waste, utilizing the products derived from waste, and managing waste more effectively and sustainably.

The use of a biogas system as a solution is supported by previous studies and community service activities, which have demonstrated that biodigesters can facilitate the treatment of organic waste, produce biogas as an alternative energy source, and provide additional economic value through the utilization of organic residues. Artiani and Handayasari (2017) demonstrated that biodigester technology can be optimized as an environmental conservation effort through organic waste treatment. Other community service activities have also shown that biodigesters can be used to process organic waste into biogas as a renewable energy source that provides practical benefits to communities (Arifandy et al., 2025). Therefore, the implementation of a biogas system is considered relevant as an appropriate technology that addresses the partner's needs and supports the optimization of waste management.

Accordingly, this community service program focuses on assisting the implementation of a green energy concept through the application of a biogas system at the KSM TPST 3R Gadingkulon partner to optimize sustainable waste management. The program aims to improve the partner's knowledge and skills in organic waste sorting and treatment, implement a biogas system as an alternative energy source, and promote a more effective and sustainable waste management system that provides environmental and economic benefits to the community.

## 2. METHODS

### Partners, Location, and Targets

The community service activity was conducted at TPST 3R Gadingkulon, Gadingkulon Village, Dau District, Malang Regency, East Java. The activity partner was the Community Self-Reliance Group (KSM) responsible for managing TPST 3R Gadingkulon. A total of 12 participants were directly involved in the activity, consisting of 4 KSM administrators, 4 TPST operators, and 4 community members or representatives.

As the TPST 3R Gadingkulon serves approximately 1,700 households, this community service activity focused on assisting KSM administrators and operators, as they are directly responsible for sorting, processing, and utilizing organic waste at the partner site. A participatory approach was employed by involving the partner throughout the problem identification, technology design, installation, operation, monitoring, and evaluation processes. This involvement was intended to ensure that the applied technology met the partner's needs and could be operated independently after the program ended.

### Appropriate Technology for Biogas Systems

The appropriate technology implemented in this program was an organic waste treatment system using a biogas reactor or biodigester. This technology was selected in response to the partner's challenges, particularly the suboptimal utilization of organic waste and the limited waste treatment equipment available.

The reactor had an effective capacity of 550 liters and was cylindrical, measuring approximately 1.5 meters in length and 1 meter in diameter. Sorted and size-reduced organic waste was mixed with water to form a feedstock or slurry. The mixture was then introduced into the reactor to undergo an anaerobic fermentation process. This process produced biogas and a residual slurry. The biogas was channeled through a distribution system and utilized as an alternative energy source, particularly to support lighting needs in the TPST area, while the residual slurry had the potential to be utilized as organic fertilizer.

The supporting equipment used in the implementation included a biodigester reactor, feed inlet, residue outlet, biogas distribution pipes, gas flow control valves, a gas storage unit, and a biogas-fueled lighting unit. Process monitoring was conducted using a digital scale, thermometer, pH meter, manometer, and a simple gas volume measurement device. Measurement data were recorded on monitoring sheets to determine the amount of feedstock processed, fermentation conditions, biogas production, energy utilization, and the amount of residue generated.

The technology implementation involves the provision of the necessary resources and equipment, accompanied by training and assistance on feedstock sorting, reactor loading, fermentation management, biogas distribution, residue utilization, leak detection, and system maintenance. Internet of Things and machine learning-based systems were initially not included in this program, but were referenced for future system development.

**Stages of Implementation**

The implementation of the program consists of five stages: identification of initial conditions, technology design, partner training, system installation and operation, and monitoring and evaluation.

**1. Identification of initial conditions**

The first stage involved field observations, interviews, and focused discussions with the management and operators of TPST 3R Gadingkulon. This stage aimed to identify the existing waste management conditions prior to program implementation, the types of waste available, current waste sorting practices, the amount of untreated organic waste, the equipment available to the partner, and the operators' capacity to manage waste treatment technologies.

Baseline data were also collected, including the amount of available organic waste, waste handling practices, forms of waste utilization prior to the program, and the technical and non-technical constraints faced by the partner.

**2. Technology design**

The second stage involved designing the technology according to the site conditions and the partner's operational capacity. The design covered the reactor capacity, feedstock type, installation location, feedstock input flow, fermentation process, biogas distribution, energy utilization for lighting, and residue discharge.

