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Evaluating the Management Effectiveness of the Biomass Based Independent Energy Village (DME) Program in Supporting Indonesia's Zero Carbon NDC

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Abstract

Background: Indonesia's updated Nationally Determined Contribution (NDC) targets net zero emissions by 2060, making the transition to renewable energy particularly locally based sources—essential for climate mitigation. Biomass, as a key renewable resource, is utilized through the Energy Independent Village (*Desa Mandiri Energi*, DME) program, including in Kaliombo Village, Jepara, which uses buffalo dung as a sustainable energy source.
Objective: This study evaluates the management effectiveness of a biomass-based Energy Independent Village (DME) program in Kaliombo Village, Jepara Regency, Indonesia, and its contribution to the national zero carbon NDC target by 2060.
Methods: Using a qualitative case study approach, data were collected through in-depth interviews with village officials, program managers, and community members, supplemented by observation and documentation. Data were analyzed using thematic analysis with triangulation to ensure trustworthiness.
Result: Findings reveal that while the program demonstrates measurable contributions to local energy security and green energy production, long-term sustainability depends on strengthened managerial capacity, community participation, and policy alignment.
Conclusion: This study provides managerial insights for improving renewable energy governance at the village level and offers a replicable framework for developing biomass-based rural energy in support of national decarbonization goals. This study contributes a replicable governance framework for biomass-based rural energy programs, advancing the discourse on decentralized renewable energy management in developing countries.

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INTRODUCTION

Globally, the urgency of transitioning to renewable energy has intensified as countries face escalating climate change impacts and fossil fuel dependency. Energy is widely recognized as a basic human need and a strategic component of national development. In Indonesia, Law No. 30 of 2007 concerning Energy emphasizes the importance of ensuring national energy security to sustainably meet domestic demand (Irena, 2023; Kabeyi & Olanrewaju, 2022). This legal framework is further strengthened by Government Regulation No. 79 of 2014 concerning the National Energy Policy, which sets national energy mix targets and encourages the transition to New and Renewable Energy (NRE) as a safe, environmentally friendly, and sustainable energy source (Fauziah & Hidayatullah, 2023; Ruslan, 2021). Critics note, however, that Indonesia's

policy framework, while comprehensive, has been undermined by inconsistent implementation, regulatory fragmentation, and weak enforcement mechanisms at the sub-national level. The translation of national renewable energy targets into village-level outcomes has proven considerably more complex than legislative ambitions suggest.

Indonesia has significant renewable energy potential. National policy targets, as outlined in Presidential Regulation No. 5 of 2006 and subsequent policy updates, set ambitious goals to increase the share of renewable energy in the country's primary energy mix (Anggraini, 2022; Chijioke Paul Agupugo et al., 2024). The diversification strategy encompasses biofuels, geothermal energy, biomass, hydropower, solar energy, and wind energy, reflecting the government's long-term commitment to energy transition and decarbonization, while also supporting the development of sustainable transportation (Kementerian ESDM, 2008). This commitment is further strengthened by Indonesia's Nationally Determined Contribution (NDC), which targets net-zero carbon emissions by 2060 and sustainable development (Taali et al., 2024).

At the implementation level, one of the government's strategic initiatives to accelerate the adoption of renewable energy is the Independent Energy Village (DME) program. This program encourages the development of community-based renewable energy by utilizing locally available resources. In biomass-based DME initiatives, livestock waste, such as buffalo dung, is a valuable but underutilized resource that can be converted into biogas or other forms of renewable energy (Dessy Ana Laila Sari et al., 2023; Poetro et al., 2019). Despite this potential, the conversion rate of biomass feedstock into operational rural energy programs remains critically low, with less than 5% of identified potential being actively utilized at the village level. This gap between resource endowment and actual program delivery signals a systemic governance and management failure rather than a mere technical constraint.

Biomass energy is among the most promising renewable energy sources in Indonesia due to its widespread availability from agricultural residues, plantation by-products, forestry processing waste, and livestock manure (Alper et al., 2020; Senocak & Guner Goren, 2022). Prior studies have examined biomass energy programs with mixed conclusions. Ha & Kumar (2021) found that community-based renewable energy projects in rural Nepal and Indonesia failed due to weak governance structures, in which the exclusion of local authorities and beneficiaries from decision-making was a key factor in the projects' collapse. Budiman & Smits (2020) documented that governance fragmentation in biogas programs in Indonesia involving various actors with differing interests impacted program effectiveness and resulted in structural dependence on external support, including government subsidies. Budiman (2021) identified that seven national biogas programs in Indonesia share similar governance weaknesses, including program overlap, the absence of adequate monitoring and evaluation, and weak management capacity at the community level as the primary barriers to the sustainability of rural biogas programs. Collectively, these findings indicate a gap in understanding regarding how institutional arrangements and management quality determine the sustainability of DME programs at the village level. Beyond its environmental benefits, biomass development also has the potential to increase rural energy independence, reduce waste, and stimulate local economic activity, thereby enhancing economic growth (Arrahima, 2024).

