Analyzing the Constraints of Cow Manure Biogas Program with Biodigester: Implications for Sustainable Development in Rural West Sumatra

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Keywords: Biogas, Social Engagement, Sustainable Development, Program Failure, Renewable Energy.

Abstract: This study examines the barriers that hinder the success and desirability of a cow dung biogas program in Pasaman District, West Sumatra, within the framework of rural sustainable development. Although biogas technology is promising as a renewable energy source, its implementation can face significant challenges, including inadequate government support, inadequate training, and inconsistency with local socio-economic and cultural conditions. Guided by Travis Hirschi's social control theory, this study reveals that low levels of sustainability, commitment, and community involvement undermine participation and ownership among farmers. Furthermore, Pierre Bourdieu's concept of social capital highlights the detrimental effects of weak trust and collaboration in social networks. At the same time, Edward Hall's anthropological communication theory underscores the impact of ineffective and culturally insensitive communication practices. Using a qualitative case study approach, this study involved in-depth interviews and focus group discussions with farmers, agricultural extension workers, and government officials. Findings suggest a systemic lack of social support, including a lack of advanced techniques and weak interactions within the mesosystem, as described by Bronfenbrenner's ecological systems theory. This lack of understanding results in farmer isolation and limited access to resources and guidance needed for effective biogas management. The study concludes that a holistic strategy is essential to address these socio-technical barriers. Key recommendations include active community engagement training, enhancing social networks to enhance collaboration and resource sharing, and ensuring consistent government support through tailored training and adaptive technology using model predictive control (MPC) . By addressing these issues, biogas programs can become more effective, sustainable and scalable, and make a significant contribution to the rural energy transition. This study enriches the discourse on sustainable development by emphasizing the critical role of social dynamics in renewable energy initiatives. It offers actionable insights and a strategic framework to guide the implementation of biogas programs in similar rural contexts, paving the way for a more inclusive and sustainable energy future.

1 INTRODUCTION

The government's efforts to advance renewable energy to address energy demand in rural areas have encountered many challenges, especially in implementing the biogas program. Although rural communities are expected to benefit the most from this program, many need to understand biogas technology. Indonesia's continued dependence on fossil fuels, such as oil and coal, has not only contributed to environmental degradation and severe greenhouse gas emissions (Hidayati et al., 2019) but has also raised concerns about future energy security, as projected oil reserves only last for 12 years (BP Migas, 2011).

One of the significant constraints in implementing biogas programs is the need for greater involvement of key stakeholders, including agricultural extension agencies and local governments. This gap has resulted in poorly designed and unsustainable training

Hidayat, M., Syah, N., Erianjoni, , Mardhiah, D., Wardefi, R. and Amelia, L.
Analyzing the Constraints of Cow Manure Biogas Program with Biodigester: Implications for Sustainable Development in Rural West Sumatra.
DOI: 10.5220/0013415800004654
In *Proceedings of the 4th International Conference on Humanities Education, Law, and Social Science (ICHELS 2024)*, pages 51-63
ISBN: 978-989-758-752-8

initiatives, leaving communities unprepared to utilize biogas technology (Aji, 2022) effectively. In addition, cultural practices and community behavioural patterns significantly affect program outcomes. Challenges such as limited access to suitable raw materials, including livestock manure, and inadequate management systems further hamper the efficiency of biogas production (Rahadi et al., 2018).

Biogas offers enormous potential as a sustainable and environmentally friendly energy source due to its high methane content (55%-75%) and high calorific value (4800-6700 kcal/m³) (Aisah & Herdiansyah, 2020). However, proper control of the fermentation process and consistent maintenance of the biogas system are essential to realize this potential. If implemented effectively, biogas technology can improve the livelihoods of rural populations and contribute to national policies aimed at reducing dependence on fossil fuels while expanding the use of renewable energy.

Biogas technology offers a sustainable solution for rural development, especially in livestock areas. This technology utilizes organic waste, especially animal waste, to provide an alternative energy source (Ramdhan et al., 2021; Sugiono et al., 2023). A biogas system can provide economic benefits, energy independence, and environmental improvements in rural communities (Kuntang et al., 2018; Dewi Hastuti, 2009). However, successful implementation requires community participation, government support, and proper management (Julianita et al., 2020; Andhina et al., 2020). Although biogas technology is relatively simple and easily adaptable to areas with limited human resources, there are challenges, such as maintenance issues and the need for continuous socialization (Fahmi Arifan et al., 2019; Andhina et al., 2015).

Community involvement in rural biogas programs through active participation of residents in the planning and implementation of biogas programs has been shown to increase the success and desirability of the program (Julianita & Fatchiya, 2020; Aisah & Herdiansyah, 2020). A holistic and participatory approach, such as the SHIP method, is needed to overcome technical and social obstacles often occurring in program implementation (Sucipta et al., 2017). Biogas programs provide dual benefits, such as alternative energy and waste processing (Ajija et al., 2020; Oktavia & Firmansyah, 2016). Education and training for the community regarding the benefits and technology of biogas can increase understanding and adoption of this technology in the community (Anugrah et al., 2023). Collaboration between the community, government, and non-governmental organizations is essential to achieve the success of this program (Yasin & Pratiwi, 2024). Community involvement also effectively increases interest in learning in rural areas, showing the broader potential of community-based approaches (Putri et al., 2023).

This study aims to identify factors contributing to the constraints faced by the biogas program utilizing cow dung biodigesters in Pasaman Regency, West Sumatra, within the framework of sustainable rural development. The increasing demand for renewable energy and the potential of biogas recognized as a viable alternative energy source are the basis for this study. Although the biogas program in Pasaman has received government and institutional support, the program continues to face constraints such as inadequate training and limited community involvement.

Ideally, training can be adapted by involving community members in the development process so that the training content reflects the specific challenges they face and the language they use every day. In addition, more hands-on and interactive learning methods, such as hands-on documentation and field visits to operating biogas plants, can enhance participants' understanding and skills. This adaptation will help communities understand how to manage and maintain biogas systems and build a sense of ownership and responsibility for their technology.