The implementation team and the partner also developed standard operating procedures covering organic waste sorting, feedstock composition, reactor loading, fermentation process monitoring, gas line inspection, biogas utilization, residue discharge, and facility maintenance.

**3. Partner training**

Training was provided to the KSM management and operators using lectures, discussions, demonstrations, and hands-on practice. The training materials covered organic and inorganic waste sorting, biodigester operating principles, feedstock preparation, anaerobic fermentation, operational safety, biogas utilization, residue management, and system maintenance.

Participants' knowledge was assessed using a pre-test before the training and a post-test after the training. In addition to written assessments, participants' practical skills were evaluated through reactor loading, gas flow regulation, system inspection, and biogas utilization. An educational, participatory, practical, and collaborative approach was adopted to ensure that participants developed both conceptual understanding and practical skills (Balakrishna A et al., 2022).

### 4. System installation and operation

The next stage involved installing the reactor, feedstock inlet, residue outlet, gas distribution network, safety components, and biogas utilization unit. After all components had been installed, the connections were inspected and leak tests were conducted before the reactor was put into operation.

Operation began with the sorting and preparation of organic waste. The feedstock was size-reduced, mixed with water according to the composition used in the program, and then introduced into the reactor. During the fermentation process, the implementation team and the partner monitored temperature, pH, gas pressure, feedstock volume, biogas volume, and the physical condition of the reactor. The biogas produced was subsequently tested and utilized as an energy source for lighting within the TPST area. The partner received direct assistance throughout the process until they were able to independently perform the operation and maintenance procedures.

### 5. Monitoring and evaluation

Monitoring was conducted periodically every 2–3 days over a four-week period. This activity aimed to assess the continuity of the fermentation process, the amount of feedstock processed, biogas production, the duration of energy utilization, the amount of residue generated, and operational challenges encountered during implementation.

**Table 1.** Stages of implementation overview

| Stages | Activities | Objectives | Participants | Time |
|---|---|---|---|---|
| Initial identification | Observations, interviews, discussions with partners, and baseline data collection | Identifying the partner's problems, needs, and initial conditions. | Community service team, KSM administrators, and operators. | 2nd week of March 2026 |
| Technology design | Determination of capacity, installation location, and process flow, and development of SOPs. | Produce technology designs that meet the partners' needs. | Community service team and KSM administrators | 4th week of March 2026 |
| Partner training | Assistance, demonstration, practical work, pre-test, and post-test | Enhancing the knowledge and skills of administrators and operators. | Community service team, source persons, and participants | 2nd week of April 2026 |
| System installation | Installation of the reactor, gas lines, and supporting components, and leak testing. | Ensuring the system is installed and safe to operate. | TPST technical team and operators | 3rd week of April 2026 |
| System operation | Preparation of materials, reactor filling, fermentation, and biogas utilization. | Training partners to operate technology independently | TPST technical team and operators | 4th week of April – 4th week of May 2026 |
| Monitoring and evaluation | Performance measurement, skills evaluation, interviews, and problem resolution. | Assessing the success and sustainability of the program | Community service team and KSM administrators | 4th week of May 2026 |

Evaluation was conducted by comparing conditions before and after the implementation of the biogas system. Data were collected from pre-test and post-test results, observations of operator skills, reactor operation records, biogas production measurements, documentation of energy utilization, and interviews with the partner. Technical issues identified during monitoring were discussed jointly to determine corrective actions and ensure the continued operation of the technology.

**Success Indicators**

The success of the appropriate technology implementation is assessed using the following quantitative and qualitative indicators:

1. The activity involves 12 participants, comprising KSM administrators, TPST operators, and community representatives.
2. At least 80% of participants complete the entire series of training, operational practice, and mentoring sessions.
3. The average post-test score increases by a minimum of 30 percentage points compared to the average pre-test score.
4. A biogas reactor with an effective capacity of 550 liters is successfully installed and can be operated according to standard operating procedures.
5. The system is capable of processing an average of 15–25 kg of organic waste per day, mixed with water to produce approximately 16–20 liters of feedstock or slurry.
6. Once the fermentation process reaches a stable state, the system is targeted to produce approximately 0.3–0.5 $m^3$ of biogas per day.
7. The produced biogas can be channeled to a stove and utilized as fuel to meet cooking needs during the operational activities of the TPST 3R Gadingkulon.
8. The biogas is targeted for use in powering a stove for an average of 1–2 hours per day, maintaining a relatively stable flame during testing and utilization.
9. Biogas utilization reduces LPG consumption for cooking needs at the TPST, as demonstrated by comparing the frequency or quantity of LPG usage before and after the system's implementation.
10. The processing yields a slurry residue of approximately 25–50 liters per day, which has the potential to be utilized as organic fertilizer.
11. Implementation of the system reduces untreated organic waste by at least 50 kg per day compared to pre-program conditions.
12. At least three operators are capable of independently performing raw material sorting and preparation, reactor filling, leak checks, gas flow regulation, stove ignition, operational parameter recording, and basic system maintenance.