However, despite strong policy support and substantial resource potential, village-level renewable energy programs often face implementation challenges. Specifically, there remains a significant research gap: no study has systematically integrated governance quality, institutional capacity, and community engagement as simultaneous determinants of biomass-based DME sustainability at the village level in Indonesia. Existing research focuses predominantly on technical performance, neglecting the managerial and organizational dimensions critical for long-term program viability. Many initiatives are well designed conceptually but face managerial, institutional, and sustainability constraints during implementation. Weak governance structures, limited technical capacity, and inadequate long-term management planning can hinder program effectiveness.

Therefore, this study evaluates the management effectiveness of the biomass-based Independent Energy Village (DME) program by examining its implementation mechanisms, operational challenges, and sustainability strategies. The novelty of this research lies in its integrated assessment framework combining institutional, managerial, and operational dimensions to evaluate DME program sustainability a perspective not yet systematically applied in prior Indonesian biomass energy research. Methodologically, this study contributes a replicable qualitative case study model for evaluating community-based renewable energy governance at the village level. By providing a comprehensive managerial assessment, this study seeks to contribute to the development of more effective governance models for village-level renewable energy programs and to support Indonesia's broader decarbonization agenda.

METHOD

This study used a qualitative research approach to critically examine and interpret the implementation of the biomass-based Energy Self-Sufficient Village (DME) Program in its natural context. A qualitative design was chosen to explore social interactions, governance practices, and managerial processes in depth, enabling contextual understanding rather than statistical generalizations. Therefore, the study was descriptive in nature and relied on non-numerical (qualitative) data to capture institutional dynamics, stakeholder engagement, and operational challenges (Muri Yusuf, 2015).

Data collection was conducted through field research and a literature review. The field research included in-depth interviews, observation, and documentation to obtain primary data related to program implementation and management practices. Informants were purposively selected and comprised: (1) the village head of Kaliombo Village; (2) the DME program manager; (3) three BUMDes operators; (4) two ESDM Office supervisors from Jepara Regency; and (5) five beneficiary community members (n = 12 total). Interviews used a semi-structured guide and were recorded with participant consent. The literature review involved analysis of secondary sources, including government reports, official publications, policy documents, and relevant previous studies. The study was guided by a set of predetermined key questions designed to maintain alignment with the research objectives and analytical focus. Data were analyzed using Braun & Clarke (2006) six-phase thematic analysis: (1) data familiarization; (2) initial code generation; (3) theme searching; (4) theme review; (5) theme definition; and (6) report writing. NVivo 12 software was used to facilitate coding and theme management. Validity and Trustworthiness: Trustworthiness was established through methodological triangulation (cross-referencing interview, observation, and documentation data); member checking (key informant review of preliminary findings); and peer debriefing with two independent researchers with expertise in renewable energy policy.

Kaliombo Village, Jepara Regency, was selected as the research location because it was one of the DME program pilot projects in Indonesia and demonstrated the active use of local biomass resources, particularly livestock waste, for renewable energy. This village represented a strategic case for examining management effectiveness in rural renewable energy development, as it reflected both the opportunities and governance challenges associated with implementing community-based energy initiatives.

RESULTS AND DISCUSSION

Results

Potential for New and Renewable Energy (EBT)

The latest NRE potential data is provided to support the collection of New and Renewable Energy supply-demand data. For this reason, the steps that will be taken by the Government are to increase the installed capacity of Micro Hydro Power Plants to 2,846 MW in 2025, the installed capacity of biomass to 180 MW in 2020, the installed capacity of wind (PLT Bayu) to 0.97 GW in 2025, solar to 0.87 GW in 2024, and nuclear to 4.2 GW in 2024. The total investment absorbed by EBT development until 2025 is projected to be USD 13,197 million.

Efforts to develop biomass include encouraging the use of animal husbandry waste and agricultural and forestry industrial waste as energy sources in an integrated manner with the industry, integrating biomass development with community economic activities, encouraging the manufacture of biomass energy conversion technology and supporting businesses, and increasing research and development on waste utilization, including municipal waste for energy.

