Barriers of Small-Scale Biogas Plants in Indonesia

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By 2025, biogas is estimated to become a larger part of Indonesia's energy mix. Biogas is a renewable energy source that also has economic and environmental advantages. Domestic biogas generation has been embraced in Indonesia as a response to the country's energy security concerns in rural areas. Since the 1970s, 48,038 biogas plants have been built in the region. To fully develop this technology, Indonesia must discontinue relying on fossil fuels and substitute current fossil-fuel-based energy.

Keywords: small-scale biogas ; biogas adoption ; developing countries ; adoption barriers

1. Introduction

Notwithstanding the major progress in reducing Indonesia's reliance on fossil fuels, renewable energy still falls short of coal and other fossil fuels. As the country's population grows, so does the country's demand for energy. Amidst substantial efforts to reduce fossil fuel use, CO_2 emissions per person in Indonesia reached 2.03 tons in 2016, an increase of 10% from the previous year (over 1.93 tons in 2015). Climate change is a major contributor to massive emissions because of Indonesia's reliance on fossil fuels. According to Indonesia's energy mix, oil, gas, and coal account for 80% of total energy, hydropower accounts for 18%, and geothermal accounts for 2% [1]. Compared to China and India, Indonesia has had difficulty disseminating renewable energy technology [2]. As a result, hydroelectric and geothermal power plants generate a greater proportion of the electricity generated because other plants are underutilized. By 2025, Indonesia has only accomplished 9.5% of its 23% renewable energy target. Indonesia has been transitioning to a sustainable energy source since discovering biogas technology in the 1970s and implementing numerous biogas initiatives. Since then, Indonesia has constructed 48,038 biogas systems that produce 75,044.2 m^3/day or around 26.72 million m^3/year of biogas. There are now 96.21 MW of commercial biogas available [3]. In Indonesia, small-scale biogas systems with fixed domes are most suited to the conditions due to the livestock waste availability from cattle and poultry [4]. Biogas, which contains methane, is produced when organic materials are not exposed to oxygen (anaerobic process). The cost of installing a system is relatively affordable for farmers [5]. However, when compared to China and Nepal, Indonesia's adoption rate is still insufficient [6]. Farmers' decisions to use biogas have been explored in several studies to understand what influences their decision [6]. Several stimulating measures have been employed in various countries. For example, in 2017, the Chinese Government offered more than 630 thousand (in USD) in biogas subsidies in rural areas (Sun, 2014). In Bangladesh [7], biogas users have increased because of public and commercial incentives, and as a result, household income and education levels have increased. Few studies have revealed constraints on biogas adoption in developing countries. Kamp and Forn [8] investigated the environmental impact of fuel prices in Ethiopia and found that the lower the fuel price, the greater the adoption of biogas. In Ethiopia and Uganda, researchers discovered that physical facilities such as decent roads and electricity access significantly impact the decision to use small-scale biogas technology [9][10].

2. Technical Barriers

Small-scale biogas facilities can cause technical challenges that are hazardous to the environment and the user. As a result, identifying the problems is critical to their resolution. A study recognised limited access to biogas and waste storage as a technical issue [11][12]. Several success stories using cattle dung as feedstock in biogas plants indicate a certain level of technological maturity at the household scale [4][12][13].

Table 1. Technical barriers for biogas adoption.

No.	Technical Barriers Description	References
1	**Lack of standard quality and control measures**	[11][12][14][15]
2	**Inadequate design and construction**	[1][12][16][17]
3	**Technical knowledge and training are lacking**	[11][18][19][20][21][22]
4	**Insufficient feedstock**	[11][19][21][22][23]
5	**Local research is lacking for tailor-made technology and context**	[11][16][24][25]
6	**Lack of biogas technical knowledge for daily maintenance**	[16][23][26][27][28]

Study of Bhat [20] discovered the lack of storage tanks and pipelines in communal digesters may result in insufficient biogas production, also inadequate design for biogas construction [17] and insufficient feedstock [21]. Studies carried out by Bößner and Silaen et al [22][29] found that biogas output may be insufficient if cow and poultry manure are not always available. Each home requires eight heads of cattle, according to Khan et al. [24], to produce enough energy for cooking and power. Without enough technical support, expanding the number of biogas adoptions is challenging. It is vital to consider the perspectives of biogas users. Due to a lack of expertise in creating and maintaining the process, biogas adoption would be difficult [26][27]. As a result, if insufficient expertise is applied, biogas might have negative implications.

Aside from that, Mwringi and Tumutegreieze et al [6][28] defined the failure criteria for five technical subsystems, including structural components (e.g., inlet and exit issues) and pipe systems (e.g., problems with the inlet and outlet) as well as insufficient digester feedstock, unreliable feedstock supply, anaerobic digestion, and biogas production (such as leakages in a reactor, poor quality biogas and its smell, and breakdown of anaerobic digestion) [23][25][27][28][30].