This study is supported by the assumption that active community participation and strong social networks are essential for the success of a biogas program. This study addresses the following questions: "To what extent does community involvement influence the success of a biogas program, and how do social networks shape the social support received by farmers?" and "What are the main factors that facilitate or hinder social support in the implementation of a biogas program?"

By answering these research questions, this study aims to explain the social dynamics of the community and propose actionable strategies to improve social support mechanisms. This improvement ensures that the biogas program is a practical, sustainable, and scalable solution to rural energy needs. This study highlights the importance of encouraging community involvement, building strong social networks, and providing adequate social support in achieving successful development outcomes. Previous studies have consistently shown that the termination and effectiveness of development initiatives are greatly enhanced through active community involvement (Aminah et al., 2023; Anugrah, 2023).

2 LIBRARY REVIEWS

2.1 Social Control

The concept of social control by sociologists-anthropologists such as Emile Durkheim and Robert K. Merton, Pravis is a mechanism for how order in society is formed and how deviations and behaviour can be managed. According to Merton, there are two types of social control: preventive (preventive) and repressive (punishing)—Durkheim views social control as a prophylactic measure to maintain order and morality in society. Social deviation is seen as a result of weak social ties and weak community control over individuals. The sustainability of the biogas empowerment program in Pasaman must be connected to the social control in the local community. (Ristianingsih et al., 2018; Lie et al., 2022; Munahar et al., 2021; Hendrasarie & RP, 2021).

Based on the context of biogas in Pasaman, the obstacles and deviations in the program's sustainability are the weakening of social ties and community control over individual biogas farmers. This condition causes a lack of community participation, which hampered the understanding of optimal biogas management forts that can be made to encourage the success of the biogas program in Pasaman, which requires strengthening social control at the community level. This can be done through: 1) Strengthening community institutions related to the biogas program, 2) Increasing community participation in the planning, implementation, and evaluation process of the biogas program, 3) Strengthening understanding and capacity in the community for optimal biogas management (Lie et al., 2022; Purwantono et al., 2022). By strengthening social control at the community level in the biogas sector, it is hoped that it can become a preventive control or prevention through strengthening existing norms and values in the community, which influence individual decisions to adopt new technologies such as sustainable biogas in Pasaman and minimize obstacles that often arise.

2.2 Social Capital

Sociologists-anthropologists explain that social capital can be divided into several things, such as trust, values and norms, and networks owned by a community. Karl Marx saw social capital as a framework needed to carry out social activities in a community. Marx explained social capital as a relationship of mutual trust, shared values and norms, and a network of cooperation built within a community (Christy et al., 2019). According to Putnam, social capital consists of trust, norms, and networks that can increase the efficiency of society by facilitating collective action (Bowling Alone, 2023). Trust, values, standards, and social networks are essential in supporting the development and sustainability of community development programs such as the biogas program in Pasaman.

Social networks and trust play a central role in the success of biogas programs but can sometimes be obstacles if not appropriately managed (Purwantono et al., 2022). In Waru Barat Village, Pamekasan, research shows that strong social networks between farmer groups and other stakeholders, such as government, distributors, and suppliers, are beneficial in facilitating the distribution and promotion of biogas (Hadi et al., 2021). However, if these networks are unstable or disrupted by anxiety or dissatisfaction, this can lead to operational disruptions and decreased community interest. In Areng Village, Cibodas, the positive impact of social networks was seen in increased community awareness and participation after effective communication between extension workers and the community. They managed to increase the trust ratio through lectures and brainstorming methods, which ultimately helped build a high radius of trust (Barhoun & Ed-Djibouti, 2023). This shows that solid social networks and high trust can be the main drivers in driving the success of biogas programs, while the creator or lack of trust can hinder it.

Social capital can play a role in supporting the success of the biogas program in Pasaman, for example through (Ari et al., 2022): 1) Increasing community trust and confidence in the benefits of biogas, 2) Strengthening values and norms that support biogas development at the community level, 3) Strengthening cooperation networks between communities, governments, and other stakeholders in biogas development (Lie et al., 2022) (Purwantono et al., 2022). By strengthening social capital in the community, it is hoped to encourage more optimal community participation and Contribution to the biogas program so that obstacles such as limited community understanding and low biogas consumption can be minimized.

2.3 Ecological System

Sociologists- Anthropologists explain the concept of ecological systems, which is that the surrounding environment, both physical and social environments, significantly influences the development of individuals or communities. The system has an

environmental system to understand the relationship between humans and their environment. (Indrajati et al., 2023). Ecological anthropologist Julian Steward explains the ecological system associated with the First Ecological Law: a population, organism, or community must be studied about its environment to understand an ecological system. The second environmental law states that each ecological system has various factors that influence each other. The third environmental law explains that human awareness, reasoning, and intelligence allow them to adapt to existing ecological systems through experience and learning (Syafina & Ahmad, 2022).

The ecological system in the biogas program in Pasaman can affect its success. What is conveyed in the first environmental law, the ecological system, both the physical environment and the social environment in Pasaman, must be well understood, for example, the potential for livestock waste biomass, community lifestyle, culture, availability and access to capital, and existing institutional support. Then, as in the second ecological law, the interrelated factors in the environmental system can influence each other and determine the success of the biogas program in Pasaman. Furthermore, the third environmental law also states that with the human ability to adapt, the biogas development program in Pasaman can be carried out well through learning and experience (Ristianingsih et al., 2018). Thus, if the ecological system in Pasaman supports it, it will be easier for the community to adapt biogas technology sustainably, as explained in the third environmental law.

3 METHODS

3.1 Unit Analysis

The analysis of the failure of the biogas program using cow dung and biodigesters in Pasaman Regency, West Sumatra, focuses on three essential elements: the case, the location, and the actors involved. The case applies biogas technology to encourage sustainable development in rural areas by utilizing cow dung as an alternative energy source. Pasaman Regency was chosen as the research location because it has unique social, economic, and cultural characteristics, which significantly affect the adoption and success of the program. Osei-Marfo et al. (2020) emphasize that local community involvement and socio-economic dynamics are essential determinants of biogas technology uptake. In addition, key actors—such as farmers, agricultural extension workers, and local government officials—are critical in program implementation and evaluation. Gift (2023) highlights that effective stakeholder engagement is essential to optimizing biogas production outcomes.