## 3. RESULTS AND DISCUSSION

**Socialization and Education**

Socialization and educational activities were conducted as the initial stage of partner capacity building before the implementation of the biogas system at TPST 3R Gadingkulon. The activities involved KSM administrators, TPST operators, and community representatives who were directly involved in organic waste sorting and processing. The activities aimed to improve partners' knowledge and skills in waste management based on the principles of reduce, reuse, and recycle (3R), as well as to introduce the utilization of organic waste as feedstock for biogas production.

The activities were conducted through material presentations, interactive discussions, demonstrations, and hands-on practice. These methods were used to ensure that participants not only understood the concepts but were also able to identify different types of waste, perform waste sorting, and understand the basic stages of biodigester operation. A participatory approach was applied by providing participants with opportunities to discuss waste management problems encountered at the TPST and explore alternative solutions together with the implementation team.

The socialization materials covered waste classification and characteristics, techniques for sorting organic and inorganic waste, and the environmental and health impacts of improper waste management. Participants were also introduced to the principles of anaerobic fermentation, the main components of the biodigester, feedstock preparation procedures, and the utilization of biogas as a fuel for cooking needs at the TPST. In addition, the materials covered safety procedures, leak detection, gas flow regulation, and the utilization of slurry residue as organic fertilizer.

**Figure 2.** Socialization Activities for Community Self-Reliance Groups

Figure 2 documents the presentation of materials and discussions between the implementation team and the administrators and operators of TPST 3R Gadingkulon. During the activity, participants received explanations regarding organic waste management problems and the biogas technology concept to be implemented. The discussion also served to identify the partner’s needs, existing waste management practices, and potential challenges that might arise during the implementation stage.

### Pre-test and Post-test

The socialization and educational activities were evaluated using pre-test and post-test assessments involving 12 participants, consisting of KSM administrators, TPST operators, and community representatives. The pre-test was administered before the delivery of the materials to assess participants’ initial level of knowledge, while the post-test was conducted after the completion of all material presentations, discussions, demonstrations, and practical activities. The evaluation instrument consisted of nine questions covering three main aspects: waste sorting, knowledge of biodigester and biogas systems, and awareness of environmental management.

Each participant’s response was assigned a score, and the total score was converted into a percentage. The pre-test and post-test scores were then compared to assess changes in participants’ level of understanding after participating in the activities. The results of the evaluation of participants’ knowledge before and after the socialization and educational activities are presented in Table 3.

The evaluation involved 12 participants consisting of KSM administrators, TPST operators, and community representatives. The pre-test and post-test instruments consisted of nine indicators grouped into three aspects: waste sorting, knowledge of biogas, and environmental awareness. Participants’ scores were converted into percentages to indicate their average level of mastery before and after the socialization and training activities.

**Table 2**. Pre-test and Post-test Results of Training Participants (n = 12)

| Aspects | Indicators Assessed | Pre-test (%) | Post-test (%) | Increases (%) |
|---|---|---|---|---|
| Waste sorting | The ability to distinguish between organic and inorganic waste. | 42 | 83 | 41 |
| Waste sorting | Understanding the importance of waste sorting at the source. | 45 | 85 | 40 |
| Waste sorting | The ability to identify organic waste suitable for use as biodigester feedstock. | 48 | 87 | 39 |
| Biogas knowledge | Understanding the working principles of a biodigester | 28 | 78 | 50 |
| Biogas knowledge | Knowledge regarding the process of converting organic waste into biogas. | 30 | 80 | 50 |
| Biogas knowledge | Understanding the utilization of biogas for cooking purposes at TPST. | 32 | 82 | 50 |
| Environmental awareness | Awareness of the impact of waste disposal and burning | 48 | 88 | 40 |
| Environmental awareness | Willingness to consistently sort waste | 50 | 90 | 40 |
| Environmental awareness | Willingness to support the operation and maintenance of the biogas system | 52 | 92 | 40 |
| **Mean** | | **41,7** | **85,0** | **43,3** |

