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Biogas Energy Application for Eco-Friendly Development in Dukuh Village, Banyudono District, Boyolali

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Abstract: *Waste management has become a significant challenge due to the increasing volume of waste driven by rapid population growth. Banyudono District, a major contributor to waste in Boyolali Regency, faces considerable difficulties in managing this waste. This community service initiative applies the Community-Based Resource (CBR) approach to empower the local community in processing organic waste and livestock manure into biogas energy. Through the implementation of biogas machines, capacity-building training, and technology guidance, the community is actively involved in the process. As a result, Dukuh Village now operates a biogas production system, and the community has gained the necessary knowledge and skills to independently manage waste and livestock manure for biogas production. This project not only addresses waste management issues but also promotes sustainable energy solutions by leveraging local resources and fostering active community participation.*

Introduction

Waste management is a new challenge, along with the increasing waste production due to the rapid growth of the population[1]. According to UNEP data (United Nations of Environment Programme), waste production has increased significantly. In 2020, world waste production reached 2.1 billion tonnes per year, and it is projected that in 2050, it will increase by 56% to 3.8 billion if essential steps are not taken[2]. In recent years, waste has become a global problem contributing to climate change by contributing around 1,580 billion tonnes of CO2e (CO2 equivalent), equivalent to 3.2% of total CO2 emissions worldwide[3]. Indonesia is one of the largest waste-producing countries in the world. In 2020, it occupied the 5th position in the most waste producers, reaching 65.2 million tons[4], and became the country with the most significant food waste production in Asia in 2021, reaching 20.93 tons annually[5]. Based on data from the Directorate of Waste Management of Indonesia, food waste has the most significant composition, which is 43.1% of the total landfill in Indonesia, with the most considerable source coming from household waste (38.2%), traditional markets (20%), and retail center (18.6%) [6].

Banyudono District is one of the most significant contributors to waste in Boyolali Regency, where in 2021, Banyudono District contributed 163.60 (m3/Day) of garbage. One of the most significant contributors to waste in Banyudono District is the Pengging tourist area located in Dukuh Village, especially from the Pegging market made up of vegetables, fruits, and processed foods that are not sold. The high landfill also comes from the waste of culinary business actors around the market and the square of Pengging. More than ten garbage disposal points have yet to be managed by market and square managers, traders, culinary business actors, and the surrounding community. The waste from food waste disposal in Pengging Market and Pengging Square has only been collected and then picked up by garbage transport cars to be sent to the final garbage disposal site (End-of-pipe approach) [7].

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[7] Agus Eko Setyono and Nazaruddin Sinaga, "Zero Waste Indonesia: Peluang, Tantangan Dan Optimalisasi Waste To Energy," *Eksergi* 17, no. 2 (2021): 116, https://doi.org/10.32497/eksergi.v17i2.2619.

The amount of litter is caused by insufficient trash cans in Pengging Market and Pengging Square and the low awareness of visitors, especially culinary business actors related to environmental cleanliness and waste management from food production.

In addition to organic waste, livestock manure in Dukuh Village also has the potential to be used as Biogas. In addition to the agricultural and tourism sectors, livestock is also a potential village and livelihood for residents in Dukuh Village[8]. These livestock activities produce manure waste that impacts climate change, reaches 14.5% of greenhouse gases[9], and increases soil and water pollution[10]. On the other hand, livestock manure has the potential to produce high biogas, reaching 5.74 to 6.73 megajoules (MJ)[11][12].

The high composition of food waste and livestock manure contributes significantly to climate change[13] [14]. Food decomposes aerobically, with landfills undergoing a decaying process producing methane gas, a more potent greenhouse gas than carbon dioxide[15]. Livestock manure contributes more than 14.5% of total greenhouse gases[16]. Intensive food waste and manure livestock processing is needed to manage food waste and benefit the life sector[17].

Waste management into renewable energy (energy waste) is essential in an era of global energy uncertainty and the negative impacts of climate change[18].

[8] Badan Pusat Statistik Kabupaten Boyolali, "Kecamatan Banyudono Dalam Angka 2024" 46 (2024).