Despite having many advantages, the application of biogas technology in Indonesia, especially in Pasaman Regency, West Sumatra, still needs to overcome various challenges. This research was conducted in Jorong IV Mahakarya, Luhak nan Duo District, West Pasaman. The reason for conducting this research in this area is based on data from the Ministry of Energy and Mineral Resources; the achievement of the distribution of biogas reactors in Indonesia, including Pasaman, only reached around 30% of the target set in 2018, indicating serious problems in the implementation of the program (Tempo, 2019). Biogas has yet to be utilized optimally, and efforts are needed to develop technology and public understanding (Munahar et al., 2021; Lie et al., 2022; Ristianingsih et al., 2018). The human error factor shows that 96% of the cases are caused by a lack of understanding and support from users of the biogas system (Puji, 2016). This shows the failure of public acceptance because it does not consider socio-economic constraints during the design and implementation of the program (Jan 2021).

3.2 Resources

This study combines multiple sources of information to comprehensively analyze the failure of the biogas program in Pasaman District. Primary data were collected from key informants, including farmers participating in the program, agricultural extension workers, and local government representatives, who provided first-hand insights into the challenges and experiences associated with biogas technology adoption. Additional perspectives from renewable energy experts and academics were drawn to provide a broader contextual understanding. Secondary data sources included program reports, previous research manuscripts, and documents from government agencies and non-governmental organizations, which were rich in analysis. Additionally, news articles and related publications were reviewed to capture socio-economic factors that influenced the success or failure of the program.

3.3 Data Collection

The data collection used a combination of methods to ensure a thorough understanding of the phenomenon under study. These methods included desk observations, field observations, in-depth interviews,

and focus group discussions (FGDs). Initially, a desk review was conducted to examine relevant documents such as program reports, scientific literature, and secondary data to establish the background and context of the biogas program. Field observations were conducted next, allowing researchers to directly assess farmers' conditions and challenges in managing biogas facilities. In-depth interviews with key respondents—farmers, extension workers, and local government officials—provided insights into factors influencing program outcomes. Finally, FGDs brought together various stakeholders to identify key challenges and explore potential solutions to improve the desired program.

3.4 Data Analysis

Data analysis was guided by Travis Hirschi's social theory, which served as an analytical framework. The process began with data reduction, where information from interviews, observations, and FGDs was organized and discussed into emerging themes. These were then explained using Hirschi's four social elements: attachment, commitment, involvement, and belief. This approach allowed the researcher to examine how farmers' social connectedness to the biogas program influenced their participation and overall success. The analysis provided more profound insights into the social dynamics underlying the adoption of sustainable biogas technologies by linking the findings to Hirschi's framework.

4 RESULTS AND DISCUSSION

4.1 Biogas Management: Then and Now

The cow dung-based biogas program in West Pasaman Regency, especially in Luhak Nan Duo District, began with great enthusiasm as part of the government's initiative to promote renewable energy. In 2014, the West Sumatra Agricultural Technology Assessment Center (BPTP) held a biogas production training in Jorong Mahakarya. This initiative involved local farmer groups and utilized available resources such as cow dung to produce methane gas for cooking and lighting.

However, the technology used in this program is relatively simple, utilizing materials such as polyethene (PE) plastic for gas storage. Although cost-effective, this approach has many drawbacks, including low efficiency and limited durability. One informant, Mr Suparman, noted that the biogas produced is insufficient even to boil air for a reasonable period. Furthermore, the maintenance complexity and frequent plastic leakage add to operational constraints, making this system unsustainable in the long term.

At the beginning of the program, farmer groups of about 20 people each were given 40 cows to produce manure for biogas production. Despite this support, the program quickly lost momentum due to a lack of post-training supervision and ongoing mentoring from BPTP. Farmers struggled to manage the biogas system independently without guidance from extension workers.

Another significant obstacle is the pragmatic response of communities to the program. When biogas systems fail to meet expectations, particularly regarding energy efficiency and maintenance costs, many farmers turn to liquefied petroleum gas (LPG), which is more practical and cost-effective. Government subsidies for LPG and stoves further reinforce this conservation, hampering the sustainable use of biogas.

Today, the remains of the biogas program in West Pasaman are barely visible. Many former biogas facilities, such as cow dung storage, have been converted to function—for example, as a pond for catfish farming. This transformation underscores the difficulty that simple technologies like biogas face when competing with conventional energy solutions when sustainable support is lacking.

4.2 Lessons Learned and Recommendations

The failure of the biogas program highlights the need for a comprehensive and sustainable approach to ensure success. Reliable technology, intensive training, and consistent support from the government and stakeholders are essential to harness the potential of renewable energy sources such as biogas.

One of the key issues identified in this study is the need for a sustainability monitoring and evaluation system. After the initial training provided by BPTP, there needed to be a mechanism to initiate progress or provide follow-up assistance to sustain the program. This gap between training and field implementation leaves farmers needing more technical resources or support to address operational challenges.

The failure of this program can also be attributed to the lack of an adaptive approach that is in line with local needs. The development of biogas technology tailored to the community's social and economic conditions needs to be improved. For future programs, the desire requires active involvement of

the government, extension workers, and local communities in ongoing collaboration. Periodic evaluations must be carried out to refine the technology and adjust the implementation of strategies based on field conditions.

Figure 1: Current condition of biogas processing plant in Pasaman, 2024.

4.3 Biogas Program Failure

Analysis of the failure of a biogas program Analysis of the failure of a biogas program utilizing cow dung and biodigesters in Kabupaten, West Sumatra, reveals critical challenges in maintaining farmer participation. Statistical data from interviews with farmers and agricultural extension workers show that only about 30% of farmers initially involved in the program continued using the biogas system after two years of implementation. Participation levels were categorized as medium-high (40%), medium-high, and low (30%), highlighting the gap in sustained engagement.