Based on Table 1, the participants' overall mean score increased from 41.7% in the pre-test to 85.0% in the post-test, representing an increase of 43.3 percentage points. This improvement indicates that the socialization, discussions, demonstrations, and hands-on practice helped participants develop a better understanding of waste management and the implementation of the biogas system.

In the waste sorting aspect, participants demonstrated improved ability to distinguish between organic and inorganic waste, understand the importance of source-based waste sorting, and identify suitable organic materials for the biodigester. The average score for this aspect increased from 45% to 85%. This result indicates that participants acquired the basic knowledge required to properly prepare feedstock for the reactor.

The highest increase was observed in biogas knowledge, with the average score increasing from 30% to 80%. Following the training, participants demonstrated a better understanding of the operating principles of the biodigester, the biogas production process, and its utilization as a fuel for cooking at the TPST. In the environmental awareness aspect, the average score increased from 50% to 90%, indicating strengthened awareness of the impacts of improper waste management and the importance of maintaining the sustainability of the biogas system.

## Implementation of Biogas System

The implementation of the biogas system constituted the core stage of the community service program and aimed to optimize the utilization of organic waste at TPST 3R Gadingkulon as a source of renewable energy. The implementation involved the construction and operation of a biodigester system designed according to the available organic waste volume at the partner site.

The implementation process began with the collection of feedstocks consisting of organic waste from household waste, food residues, and agricultural and livestock waste. The feedstock was then shredded to reduce particle size and facilitate the decomposition process. The organic materials were subsequently mixed with water at a predetermined ratio to produce a homogeneous slurry before being introduced into the biodigester reactor.

The primary process within the biodigester was anaerobic fermentation, in which microorganisms decompose organic matter in the absence of oxygen. This process produces methane ($CH_4$ ) as the main component of biogas, along with sludge residue that can be utilized as organic fertilizer. The fermentation period was adjusted according to the characteristics of the feedstock and the operating conditions of the system to support optimal biogas production.

The fermentation process in the biodigester was influenced by the interaction of several parameters, particularly temperature, pH, pressure, substrate volume, and methane concentration. Monitoring these parameters provided an indication of microbial activity during fermentation. Research on smart biodigester systems has shown that relatively stable temperatures, near-neutral pH, and increasing gas pressure are associated with higher methane concentration and production (Junus et al., 2026).

During the implementation stage, intensive technical assistance was provided to TPST managers and community members. The assistance covered the introduction of standard operating procedures (SOPs), feedstock loading techniques, fermentation process control, and biodigester system maintenance. In addition, several operational parameters were monitored, including the volume of feedstock introduced, fermentation duration, and the quantity and stability of biogas production.

**Figure 3.** Preparation and Shredding of Organic Waste and Cow Manure Feedstock

The sorted and shredded organic waste was weighed at 15–25 kg per day and mixed with water at a 1:1 ratio to produce a relatively homogeneous feedstock slurry. The slurry was then loaded into the reactor and subjected to anaerobic fermentation to produce biogas and processing residue. A flowchart of the organic waste processing process for biogas production is presented in Figure 4.

Based on Figure 4, the processing begins with sorting the organic waste to remove non-biodegradable materials. The organic waste is then shredded and mixed with cow manure and water to form a slurry. The mixture is subsequently fed into the biodigester for anaerobic fermentation. During the process, temperature, pH, and gas pressure are monitored periodically to maintain stable fermentation conditions.