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[17] Kurniawan et al., "Leveraging Food Waste for Electricity: A Low-Carbon Approach in Energy Sector for Mitigating Climate Change and Achieving Net Zero Emission in Hong Kong (China)."

[18] Setyono and Sinaga, "Zero Waste Indonesia: Peluang, Tantangan Dan Optimalisasi Waste To

Biogas is a gas produced from anaerobic activities or fermentation from organic materials used as electricity or fuel that is more environmentally friendly. Processing organic waste into biogas is an environmentally friendly solution to manage waste and produce sustainable energy[19]. Waste management into renewable energy aligns with the Sustainable Development Goals set in SDG Goal 11, namely Sustainable cities and settlements, SDG Goal 12 is responsible for consumption and production, and SDG Goal 7 provides access to clean energy.

As one of the famous tourism villages in the Boyolali Regency area, waste management efforts are necessary because they affect the attraction and comfort of visitors. Environmentally friendly waste management is also important in realizing an Independent Hamlet Tourism Village (Dewi Mandiri) and supporting the development of Hamlet Village as a Smart Village through organic waste management to create an innovative environment.

Method

The partners involved in this service are the Head of Dukuh Village, Banyudono District, and Boyolali Regency. Dukuh Village, with a population of 3,805, is located at 7°43'51.36" S and 110°47'33.75" E, 22.2 km from Universitas Sebelas Maret (UNS). This community service uses the Community-Based Resource (CBR) approach, ensuring active participation from the community throughout the process. The service is carried out in several stages:

1. Identification of Community Issues and Resources: In collaboration with the Village Head and BUMDes (Village-Owned Enterprises), the community's challenges and resources are identified. This participatory process helps design a program that aligns with local needs and leverages available resources.
2. Survey of Biogas Machine Location: A survey is conducted with the community's involvement to select a suitable location for the biogas machine, ensuring the decision is based on the local context.
3. Co-creation of Biogas Machines: Based on the community's input and the results of the survey, biogas machines are designed and constructed, considering the size of the location, and the daily production of organic waste and livestock manure.
4. Community Capacity Building in Renewable Energy: This phase focuses on

Energy."

[19] B. S. Dhanya et al., "Development of Sustainable Approaches for Converting the Organic Waste to Bioenergy," *Science of the Total Environment* 723 (2020): 138109, https://doi.org/10.1016/j.scitotenv.2020.138109.

enhancing the community's understanding of renewable energy, particularly biogas. Community members are encouraged to explore how biogas can serve as an eco-friendly alternative to conventional fuels.

5. Hands-on Training and Technological Empowerment: Community members receive training in operating biogas machines. This hands-on learning equips them with the skills to independently process waste into biogas, fostering self-sufficiency and long-term sustainability.