Insights from the interviews shed light on the factors behind this decline. One farmer stated, "Initially I was very enthusiastic, but after a few months, I felt there was no support from the government, and it became difficult to maintain the system." This sentiment highlights the significant challenges farmers face, including inadequate technical assistance, lack of institutional support, and difficulties in maintaining biogas systems independently.

Limited financial support from the government for initial investment in biogas infrastructure is a significant challenge. Many farmers can only afford the relatively high cost of building a biogas system with subsidies or affordable loans for infrastructure improvements. Technical support is also needed, especially in training and education on effectively designing, operating and maintaining biogas systems. Many communities need more knowledge or skills to make the most of this technology with adequate training programs.

This finding underscores critical gaps in sustainable social and institutional support, significantly contributing to program failure. The absence of strong collaborative relationships between farmers and agricultural extension workers further exacerbates this problem. These results underscore the need to foster partnerships, provide consistent technical assistance, and offer ongoing support to increase the desirability and success of renewable energy programs in rural communities.

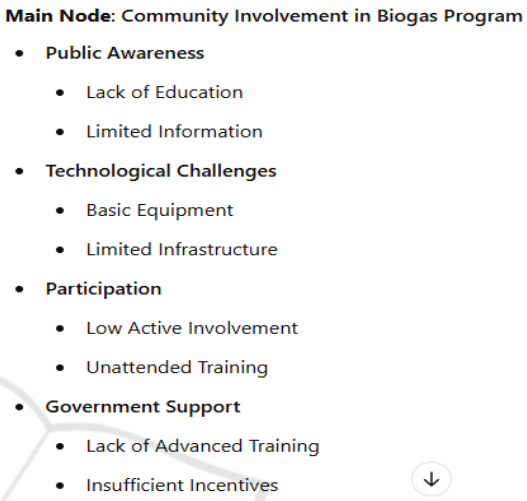

Figure 2: Condition of community interaction map in the biogas program in Pasaman, 2024.

4.4 Community Involvement in Cow Manure Biogas Program

Community engagement in the cow dung biogas program in Pasaman District, West Sumatra, faced significant challenges that ultimately led to its failure. The study identified low community awareness of the benefits of biogas technology and technological limitations, such as inadequate equipment, as significant barriers to active farmer participation. Furthermore, while training sessions were conducted, many farmers needed to apply the knowledge gained, and government support, including further training and incentives, needed to be improved. These combined factors could help achieve the program's goal of advancing sustainable development in rural areas.

The pattern of community involvement in the biogas program shows a trend that has implications for its loss and effectiveness. Although communities initially showed high enthusiasm for the initiative, participation rates have declined sharply. This decline can be attributed to a lack of comprehensive understanding of biogas technology and the absence of sustained government support after initial training. Farmers also face operational challenges from limited

access to appropriate equipment and infrastructure, undermining the program's ineffectiveness.

4.5 Social Support and Sustainability Programs

Social support for the cow dung biogas program was another important factor influencing its success in Pasaman District. Data collected through in-depth interviews with farmers and agricultural extension workers revealed a widespread perception of a lack of support after the initial training phase. For example, one farmer said, "After the training, we didn't know where to go for further assistance." This gap between expectations and reality created significant mismatches in program implementation, with 70% of farmers expressing dissatisfaction with the level of support provided.

A flowchart can map out an ideal support process to better illustrate these gaps, from training and talk-through to follow-up support. The diagram can identify specific points where system support fails, visually showing the steps needed to increase farmer engagement and ensure program continuity. Emphasizing effectiveness and collaboration among all stakeholders will be critical to addressing these challenges and achieving long-term success in future initiatives.

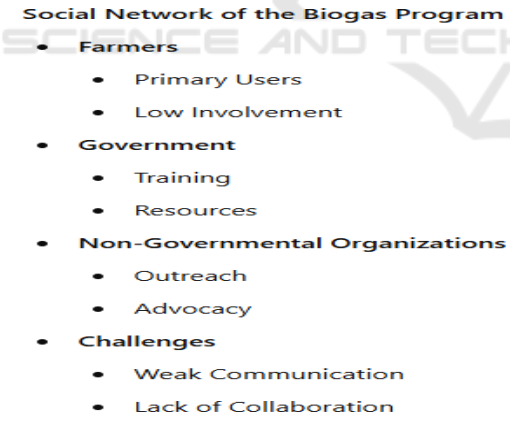

Figure 3: Map of key conditions of the Biogas Program Social Network in Pasaman, 2024.

4.6 Social Network Dynamics Program and Failure

Analysis of social network dynamics related to the failure of a cow dung biogas program in Pasaman District, West Sumatra, reveals a recurring problem of weak interaction between stakeholders. Despite government efforts to provide training and support and the proactive role of NGOs in extension services, many farmers reported feeling excluded and needed more information on how to implement biogas technology effectively.

Ineffective communication practices in biogas programs are often caused by a need to understand local communities' social and cultural context, leading to misunderstandings and technology resistance. For example, in some cases in this region, outreach conducted by external parties uses complex technical language without considering the educational background of the community, which is generally elementary school graduates, so that the information conveyed cannot be adequately understood. In addition, a one-way communication approach—where data is only transferred without any dialogue or feedback from the community—can create the impression that their needs and concerns are not being addressed.

This pattern highlights significant communication and collaboration, where farmers need more ongoing support after the initial training. As a result, the biogas management system is disrupted, resulting in unsatisfactory program results.

These findings emphasize the need to strengthen several efforts to enable synergistic interactions among all stakeholders. Increasing collaboration and communication channels is essential to encourage the development of sustainable renewable energy solutions in rural communities.

4.7 Social Support and Farmer Engagement

Data on social support for the biogas program in Pasaman District were collected through in-depth interviews with farmers and agricultural extension workers. This gap between expectations and actual support created significant unity, with 70% of farmers expressing dissatisfaction with the assistance they received.