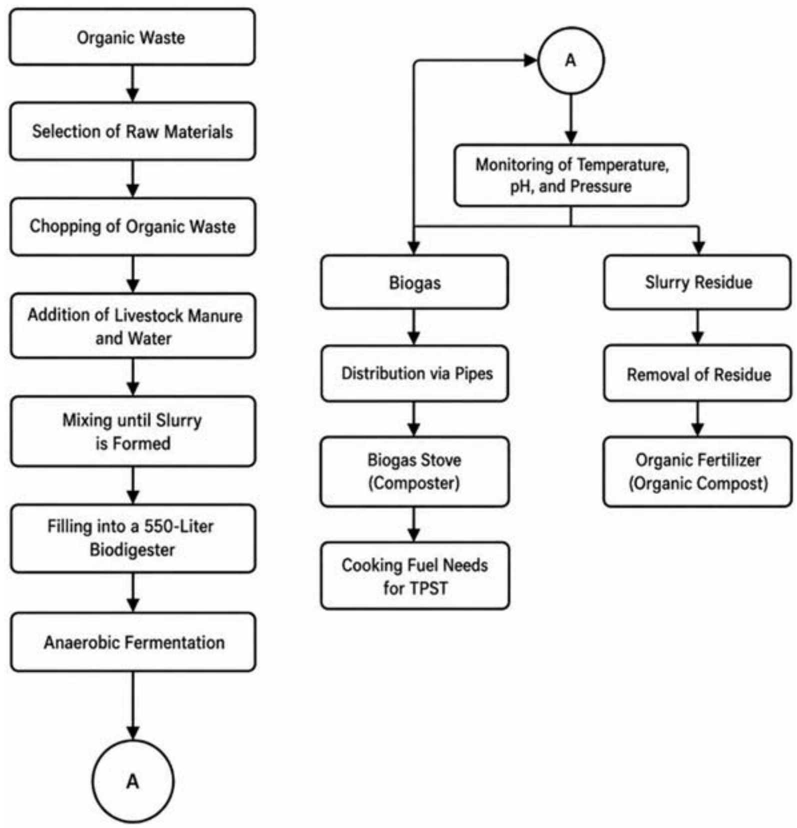


**Figure 4.** Flowchart of the process for converting organic waste into biogas.

The fermentation process produces two main outputs: biogas and slurry residue. The biogas is distributed through pipes to a stove to support cooking activities at TPST 3R Gadingkulon. Meanwhile, the fermentation residue is discharged from the reactor and has the potential to be utilized as organic fertilizer.

**Figure 5.** Installation and Operation of the Biodigester System

Based on Figure 4, the process begins with sorting the organic waste to remove non-biodegradable materials. The organic waste is then shredded and mixed with cow manure and water to form a slurry. The mixture is subsequently loaded into the biodigester for anaerobic fermentation. During the process, temperature, pH, and gas pressure are monitored periodically to maintain stable fermentation conditions.

**Table 3**. Biodigester Specifications

| Parameters | Value |
|---|---|
| Capacity | 550 liters |
| Type of feedstocks | Organic Waste and Cow Manure |
| Fermentation time | 7 - 14 days |
| Outputs | Biogas and Organic Fertilizer |

The fermentation process produces two main outputs: biogas and slurry residue. The biogas is distributed through pipes to a stove to support cooking activities at TPST 3R Gadingkulon. Meanwhile, the fermentation residue is discharged from the reactor and has the potential to be utilized as organic fertilizer.

## Utilization of Biogas as an Alternative Energy Source

The biogas produced by the biodigester system was successfully utilized as fuel for a stove to support operational activities at TPST 3R Gadingkulon. The biogas was delivered from the biodigester reactor to the stove through the previously installed distribution pipes.

Testing was conducted by opening the gas valve and igniting the stove. The results showed that the biogas could be combusted with a relatively stable flame. However, the methane concentration was not analyzed using a gas composition analyzer.

In addition, the performance of the biogas during daily use was observed, including flame duration, gas pressure, and energy utilization efficiency. The observations showed that the biogas could be used continuously to support basic operational activities at the TPST.

These results further demonstrate the potential of utilizing organic waste as an energy feedstock at the community scale. Previous research on bioreactor-based TPST systems reported an average production of approximately 22 $m^3$ of biogas and 120 kg of liquid fertilizer per ton of processed organic waste. These findings indicate that converting waste into biogas can provide energy benefits while also producing a by-product with economic value (Junus, Mustain, et al., 2025).