3. Financial and Economic Barriers

Biogas is a particularly promising as renewable energy in Indonesia. However, there are too many barriers on its implementation, including high investment costs, comparatively poor technological efficiency, location, and social considerations of the community as energy users, that have prevented this from being fully utilized. The government has encouraged the use of renewable energy to improve family earnings, education, and the vocations of the household head, all of which are indications of socio-economic constraints, according to MEMR Regulation No. 12 of 2017 and MEMR Regulation No. 12 of 2015. These major socio-economic aspects, as well as the availability of supplies such as animal feed and water, may impact a family's decision to use biogas [28][31][32].

Table 2. Financial barriers for biogas adoption in Indonesia.

No.	Financial Barriers Description	References
1	**High initial investment cost**	[29][33]
2	**Lack of financial mechanism**	[23][34][35]
3	**Inadequate subsidies, financial assistance and incentives**	[5][29][36][37]
4	**High transaction cost**	[5][33][36]
5	**Long payback period**	[5][23][29]
6	**The poor purchasing power of households**	[5][16][25][33]

Financial challenges are frequently mentioned in the literature regarding initial investment. *The National Energy Policy (Kebijakan Energi Nasional/KEN)* aims for 489.8 million cubic meters of biogas by 2025. According to the MEMR, 25.266 million cubic meters of biogas were in use in 2018 [38][39]. Given the low level of performance compared to the 2025 target, policy advocacy in both the central and municipal governments is urgent, with a particular focus on how household biogas competes with LPG in the energy mix [40]. The studies regarding economic barriers also support this investment constraint.

According to Chen et al. [41], construction, treatment, and transportation expenses are all substantial in biogas facilities, especially when delivering feedstock over long distances. [41][42]. Furthermore, subsidies, financial assistance programs, and soft loans are significant economic impediments [33][42]. Research and financing support in developing countries is considered a significant impediment to technological innovation. More finance assistance should be put towards research and development [42]. *State Electric Company* (*PLN*) states that only installations with capacities below 10 MW can be used, as stated in Regulation No. 4 of 2012 issued by the Ministry of Energy and Mineral Resources, which can pose a barrier to the growth of Biogas production.

This is supported by the Ministry of Energy and Mineral Resources Regulation No. 19 of 2013, with prices ranging from Rp. 970–1798/kWh for low-voltage grids (average tariffs considered) and Rp. 880–1450/kWh for mid-voltage grids (average tariffs considered). For Indonesia to achieve a total energy mix by 2025, biogas technology would replace fossil fuel by targeting farmers and other industries with advanced technology such as bio natural gas, a variety of feedstock, and the cattle industry. This is also supported by the fact that biogas is more expensive than natural gas, which concerns the end consumer, as it causes them to pay more than usual [42]. On the contrary, another study stated that the price of biogas must be more attractive compared to other fuels to reach a wider customer base [43]. However, competition between biogas with other renewable energy such as bioethanol could further prevent biogas adoption in the long run, for instance, biogas usage as a source of energy for vehicles [44]. Furthermore, the biogas market in Indonesia could reach 1 million units of digesters coming from 15.6 million cattle, which would account for 2 million unit of biogas compared to the 4898 million unit of biogas mandated by the National Energy Masterplan (*Rencana Umum Energi Nasional*/RUEN) by 2025 as part of the 23% renewable energy target [34][44]. Conversely, energy sources in rural areas, such as traditional solid biomass, are also preferable and cheaper [24][36][45]. Despite the constraints, other studies found that biogas technology reduces the use of natural gas to an amount of 5.6 kg/month [34][45][46].

4. Social and Cultural Barriers

Table 3. Biogas development in Indonesia faces social and cultural obstacles.

No.	Socio Cultural Barriers Description	References
1	Adverse perception of technology	[37][40][45]
2	Insufficient access to knowledge and skills regarding Biogas technology	[5][23][47][48]
3	Women and children's participation in decision making still low	[5][36][49]
4	Cultural and religious belief with stigmatization	[23][50]
5	Users' literacy and education are still low in using biogas	[23][34][36]

Numerous studies have revealed that Indonesian perspective differ greatly depending on location in the archipelago due to the diverse cultures and traditions. As a result, adoption of biogas varies greatly from region to region. This is also because of the lack of government support to promote biogas technology [33][51]. Another study found that a centralized system can hinder the investment of private sectors [8].

Both socio-economic and socio-technical constraints found a desire in biogas producers for clear policies and industry support [43]. Furthermore, a lack of knowledge about the evolution of energy policy might be a substantial impediment to biogas plant investment [40]. Biogas dissemination has been proven to be hindered by a lack of cooperation between the public and private sectors [36][49][50].

5. Environmental Barriers

Table 4. Indonesian biogas development: environmental barriers.