To better illustrate these gaps, a flowchart could map out the ideal support process—from training to follow-up—while identifying critical points where support fails to continue. Such a diagram would highlight the steps needed to increase farmer engagement, ensure program lapses, and underscore the importance of effective communication and collaboration among all stakeholders.

4.8 Social Support in Biogas Program

Research on the failure of a cow dung biogas program in Pasaman District, West Sumatra, highlighted the

need for more interaction and collaboration between farmers, government, and extension agencies. Many farmers reported a need for follow-up training and technical guidance after the initial sessions, leaving them needing clarification on managing the biogas system. Furthermore, ineffective communication between farmers and extension officers resulted in a limited understanding of the benefits of biogas and its operational requirements, leaving farmers feeling protected and unprotected in addressing the challenges they faced. This lack of strong social support contributed significantly to the program's failure, limiting its potential to serve as a sustainable alternative energy solution in rural areas.

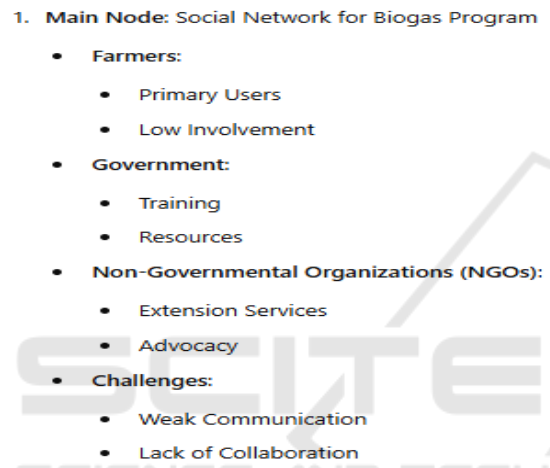

Figure 4: Main map conditions of Social Network Dynamics and Biogas Program Failure, 2024.

4.9 Social Support Patterns and Program Participation

Analysis of social support patterns revealed a negative trend. Community engagement in the biogas program could have been higher despite initial government training and support from extension agencies. Many farmers expressed dissatisfaction with the level of support, describing it as unsustainable and unable to address the technical and operational challenges they faced. This dissatisfaction was further exacerbated by ineffective communication between farmers and extension officers, resulting in a limited understanding of the benefits and functionality of the program. As a result, many farmers opted for more accessible energy solutions, such as LPG, which they perceived as more straightforward and cost-effective than biogas. The cycle of weak social support and low participation hampers the program's success as a sustainable energy initiative.

Analysis of community involvement in the cow dung biogas program in Pasaman Regency reveals the importance of low participation to program outcomes. Referring to Travis Hirschi's social control theory, community involvement is a "social bond" that encourages individuals to commit to a collective initiative (Hirschi, 1969). According to this theory, four social elements—attachment, commitment, involvement, and belief—are critical in encouraging participation. However, this study found that many farmers lack a sense of ownership of the biogas program, reducing their motivation to engage actively. Without such bonds or a shared understanding of responsibility, the program's potential for success is severely compromised.

In addition, Pierre Bourdieu's concept of social capital offers insight into the importance of relationships and trust within a community for collective action (Bourdieu, 1986). Social capital stresses that trust, networks, and leverage are critical to ensuring the sustainability of development programs. The findings highlight that weak social capital among farmers hinders collaboration and collective responsibility. Therefore, active participation—such as involving community members in program planning and implementation—can foster ownership and accountability, increasing the likelihood of program success.

Therefore, the perspective-consequence, weak community interaction structures contribute significantly to the success of the biogas program. Inadequate communication and transparency between the government and community members creates a lack of understanding of the benefits and operational mechanisms of the program. Referring to the Anthropological Communication Theory by Edward Hall (1976), this misalignment can be attributed to differences in communication styles and cultural expectations. Hall emphasized the importance of high communication in rural settings, where implicit trust and culturally appropriate interaction methods are essential.

This lack of effective communication has fostered a sense of mistrust among farmers, many of whom feel the program was imposed on them rather than designed to meet their needs. This mistrust is compounded by a lack of follow-up, which leaves farmers feeling disconnected. To address these challenges, it is critical to establish culturally sensitive communication channels and engage communities at every stage of the program. Such

steps will increase transparency, build trust, and foster collective responsibility for future initiatives.

The failure of the biogas program in Pasaman Regency can also be explained through the lens of weak ties theory (Granovetter, 1973), highlighting social networks' role in facilitating resource exchange and collaboration. Weak ties—connections with individuals outside one's immediate social circle—are often crucial in bridging and disseminating information. However, this study observed that weak social networks among farmers limited collaboration and hindered the exchange of knowledge and resources essential for implementing biogas technology effectively.

In contrast, strong social networks can act as a support structure, allowing farmers to share experiences, knowledge, and best practices. Farmers feel sheltered and unsupported without these networks, contributing to program failure. This aligns with Durkheim's concepts of mechanical and organic solidarity, which underscore the importance of connectedness in achieving collective goals (Durkheim, 1893). Stakeholders should develop strategies to strengthen social networks, such as forming working groups or learning communities, to enhance collaboration and ensure the desirability of the biogas program.

The conclusion emphasizes the importance of social pressure, encouraging participation, and ensuring program sustainability. According to Cohen and Wills (1985), social support is an essential buffer against stress, especially in challenging tasks such as adopting new technologies. Lack of adequate support from extension workers and unclear information about the benefits of biogas made farmers feel protected and motivated to maintain their efforts. This highlights the critical role of social support as a binding force in communities that encourages active participation. Without such support, programs such as biogas are at significant risk of failure.

Furthermore, Bronfenbrenner's ecological systems theory (Bronfenbrenner, 1979) provides a framework for understanding the interactions between individual behaviour and the broader social system. The failure of social cessation in biogas programs reflects a breakdown in the "mesosystem," where interactions between farmers and extension workers are weak or nonexistent. To address this gap, stakeholders must build sustainable social support systems that connect farmers with resources, training, and technical assistance throughout the program's life cycle.