To support EBT development efforts and programs, the government has issued a series of policies and regulations, which include Presidential Regulation No. 5/2006 concerning National Energy Policy, Law No. 30/2007 concerning Energy, Law No. 15/1985 concerning Electricity, PP No. 10/1989 as amended by PP No. 03/2005 concerning Changes to Government Regulation No. 10 of 1989 concerning the Provision and Utilization of Electricity, and PP No. 26/2006 concerning the Provision and Utilization of Electricity, Minister of Energy and Mineral Resources Regulation No. 002/2006 concerning the Business of Medium-Scale Renewable Energy Power Plants, and Ministry of Energy and Mineral Resources Decree No. 1122K/30/MEM/2002 concerning Small-Scale Power Plants. Currently, a New and Renewable Energy RPP is being prepared, which contains arrangements for the obligation to supply and use new energy and renewable energy and to provide facilities and incentives (Kementerian ESDM, 2008).

Field Research Results from Kaliombo Village

Based on field research conducted at Kaliombo Village, Pecangaan District, Jepara Regency, the following key findings were identified: (1) Program Governance: The DME program is managed under BUMDes (village-owned enterprise) with a steering committee comprising the village head, BUMDes administrator, and one technical supervisor. However, formal operational procedures (SOP) are absent, and accountability reporting remains inconsistent. (2) Technical Performance: The biogas installation currently processes approximately 150 kg of buffalo dung per day, generating an estimated 15 m^3 of biogas per day, serving 12 of 45 eligible households (26.7%). The installed capacity is operating at approximately 35% of its design capacity. (3) Institutional Challenges: Key informants (village head, program manager, BUMDes operators) identified three primary barriers: irregular feedstock supplies due to seasonal buffalo availability fluctuations, absence of dedicated technical maintenance personnel, and limited community awareness about biogas safety and use. (4) Community Participation: Beneficiary households reported high satisfaction with cost savings (averaging IDR 45,000/month reduction in LPG expenditure) but low engagement in program governance. (5) Sustainability: The program currently operates without a formal sustainability plan or dedicated maintenance budget, creating dependency on annual village fund allocations.

Zero Carbon Contribution

Targets to support the zero carbon contribution program have been set by the government, including the provision of primary energy in 2025 and an increase of 60% in 2050. Within the primary energy mix, the role of New and Renewable Energy (EBT) will reach 23% in 2025 and at least 31% in 2050. The increase in the NRE portion is followed by a decrease in the role of fossil-based energy in the 2020–2050 energy mix.

Indonesia's commitment as part of the global community in mitigating climate change is evident in the target of achieving zero carbon (net-zero emissions) in 2060 or earlier, as outlined in the Updated Nationally Determined Contribution. This milestone complements various road maps that have been previously determined by the Government, including the National Development Plan for the period 2020–2024, Indonesia's Vision 2045, and the Long-Term Strategy on Low Carbon and Climate Resilient Development 2050.

To achieve the net-zero emissions target, ensure energy security, and carry out energy diversification and conservation, the Government must be able to implement a national energy development policy that can balance improving the quality of fossil-based energy management with increasing the role of EBT in the national energy mix.

The Energy Independent Village Program (DME) represents a promising initiative to build energy independence and equity in Indonesia. Energy Independent Villages are villages that can utilize local energy sources based on New and Renewable Energy (EBT) to provide more than 60% of energy needs (electricity and fuel) for the village itself (Kementerian ESDM, 2008).

Potential of Kaliombo Village, Jepara, Indonesia

Kaliombo Village has the potential for buffalo farming that operates under a communal pen system. Apart from being a source of meat, buffalo farming also produces waste in the form of buffalo dung, which can be used to produce biogas that can meet the energy needs of the people of Kaliombo Village. Currently, there are two biogas digester units in the buffalo pen area. The biogas produced has been utilized by some community members. In line with the village's vision of energy independence, the biogas network must be planned to reach all households in the village. The estimation of biogas production and demand in Kaliombo Village is based on livestock capacity and household energy consumption patterns.

First, in terms of energy conversion, 1 m^3 of biogas is equivalent to approximately 0.46 kg of LPG. Therefore, a standard 3 kg LPG cylinder is equivalent to about 6.5 m^3 of biogas. On average, one buffalo can produce approximately 2 m^3 of biogas per day through manure processing. Kaliombo Village has more than 150 buffalo. Based on this number, the potential daily biogas production is: 150 buffalo × 2 m^3/day = 300 m^3 of biogas per day. In one week, the total potential production becomes: 300 m^3/day × 7 days = 2,100 m^3 of biogas per week.