No.	Environmental Barriers Description	References
1	Noise and odour pollution	[29][48][52]
2	High volume of water requirement	[28][52][53][54][55]
3	Inadequate water access	[5][16][35][54][56]
4	Pollution (air, water and land)	[29][36][55][57]

Environmental impacts reported by some studies include odours in the air [36][46][52], noise pollution [54], and water resources for biogas. Inadequately sealed digester caps and escaping gas can cause serious environmental issues, such as gas escape into the atmosphere and increasing greenhouse gas emissions. [42][46][55]. Biogas leakage is one of the reasons that contributes to global warming and pollution in the atmosphere. The second challenge is related to socio-technical constraints. Two central challenges are technology transfer and technology style. For technology transfer, new context is the focus. New context, for instance different regions or sectors, may contain different social or technological features to which the system must adapt. Additionally, earlier research on the socio-technical analysis has evolving the energy systems that laid the groundwork for the large technical systems [39][53][57][58]. This theory proposed concepts in the system development process. For the adaptation of technology style, one must consider that each social and technology context has different features [57]. Even if financial and regulatory disparities may be the primary reasons for diverse technical methods, culture plays a vital part in understanding them [58].

Although government support is crucial in increasing the diffusions of biogas technology in developing countries such as Indonesia, this reliance can create dependency and a low sense of belonging and maintenance of the technology [59][60]. One approach developed by the *Biogas Rumah* (*BIRU*) program is the scheme where farmers can access credit with various interest rates to pay for small-scale biogas in cooperation with private sectors [44][60].

With this program, cow owners can build their small-scale biogas and receive price deductions by selling their milk products to the cooperatives [61]. A cost and benefit analysis of the biogas program is essential, especially for households to understand the impact of biogas installations before adopting the technology. Furthermore, analysis of their ability to pay and their willingness to pay will give people information about the farmers' abilities in the biogas program, particularly when they should provide their budget for installation. Farmers who participate in financing installations not only provide revenue to stakeholders by installing the digesters but should also view biodigester technology as an investment in their future. This is consistent with the findings of other studies in which co-financed biogas was used rather than purely donor-based asset provision models, which have failed in many contexts [25][39][60].

6. An Indonesian Biogas Adoption Recommendations

Based on the findings, several policy recommendations for overcoming these impediments are presented. Most low- and middle-income households in rural areas have a greater need for clean and affordable energy. The upfront cost of biogas plant installation is a significant impediment to the adoption of rural biogas plants among these households. To enable the adoption of biogas technology for the development of an efficient energy source in target areas, local governments and non-governmental organizations should consider the following recommendations.

6.1. Policy Recommendation

Policy lessons from industrialized nations such as Germany and Sweden should be learned to accelerate the spread of biogas technologies in rural and urban areas. In Germany, for example, the government's prohibition on dumping municipal solid waste in landfills has changed the waste management landscape and increased demand for biogas plants to handle organic waste [61]. Regulatory barriers do not hamper the spread of decentralized biogas in rural areas. These findings indicate that contextual variables should be considered when developing effective technology diffusion strategies. It is critical to develop guidelines allowing Indonesia to produce biogas for electricity generation. Indonesia needs to develop a roadmap with cutting-edge policies at all levels to attract more investment and aid in regenerating renewable energy (municipal, regional, provincial, and central). Renewable energy subsidies include feed-in tariffs, renewable energy subsidies, and virtual power plants.

6.2. Transfer Knowledge and Capacity Building

Providing technical assistance and ongoing training on biogas process design, construction, and operation is critical to increasing biogas deployment in Indonesia. Biogas experts can also educate and train people at existing facilities. It is critical to monitor biogas output to analyse and improve it. As a result, consumers should be taught how to manage daily waste efficiently and about the benefits of biogas produced from these waste parts. Communities, schools, and markets require ongoing consultation and training on how to run their digesters efficiently as well as how to minimize the amount of trash produced, reuse for longer periods, recycle, and recover energy from waste. Co-digestion and dry anaerobic digestion may be viable solutions in areas with cattle dung and water shortages. As a result, for biogas plants to function properly, the technology type and scale should be tailored to the local conditions. There should be an awareness for techniques and applications for enhancing biogas production, such as pre-digestion with microbial additions and mechanical pre-treatment [12][36][57][61].

6.3. Subsidies and Government Assistance

Both systems have financial barriers, such as a high upfront cost and limited loan availability. Because there are no regulatory requirements for injecting biogas into the natural gas grid, using existing natural gas infrastructure for biogas is difficult. Support from the government, cooperative organizations, and industry should all be encouraged. Public–private partnerships are common examples in which governments at various levels collaborate with businesses to support large-scale applications, thereby increasing biogas technology in Indonesia. An incentive program should be implemented to encourage full compliance with government policies on effective waste management. Biogas initiatives should be appropriately promoted through media coverage, posters, brochures, and other marketing tools. Local personnel must be trained, and post-installation maintenance and repair are required for long-term benefits from biogas deployment.

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