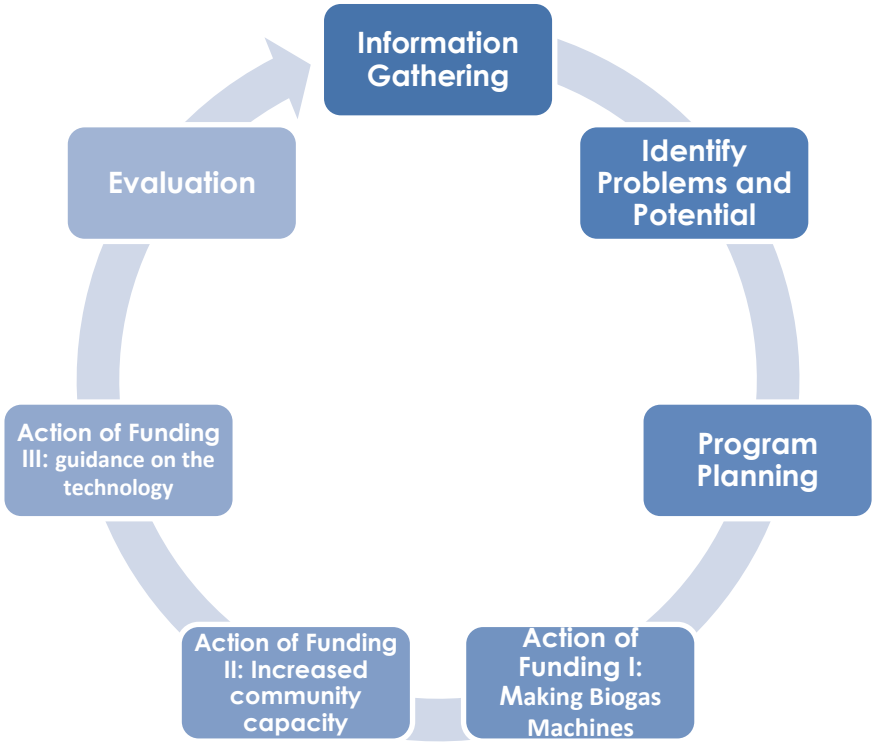

Figure 1. Diagram Process

Result

Pre-Implementation

Before the service activities are carried out, the service team identifies the problems and potentials owned by Hamlet Village as a partner. The identification was carried out by discussing with the Village Apparatus and BUMDes (Village-Owned Enterprises) to design a program to suit the problems faced by partners. The results of the problem and potential identification are presented in Table 1.

Table 1. Partner Problems and Potential

Problem	Potential	Program Plan
High waste production	1. There are already organic and inorganic waste-sorting activities 2. High amount of livestock manure production	Application of Biogas Manufacturing Machines made from organic waste and livestock manure
Low Community Understanding	1. High Interest in Community Learning 2. High Village Support	Capacity Building on the potential of organic waste to become an alternative energy to replace LPG gas
Low Community Ability	1. High Interest in Community Learning 2. High Village Support	Training and Guidance on Biogas Manufacturing Machine Operation Technology

Program Implementation

The implementation of the program is carried out in several stages. In terms of the specifics of the implementation of the program, it is:

First, survey the location of the biogas machine installation. The survey is carried out as the basis for making biogas machines according to the sizes available in Dukuh Village. Determining the location of the biogas machine installation considers the proximity to the biogas source, namely the organic and inorganic waste sorting site from the Pengging market and Pengging Square, as well as the proximity to cattle and goat farm owners as raw material for making biogas.

Figure 2. Biogas Installation Site Survey and Discussion on Determining the Location of Biogas Machine Installation

Based on the results of the survey and discussions with village officials and village communities, the biogas machine was installed in the RT 05 Warehouse of Dukuh Village so that the community can easily access it and to be close to the theme of sorting organic waste and livestock manure as the primary material for making Biogas.

Second, the procurement of biogas machines begins with making biogas

machines following the determined location size. The machine is made in two sets to provide optimal biogas results and can be used interchangeably. The activity then continued with a test of the engine cob before being given to service partners. The scheme of the biogas engine is:

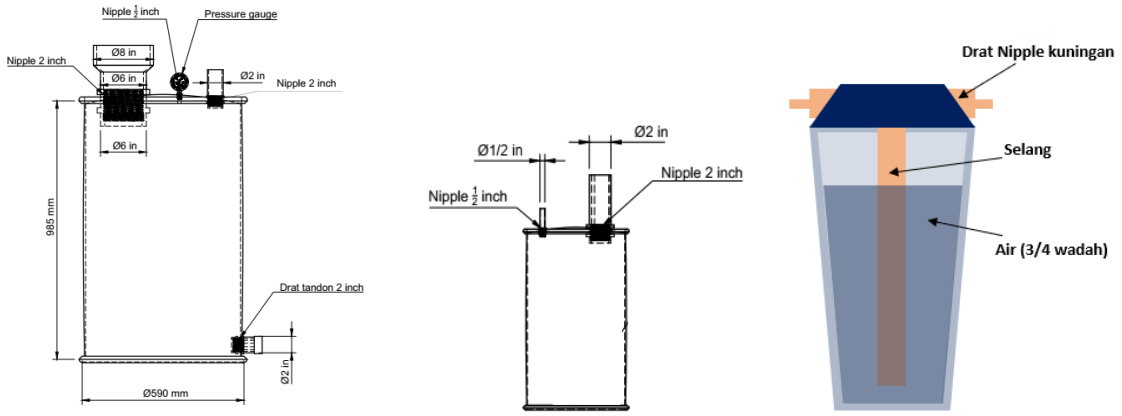

Figure 3. Scheme of The Biogas Machine

Figure 4. Biogas Machine

Figure 5. Biogas Content Checking

Third, guidance on the technology of using biogas engines is carried out. The community learned about biogas and how biogas machines work in this activity. The community was also trained to operate biogas engines and use biogas as an alternative fuel to replace Liquefied Petroleum Gas.

Figure 6. Presentation of Biogas Machine Handling Materials and Training

In this activity, the community seemed enthusiastic and actively asking questions. This program also attracted the attention of the head of the Dukuh tourism village, who was inspired to integrate biogas processing into the agenda of tourism village activities in Dukuh Village.

Discussion

Community service is one of the main points in the tri dharma of higher education. Service provides many benefits to the community because service programs are designed and implemented based on the problems partners face. In this service, Partners have problems related to waste management that have not been done much. On the other hand, waste production in Dukuh Village continues to increase because of tourism and culinary business activities at tourist sites, Pengging Square and Pengging Market as the activity center. In this problem, applying biogas-making machines is one of the right steps in overcoming the waste problem in Dukuh Village. In addition to the problem of unmanaged waste, the high production of livestock waste is also a problem that contributes to greenhouse gases [20] On the other hand, high livestock manure production can produce higher biogas than just using organic waste.

The main benefit obtained from this service program is an effort to provide education and understanding to the community that there is alternative energy as a substitute for LPG. So far, the people of Dukuh Village still depend on non-renewable energy to meet gas fuels. Through various activities that have been implemented, the community service team and village officials hope that people's habits will gradually shift to an environmentally friendly lifestyle. Through this program, it is also hoped that it can contribute to efforts to reduce the impact of climate change due to unmanaged waste, especially livestock manure waste. From the ecological aspect, some of the benefits expected through the implementation of this biogas machine are (a) water and soil conservation[21], (b) reducing pathogens[22], (c) power supply efficiency[23], and (d) pollution management and control[24].

The program carried out by the UNS worship team provides a new solution in the processing of organic waste and livestock waste in Dukuh Village. As a tourism

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village the management of garbage and livestock waste is an important thing that needs to be considered in the management of tourist villages because it will affect the attraction of tourists visiting Dukuh Village. On the other hand, developing the biogas system in tourism villages has the potential to develop new tourism village concepts, such as environmentally friendly tourism villages. Ecotourism is nature-based tourism managed sustainably, supports conservation, and is environmentally friendly[25]. Applying the ecotourism concept can minimize the impact of tourism on environmental impacts[26].

The implementation of service activities, there are several things that hinder the realization of the purpose of service. Biogas alternative energy, which is still new for the people of Dukuh Village, reduces public acceptance of service products. Many people are still comfortable using conventional fuel to meet household needs. Many people also find the switch to renewable fuels even more complicated because it requires a long processing compared to conventional fuels that only need to be bought directly at stalls or stores. So that to overcome these problems, increasing public understanding of the benefits of alternative renewable energy needs to be done before implementing biogas machines to the community. hinder in the process of technical training on the use of biogas machines.

Conclusion

In this community service activity, the community can feel the benefits of biogas-making machines, which increase knowledge and improve skills. Through various activities implemented, the community has a new understanding of waste management, which was initially an environmental problem and has moved to more optimal processing. The community also understands more about the scheme for making biogas from organic waste and livestock manure waste. The community also gets skills in making biogas through biogas machines that have been applied to the community. Through this service program, it is hoped that it will change the pattern of community dependence on the use of LPG gas. Another expected impact is that Dukuh Village can implement an environmentally friendly lifestyle and develop an ecotourism-based tourism village. In addition, it will also be planned to develop biogas production products that are integrated with tourism activities into eco-based tourism villages and tourism edu so that they can increase income for the community and the region, especially Dukuh Village.

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