**Table 4**. Comparison and Performance of Biogas Utilization

| Parameters | LPG (before) | Biogas (after) |
|---|---|---|
| Costs | Rp 150,000/month | Rp 50,000/month |
| Energy consumption | ± 3 kg LPG/week | ± 1.5–2 $m^3$ biogas/day |
| Daily stove usage | ± 2 hours/day | ± 1.5 hours/day |
| Gas pressure | Stable (in a can) | Stable (± 10–12 kPa) |
| Fire color | Yellowish-blue | Blue |
| Energy source | Fossil energy | Renewable energy |
| Availability | Dependent on LPG supply | Sustainable (produced from organic waste) |
| Effects on environment | High ($CO_2$ emissions) | Low (more environmentally friendly) |

Based on Table 3, the biogas produced was successfully utilized as stove fuel to support cooking activities at TPST 3R Gadingkulon. Its use included heating water and preparing simple meals for administrators and operators during waste management activities. The biogas could be used for approximately 1–2 hours per day, with gas pressure ranging from 10–12 kPa and producing a relatively stable flame.

The utilization of biogas reduced the use of LPG for TPST operational needs. LPG consumption, which was previously estimated at four 3-kg cylinders per month, decreased to approximately two cylinders per month. Consequently, monthly energy costs decreased from approximately IDR 150,000 to IDR 75,000, representing a reduction of approximately 50%. These results demonstrate that the biodigester, with an effective capacity of 550 liters, can provide an alternative energy source to meet part of the TPST's daily cooking needs, although it has not yet thoroughly replaced LPG.

**Figure 6.** Utilization of Biogas as Stove Fuel

The utilization of biogas provides not only economic benefits but also contributes to reducing dependence on fossil fuels and mitigating environmental pollution. Therefore, the application of biogas technology can serve as an effective solution for supporting community-based energy independence.

## Assistance and System Monitoring

The assistance activities were conducted intensively throughout the implementation period to ensure that the biodigester system could be operated independently by the community and the management team of TPST 3R Gadingkulon. The assistance covered both technical and non-technical aspects, including feedstock loading procedures with an average volume of approximately 20–30 kg/day, control of the anaerobic fermentation process, maintenance of system components, and handling of potential operational issues.

In addition, the community was provided with an understanding of standard operating procedures (SOPs) to ensure that the system could operate optimally and sustainably. Throughout the assistance period, the community demonstrated improved operational capabilities, as indicated by their ability to independently load feedstock, regulate gas flow, and utilize biogas without full dependence on the implementation team.

System monitoring was conducted periodically at 2–3-day intervals to evaluate biodigester performance and the extent of biogas utilization. The observed parameters included continuity of gas production, gas pressure stability within the range of approximately 8–12 kPa, and biogas utilization duration of approximately 1–2 hours per day for operational needs.

The monitoring results showed that biogas production remained continuous and relatively stable, with the TPST management utilizing the biogas almost daily. In addition, the technical issues encountered during operation were minimal and could be resolved independently by the community after receiving assistance.

From a social perspective, the activity also demonstrated increased participant knowledge and partner involvement in the operation of the biodigester, from feedstock collection to the utilization of the biogas produced.

The assistance activities also highlighted the importance of regular monitoring in maintaining the sustainability of biodigester operations. An automated monitoring system developed in a previous study demonstrated 98.7% agreement with manual measurements and reduced monitoring time by up to 95%. Although the program at TPST 3R Gadingkulon still relies on periodic monitoring, these findings indicate the potential for implementing an automated monitoring system to improve operational efficiency in future development (Junus et al., 2026).

Overall, the assistance and monitoring activities played an important role in ensuring program sustainability and strengthening community independence in technology-based waste management. These outcomes demonstrate that a participatory approach combined with intensive assistance can improve the effectiveness of appropriate technology implementation at the community level.