Analysis of the failure of the biogas program in Pasaman Regency shows that, although it has been started since the 1970s, its implementation at the village level still faces various obstacles. Data from interviews with farmers and agricultural extension officers show that only 30% of farmers remain active users of the biogas system two years after the program began.

Extension workers not only serve as a liaison between the government and the community but also have the potential to be effective agents of change by providing technical information, training, and ongoing support to farmers. We can design more comprehensive and relevant training programs by understanding extension workers' challenges, such as limited knowledge of biogas technology or lack of resources to conduct effective extension. In addition, involving extension workers in the decision-making process and planning of the biogas program can increase their sense of ownership of the initiative, thus encouraging them to be more proactive in educating the community (Dewi et al., 2023).

Factors contributing to this failure include 1) Limited Government Support, Minimal follow-up assistance and inadequate resource allocation, and 2) Ineffective Training: Training sessions failed to equip farmers with the skills necessary for biogas management, which is in line with Rogers' Diffusion of Innovation Theory (2003), which highlights the importance of practical knowledge transfer for technology adoption. 3) Technology Inappropriateness: Biogas technology was not adapted to the local socio-economic and cultural context.

This study uses a qualitative approach with a case study methodology to explore the experiences and perspectives of stakeholders, including farmers and government officials. In addition, this study also examines the socio-economic and cultural contexts that influence the implementation of biogas technology in Pasaman Regency. The findings of this study highlight the need for improved support systems, communication, and tailored solutions that address local needs to drive the success of biogas programs in rural areas.

Analysis of the cow dung biogas program in Pasaman District revealed several key findings that underscore its failure to achieve sustainable outcomes. Low community engagement emerged as a significant problem, with farmers demonstrating minimal ownership, commitment, and participation in the planning process. This lack of engagement hampers collective accountability and reduces the program's effectiveness. Weak social networks compound the problem, as farmers experience isolation and require more platforms to collaborate

and share knowledge, limiting their ability to address challenges collectively.

One effective way to address isolation is through regular workshops involving successful and novice farmers, where they can share first-hand experiences of challenges and solutions in biogas use. In addition, creating discussion groups or community forums where farmers can exchange information and strategies through face-to-face meetings or online platforms can increase a sense of community and support. Organizing field activities, such as visits to successful biogas plants, will also provide inspiration and practical learning for other farmers.

Figure 5.

Communication also played a significant role, with cultural inconsistencies and inadequate follow-up from extension workers creating mistrust and disengagement among participants. Finally, technological inconsistencies were evident, as training programs were ineffective, and biogas technology needed to be adapted to the local socio-economic and cultural context, leading to low adoption rates.

5 CONCLUSION

Analysis of the cow dung biogas program in Pasaman Regency revealed several significant social, technical, and systemic challenges that hampered the success and desirability of the program in the long term. Although biogas has considerable potential as a renewable energy source, obstacles such as lack of government support, inadequate training, and incompatibility with the local socio-economic and cultural context emerged as significant factors that led to the program's failure.

These findings suggest that program failures are rooted in systemic design weaknesses that ignore essential social and cultural dimensions. Lack of strong social networks and ineffective social support mechanisms further undermine the challenge, while failure to adapt technology to local needs undermines unintended programs. Communication and trust-building are also critical, as the absence of culturally sensitive strategies alienates participants and hinders their engagement.

To address these issues, several applications should be considered for future renewable energy initiatives. Program design should prioritize active community involvement. Stakeholders are involved throughout the planning and implementation stages to control ownership and responsibilities. Strengthening social networks by forming farmer cooperatives or working groups can enhance collaboration and resource sharing. Governments and policymakers should provide ongoing technical and financial support and culturally tailored communication strategies to build trust and improve program engagement. In addition, technologies should be tailored to local socio-economic conditions, with regular evaluation and refinement based on community input. By addressing these socio-technical barriers, future biogas programs can be more effective, sustainable, and participatory, contributing to broader rural development goals.

A structured action plan and transparent implementation model can provide a starting point for practitioners to address the challenges. This action plan can begin with a needs assessment at the community level to understand the challenges and potential, followed by forming a working group involving farmers, extension workers, and local stakeholders. The next stage includes intensive training and outreach on biogas technology, including caring for and maintaining the system. Implemented by gradually constructing biogas installations, starting with small units that can be multiplied based on results and feedback. The final stage is regular

monitoring and evaluation to assess the performance of the system and its impact on community welfare, as well as make necessary adjustments.

This step has been implemented in several countries, such as research in South Africa, which shows that biogas technology must be adapted to the local context and cannot use a uniform approach for all regions (Uhunamure et al., 2021). On the other hand, the strategy of opening up the use of biogas in the area triggers the importance of raw material availability, government policies, and community interest as key factors (Budi et al., 2015). The experience of the biogas program in India also highlights the importance of a deep understanding of rural resource flows and local political economy for successful technology diffusion (Lichtman, 1987).

A broad and integrated approach is essential to ensure the success of biogas programs. Key recommendations include increasing active community involvement by involving stakeholders in all program design and implementation stages, strengthening social networks to enable resource sharing and collaboration, and maintaining ongoing government support through regular monitoring, technical training, and technology adaptation to local needs. These strategies are essential to increasing ownership, participation, and sustainability of renewable energy initiatives in rural areas.

This study enriches the discourse on sustainable development by emphasizing the critical role of such emphasis in determining the outcomes of biogas programs. By providing actionable insights and a strategic framework, this study offers valuable guidance for future initiatives in similar rural contexts, with broader applicability to achieving sustainable energy solutions.

ACKNOWLEDGEMENT

We want to thank the writing team, the conference committee, the Faculty of Social Sciences UNP and the UNP campus for their support in the publication of this article.

REFERENCES

Aji, H. (2022). Challenges and Obstacles of Biogas Program in Rural Areas: Case Study in Pasaman, West Sumatra. Renewable Energy Journal, 15(2), 134–142.