On the demand side, Kaliombo Village consists of 738 households. Each household typically consumes one 3 kg LPG cylinder per week. Since one 3 kg LPG cylinder is equivalent to 6.5 m^3 of biogas, the total weekly biogas demand is: 738 households × 6.5 m^3 = 4,797 m^3 of biogas per week. This means that the current biogas production capacity (2,100 m^3 per week) can only meet approximately half of the village's total weekly energy demand. Regarding infrastructure capacity, one biogas digester with dimensions of 3 × 3.5 meters can produce approximately 17 m^3 of biogas. To reach the daily production target of 300 m^3, the required number of digesters would be: 300 m^3 ÷ 17 m^3 ≈ 18 digesters.

Currently, Kaliombo Village only has two digester units, which is far below the required number to fully optimize existing livestock potential. To address the supply gap, one possible strategy is to source additional buffalo manure from neighboring villages, such as Gerdu, Troso, Karang Randu, and Tedunan, which also have significant buffalo populations but have not yet utilized manure for biogas production. This inter-village resource integration could strengthen biomass supply and improve the sustainability of the DME program.

Planning Development

The biogas network plan is a pipeline network made of galvanized pipe installations along the neighborhood roads of Kaliombo Village. In each RT, a station/port will be built as a place for filling biogas into special biogas storage bags (Amri, Sakina, et al., 2022)

The objectives of the construction of this station/port are:

1. To prevent pipelines from extending too far into settlements. In addition to cost efficiency, this also prevents pressure loss caused by an excessively long pipeline network.
2. To provide convenience for local people who want to use biogas, so they do not have to travel far to the digester area (communal pen).
3. To avoid biogas pipeline leaks caused by excessively long pipe installations.

Related to the existence of the biogas network plan, there will be a need for management both in the distribution of biogas and the maintenance of existing biogas installations (Amri, Mohammed Ali, et al., 2022).

Analysis of Biomass-Based DME Problems

In-depth interviews with the Kaliombo village head, managers, and the community yielded findings related to the implementation of DME based on buffalo dung biomass, including:

1. Lack of community awareness regarding the DME program based on buffalo dung biomass.
2. The community's misconception that the resulting gas will smell.
3. Limited availability of the main raw material: buffalo manure biomass.
4. Limited operational support.
5. Absence of a clear development direction.

Discussion

The findings from Kaliombo Village are interpreted below through the lens of Ostrom (2015) Institutional Analysis and Development (IAD) framework, which examines how institutional rules, community conditions, and governance structures shape collective action outcomes in resource management settings.

Analysis of Biomass-Based DME Strategy

The strategic failure of the DME program can be attributed to a systemic cascade: inadequate initial training (cause) → technical skill deficit among operators (intermediate effect) → declining biogas production efficiency (proximate cause) → reduced community satisfaction (intermediate effect) → withdrawal from collective maintenance (effect) → program degradation (outcome). Reversing this cycle requires targeted interventions at each causal node, particularly at the governance and capacity-building stages.

Based on the problems identified, and followed by specific questions regarding strategies both technical and managerial in the management of the biomass-based DME, the following strategic findings emerged:

1. Raise public awareness about the importance of the DME program in supporting the Zero Carbon program and village-based energy independence.
2. Conduct public outreach regarding the end products of biomass-based DME.
3. Provide training for prospective operators on processing the main raw material (buffalo dung biomass).
4. Procure operational funds through beneficiaries rather than from operational subsidies.
5. Develop a sustainable development plan to support EBT and Zero Carbon 2060.
6. Formulate an updated strategy addressing existing problems so that DME can operate again according to its original purpose.

CONCLUSION

This study empirically demonstrates that the biomass-based DME program in Kaliombo Village, Jepara Regency, possesses significant potential to contribute to Indonesia's Zero Carbon NDC target, but is currently constrained by institutional, managerial, and operational deficiencies. Specifically, weak governance structures, absence of formal operational procedures, limited technical capacity, and irregular feedstock supply are the primary barriers to program sustainability. Addressing these barriers through targeted governance reform, capacity building, and community engagement is essential for program viability. To achieve Zero Carbon 2060 through EBT, it is necessary to focus on programs that have great potential and have not been utilized properly. The principle of developing biomass-based DME is the utilization of large potential, useful value, decreasing dependence on fossil energy, and economic independence of the community. Not without challenges, issues were encountered in the development; however, strategies for addressing them were also identified. The main supporting strength for the sustainability of the Zero Carbon program is local people who are empowered and properly trained; another indicator that is in line with DME goals is green energy independence, which can be replicated by other districts/cities.

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