**Table 5.** Environmental and Economic Impacts of the Program

| Aspects | Before Implementation | After Implementation |
|---|---|---|
| Processing facilities | Equipment for processing organic waste into biogas is not yet available | A biodigester unit with an effective capacity of 550 liters has been installed |
| Organic waste utilization | Organic waste is not yet utilized as feedstock for biogas production | A portion of the organic waste is utilized as feedstock for the biodigester |
| Feedstock capacity | Processing using a biodigester is not yet in place | Approximately 8–10 kg of organic waste is processed daily |
| Fermentation time | An anaerobic fermentation process is not yet implemented | The fermentation process takes about 7–14 days |
| Gas pressure | Biogas is not yet being produced | Gas pressure reaches approximately 10–12 kPa by the end of the testing period |
| Energy utilization | All cooking needs at the waste processing facility (TPST) are met using LPG | Biogas is used as stove fuel for about 1–2 hours per day |
| LPG consumption | Approximately four 3-kg LPG cylinders are used per month | Consumption is reduced to approximately two 3 kg LPG cylinders per month |
| Energy costs | Cost is approximately IDR 150,000 per month | Costs are reduced to approximately Rp75,000 per month |
| Energy cost savings | No cost savings have been realized from biogas usage | Estimated savings reach around Rp75,000 per month, or 50% |
| Processing residue | No residue is generated from the biodigester process | Generates a slurry residue of approximately 15–20 liters per day |
| Slurry utilization | There are no by-products from the biogas production process | The slurry has the potential to be processed and used as liquid organic fertilizer |
| Organic fertilizer production potential | Liquid organic fertilizer derived from biodigester residue is not available | Approximately 100–150 liters of slurry per month can potentially be processed, packaged, and marketed as liquid organic fertilizer |
| Potential economic value of fertilizer | No economic value is derived from slurry utilization | Projected revenue ranges from Rp300,000 to Rp450,000 per month, assuming a selling price of Rp3,000 per liter |
| Total potential economic benefits | There are no energy savings or revenue generated from the slurry | Projected total economic benefit ranges from Rp375,000 to Rp525,000 per month, combining LPG savings and potential fertilizer sales |
| Operator capability | The operator lacks experience in operating a biodigester | At least three operators are capable of preparing feedstock, loading the reactor, managing gas flow, operating the stove, and performing basic maintenance |

### Impact of Biogas System Implementation

The implementation of the biogas system at TPST 3R Gadingkulon produced initial impacts on organic waste utilization and the provision of alternative energy for the partner. The program's impact was not measured based on the total amount of waste received by the TPST, but rather on the feedstock capacity that could be processed using the biodigester with an effective capacity of 550 liters. The changes in conditions before and after the implementation of the system are presented in Table 5.

Based on Table 5, the volume of organic waste disposed of at the final disposal site (TPA) decreased from approximately 700 kg/day to 300 kg/day, representing a reduction of approximately 57%. This finding indicates that the biodigester system was able to process a substantial portion of the organic waste into more useful products.

From an environmental perspective, the level of odor pollution also decreased. Before implementation, strong odors could be detected within a radius of approximately 1 km from the TPST, whereas after the implementation of the biogas system, the odor impact was detected only within a radius of less than 300 meters.

From an energy perspective, LPG consumption of approximately 3 kg per week was partially replaced by biogas production of approximately 1.5–2 $m^3$ per day. This transition directly improved operational cost efficiency, with monthly energy costs decreasing from approximately IDR 150,000 to IDR 50,000, representing savings of approximately 66%.

In addition, from an economic perspective, the program increased the value generated from waste management. Before the program, waste processing generated approximately IDR 500,000 per month from compost sales. After implementation, the economic value increased to approximately IDR 900,000 per month through a combination of biogas utilization and organic fertilizer sales.

These results demonstrate that biodigester technology not only contributes to waste reduction and pollution mitigation but also improves energy efficiency and generates additional economic value for the community. This finding is consistent with previous research indicating that biodigester technology can improve the efficiency of organic waste management while providing sustainable economic benefits (Artiani & Handayasari, 2017).

### Discussion

The implementation of the community service program at TPST 3R Gadingkulon demonstrated a strong alignment between the activities and the community's actual needs, particularly in managing organic waste and utilizing it as an alternative energy source. The program focused on both technology implementation and improving the community's knowledge and skills in managing waste independently at the same time. This community-based approach has been shown to be effective in supporting the sustainability of waste management programs (Utama & Pratama, 2021).

The results of the program implementation indicate that the approach adopted produced meaningful changes in both participants' knowledge and their practical activities. The socialization and educational activities provided participants with new understanding of the importance of waste segregation and the potential for utilizing organic waste to produce biogas. This finding is consistent with previous studies, showing that educational and participatory methods can increase community engagement in environmental management (Balakrishna A et al., 2022).

Furthermore, the learning approach combining instruction with hands-on practice was generally more relevant than giving theoretical instruction alone. Participants not only gained a general understanding of the concepts, but were also able to directly practice the process of converting organic waste into biogas. This approach is consistent with practice-based learning, which can improve participants' applied understanding of the subject matter (Maddela et al., 2024).