Aisah, S., & Herdiansyah, S. (2020). Biogas Potential as a Renewable Energy Source in Indonesia. Journal of Energy Technology, 12(3), 90-98.

Ajija, M., Naimah, R., & Hartono, P. (2020). The Influence of Government Policy on Community Acceptance in Biogas Programs in Rural Areas. Journal of Energy Policy, 8(4), 45-53.

Al Batistuta, RA, Sugiono, E., & Santoso, P. (2021). Utilization of Biogas Technology for Sustainable Development in Livestock Areas. Journal of Energy and Environment, 12(3), 123-135.

Aminah, R., Anugrah, T., & Suryanto, B. (2023). Community Participation in Renewable Energy Development in Rural Areas. Journal of Community Development, 9(1), 1-12.

Anugrah, T. (2023). Community Participation in Renewable Energy Programs: Participatory Approach in Villages. Journal of Social and Energy, 4(1), 23–34.

Arifan, F., Putra, W., & Wijaya, B. (2019). Challenges and Solutions in Implementing Biogas Technology in Remote Areas. Journal of Renewable Energy Technology, 14(3), 122-134.

Ari, I. RD, Waloejo, BS, & Hariyani, s. (2022). Gender Equality and Its Relation to Social Capital in Community Development in Indonesia: A Case Study of Bumiaji District, Batu City, East Java. In Journal of Urban Development (Vol. 10, Issue 1, p. 23). Diponegoro University. https://doi.org/10.14710/jpk.10.1.23-35 .

World Bank. (2018). Renewable Energy for Rural Areas: Strategies and Best Practices. Washington, DC: World Bank.

Barhoun, R., & Ed-daibouni, M. (2023). Trust modelling in distributed collaborative environments: Application to collaborative healthcare systems. In International Journal of Information Security (Vol. 22, Issue 6, pp. 1585). Springer Science+Business Media. https://doi.org/10.1007/s10207-023-00707-w

Berliany, J., & Fatchiya, A. (2020). Community Participation in the Application of Biogas Technology in Rural Areas. Journal of Community Service, 3(4), 205-217.

Bowling Alone. (2023). https://www.citizenshandbook.org/bowling_alone.html .

Bourdieu, P. (1986). Forms of Capital. In J. G. Richardson (Ed.), Collected Theory and Research for the Sociology of Education (pp. 241–258). Greenwood Press.

BP Migas. (2011). Energy Reserves and Development of Alternative Energy Source Projects in Indonesia. Upstream Oil and Gas Regulatory Agency.

Bronfenbrenner, U. (1979). *The Ecology of Human Development: An Experiment by Nature and Design*. Harvard University Press.

Budi, L. (2015). Biogas Utilization Acceleration Strategy in Rural Areas. , 1, 109–112. https://doi.org/10.18502/KEN.V1I1.336.

Christy, ES, Jamila, RF, Putra, GP, & Harsritanto, BI (2019). Accessibility Study of Parks in Residential Areas (Case: Bumirejo Park, Pudak Payung, Semarang). In Module (Vol. 19, Issue 2, p. 104). https://doi.org/10.14710/mdl.19.2.2019.104-109

Cohen, S., & Wills, T. A. (1985). Stress, Social Support, and the Buffering Hypothesis. Psychological Bulletin, 98(2), 310-357.

Cornwall, A. (2008). Development and Political Participation: A Critical Review. Development Studies, 44(2), 1–8.

Dewi, K., Azis, AA, Fitria, R., & Palupi, FH (2023). Health Promotion and Nutrition Counseling to Improve the Welfare of Rural Communities. In Easta Innovative Community Service Journal (Vol. 1, Issue 3, p. 171). https://doi.org/10.58812/ejincs.v1i03.124

Pasaman Regency Agriculture Service. (2022). Report on Renewable Energy Development Activities in Pasaman. Pasaman Regency Agriculture Service.

Durkheim, E. (1893). *The Division of Labor in Society*. Free Press.

Granovetter, MS (1973). The Strength of Weak Ties. American Journal of Sociology, 78(6), 1360-1380.

Hadi, S., Suroso, B., Wijaya, I., & Jalil, A. (2021). Assistance in the Management of Animal Waste into Organic Fertilizer and Biogas in Tetelan Hamlet, Seputih Village, Mayang District, Jember Regency. In JIWAKERTA Scientific Journal of Insights Real Work Lecture (Vol. 2, Issue 2, p. 64). https://doi.org/10.32528/jiwakerta.v2i2.6734

Hastuti, D. (2009). Application of Biogas Systems in Rural Communities. Journal of Environmental Technology, 5(1), 78–85.

Hall, E.T. (1976). Beyond Culture. Anchor Press.

Hendrasarie, N., & RP, E. (2021). TRAINING ON PRODUCING BIOGAS FROM RESTAURANT WASTE AND FECES. In ABDIMAS UNWAHAS (Vol.6, Issue 2). https://doi.org/10.31942/abd.v6i2.5687

Heriyanti, AP (2015). Analysis of Biogas System Maintenance Problems in Rural Areas. Journal of Natural Resource Management, 8(2), 99-112.

_____. (2020). The Role of Government in Supporting the Adoption of Biogas Technology in Rural Areas. Journal of Energy Policy, 9(2), 151-165.

Hidayati, N., Irawan, A., & Prasetyo, D. (2019). Analysis of Biogas Program Failure in Pasaman, West Sumatra: Case Study from Community Participation Perspective. Journal of Natural Resources, 21(1), 101-112.

Hirschi, T. (1969). Causes of Juvenile Delinquency. University of California Press.

Indrajati, S., Emawati, E., & Azkar, Muh. (2023). Actualization of Environmental Jurisprudence Education (Fiqh Al-Bi'ah) in the Forest Area Community of Genggelang Village, Gangga District, North Lombok Regency. In MANAZHIM (Vol. 5, Issue 2, p. 644). STIT Palapa Nusantara. https://doi.org/10.36088/manazhim.v5i2.3323 .

Jan, I. (2021). Socio-economic characteristics influencing farmers' willingness to adopt household biogas technology in rural Pakistan. Environmental Science and Pollution Research, p. 28, 20690–20699.

Joko, H. (2016). Government Support and Failure of Biogas Program in Rural Indonesia. Journal of Rural Development Policy, 13(2), 150–165.

Juliana, I., & Fatchiya, M. (2020). The importance of community involvement in rural biogas programs. Journal of Social and Technology, 9(1), 25-36.

Ministry of Energy and Mineral Resources of the Republic of Indonesia. (2014). Guidelines for the Implementation of Biogas Technology in Indonesian Villages. Jakarta: Ministry of Energy and Mineral Resources of the Republic of Indonesia.

Lie, D., Adnyana, IWB, & Nindhia, TGT (2022). Study of Emissions and Fuel Consumption of 2-Stroke Dual Fuels (Biogas – Methanol) Genset Engines. In the METTEK Journal (Vol. 8, Issue 2, p. 103). Udayana University. https://doi.org/10.24843/mettek.2022.v08.i02.p05

Moestopo, M., & Prasetyo, S. (2010). Technology Adaptation in Rural Communities: A Case Study of Biogas in Indonesia. Journal of Rural Energy Development, 15(2), 102-115.

Mulyadi, R. (2021). Communication Barriers in Agricultural Extension Programs: Lessons Learned from Biogas Adoption. Indonesian Journal of Agricultural Extension, 14(2), 88–100.

Munahar, S., Purnomo, BC, & Widiyanto, A. (2021). Concept of Technology Development for Utilizing Gas Fuel (Biogas) as Milk Cooling Energy. In Proceedings of the National Seminar on Community Service Program. https://doi.org/10.18196/ppm.26.536 .

Osei-Marfo, E., Poku, M., & Mohammed, D. (2020). Socio-Cultural and Economic Factors Influencing Biogas Adoption in Rural Ghana: Implications for Policy and Practice. Energy Policy, 38(5), 250-258.

Cantik, J. (1995). Participatory Learning for Sustainable Agriculture. World Development, 23(8), 1247–1263.

Puji Lestari, N, et al. (2016). Evaluation of Reliability of Household Scale Biogas Reactor in Special Region of Yogyakarta Using Fault Tree Analysis Method. Process Engineering Journal, Volume 10 No.1, 2016, pp. 1-9.

Purwantono, P., Aziz, A., & Adri, J. (2022). Bio Gas during the Covid Pandemic as an Application of Appropriate Technology in Palangki Koto IV Village, Sijunjung Regency. In Suluah Bending Scientific Journal of Community Service (Vol. 22, Issue 1, p. 61). https://doi.org/10.24036/sb.02000 .

Putri, RD, Rahayu, E., & Yuliana, M. (2023). Community involvement in increasing learning interest in rural areas: The broader potential of a community-based approach. Journal of Education and Community Development, 21(4), 112-123.

Ristianingsih, D., Dharmawan, AH, & Putri, EIK (2018). Sustainability Analysis of Rural Tofu Waste Biogas (Case Study in Kalisari Village, Banyumas Regency). In Journal of Environmental Science (Vol.16, Issue 2, p.104). Diponegoro University. https://doi.org/10.14710/jil.16.2.104-112 .

Rahadi, S., Sigit, W., & Fadilah, D. (2018). Social and Cultural Factors in the Development of Biogas Technology in Rural Areas. Alternative Energy Journal, 6(1), 45-53.

Rogers, E.M. (2003). Diffusion of Innovations (5th ed.). Free Press.

Smith, J., & Jones, R. (2015). Rural Energy and Sustainable Development: Biogas as a Renewable Energy Source. Journal of Sustainable Energy, 22(4), 334–348.

Sucipta, Y., Sulaiman, T., & Nurhasanah, S. (2017). Holistic and participatory approach in biogas program: Overcoming technical and social constraints. Journal of Technology Development, 10(2), 57-70.

Sugiono, E., Santoso, p., & Al Batistuta, r. A.(2023). Biogas Technology as a Renewable Energy Solution in the Livestock Sector. Journal of Agricultural Technology, 17(1), 45-60.

Syafina, R., & Ahmad, M. (2022). Improving School Quality During the Pandemic Through Social Capital in Senior High Schools. In EDUCATIONAL JOURNAL OF EDUCATIONAL SCIENCE (Vol. 4, Issue 1, p. 862). Pahlawan Tuanku Tambusai University. https://doi.org/10.31004/edukatif.v4i1.1937

Sumarno, T., & Ariani, R. (2020). The Role of Social Networks in Agricultural Development Programs: The Case of Biogas in Pasaman. Journal of Social Science Research, 22(4), 189-201.

Tempo. (2019). Sustainable Energy and Business: Biogas a Pile of Distribution Obstacles. February 1, 2019 by Ibnu Budiman.

Tiro, A. (2020). Social Support and Its Role in Rural Project Development: A Case Study of Biogas. Journal of Community Development, 17(1), 45–59.

Uhunamure, S., Nethengwe, N., & Tinarwo, D. (2021). Development of a Comprehensive Conceptual Framework for Biogas Technology Implementation in South Africa. Source. https://doi.org/10.3390/RESOURCES10080076.

Wibowo, A., & Sumarno, T. (2021). Community Involvement and Participation in Renewable Energy Programs: The Case of Biogas in West Sumatra. Journal of Renewable Energy and Development, 9(3), 215-227.

Winangun, k., & Putra, w. (2018). Benefits of Biogas Systems in Rural Development. Journal of Rural Development, 7(2), 91-104.

Yasin, A., & Pratiwi, L. (2024). *Collaboration of communities, government, and NGOs in rural biogas programs*. Journal of Energy Policy, 13(1), 33-44.

Yuliana, S. (2019). Barriers to Biogas Implementation in Indonesia: Case Study of Pasaman Regency. Indonesian Journal of Environmental Studies, 8(1), 23–34.