From a technical perspective, the implementation of the biodigester system demonstrated that the technology can be effectively applied at the community level. The system, designed with a capacity of 120 liters and a fermentation period of 7–14 days, was able to produce biogas that could be directly utilized as cooking fuel. This finding indicates that biodigester technology is sufficiently adaptable to local conditions and the availability of feedstock (Guimarães et al., 2018).

The utilization of biogas as an alternative energy source also had a tangible impact on energy efficiency. The use of biogas reduced dependence on LPG and helped lower operational costs. In addition, the quality of the biogas produced was indicated by a stable blue flame, suggesting a relatively high methane content. This finding is consistent with previous research showing that biogas produced by biodigesters can be utilized as an alternative household energy source (Pena et al., 2022).

From an environmental perspective, the implementation of the system reduced the volume of organic waste previously disposed of at the landfill. This reduction decreased the amount of waste disposal, thus helped mitigate potential environmental pollution. The treatment of organic waste through biodigesters has been shown to reduce its negative environmental impacts (Kothari et al., 2010).

From an economic perspective, the program also generated additional value for the community. Prior to the implementation, waste management primarily produced compost with limited economic value. Following the implementation of the biogas system, the community gained additional benefits through the provision of alternative energy and increased economic value from waste processing. This finding further demonstrates that technology-based waste management can generate sustainable economic benefits (Artiani & Handayasari, 2017).

The continuous assistance provided throughout the program was also an important factor contributing to its success. The assistance helped the community understand and address technical challenges that emerged during system operation while also strengthening their capacity to operate and manage the biodigester independently. This finding is consistent with the concept of technology-based community empowerment, which emphasizes the importance of knowledge and skills transfer (Junus et al., 2025).

Taken together, the results demonstrate that integrating community education, biodigester technology implementation, and continuous assistance constitutes an effective approach to community-based waste management. This model has the potential to be adapted and implemented in other areas with similar characteristics as a solution to waste management challenges and the need for alternative energy sources.

## 4. CONCLUSION AND RECOMMENDATIONS

### Conclusion

The community service program at TPST 3R Gadingkulon successfully implemented the green energy concept through the application of a biogas system to optimize sustainable organic waste management. The socialization, training, installation, and operational assistance of the biodigester, which had an effective capacity of 550 liters, increased the partners' knowledge, as indicated by an increase in the mean evaluation score from 41.7% in the pre-test to 85.0% in the post-test. The program also improved the operators' skills in preparing feedstock, operating the reactor, regulating gas flow, and performing basic system maintenance. The biodigester was able to process approximately 8–10 kg of organic waste per day, generate gas pressure of up to 10–12 kPa, and provide biogas that could be utilized as cooking fuel at the TPST for approximately 1–2 hours per day.

The utilization of biogas potentially reduced LPG consumption from approximately four to two 3-kg cylinders per month, corresponding to an estimated 50% reduction in energy costs. In addition, the fermentation process generated approximately 15–20 liters of slurry per day, which has the potential to be further processed into organic fertilizer and developed as a value-added product. Thus, the implementation assistance provided through the biogas system generated initial benefits in the form of increased partner capacity, utilization of organic waste as an alternative energy source, reduced energy consumption, and opportunities for developing organic fertilizer products to support the sustainability of waste management at TPST 3R Gadingkulon.

**Recommendations**

The implementation of this program still has several limitations, particularly the pilot-scale capacity of the biodigester, the limited monitoring period, and the absence of continuous operational and economic records. Therefore, several follow-up measures are recommended.

First, the capacity of the biodigester should be increased gradually to enable the processing of larger quantities of organic waste and support more continuous biogas production. Second, long-term monitoring should be conducted to record the amount of feedstock, temperature, pH, gas pressure and volume, duration of stove use, slurry production, and reductions in LPG consumption. Such monitoring would provide more accurate quantitative evidence of the program's benefits. Third, KSM administrators and operators should receive further assistance on safety procedures, leak detection, reactor maintenance, and troubleshooting. Fourth, the quality and nutrient content of the fermented slurry should be assessed before it is packaged or marketed as organic fertilizer, accompanied by a feasibility study covering business viability, packaging, pricing, and required permits. Fifth, collaboration among local government, universities, and the private sector should be strengthened to support facility procurement, human resource development, and replication of biogas systems in other TPSTs with similar conditions.

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