Sustainability Challenges of The Landfill Gas Power Plants in Indonesia

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Abstract. As part of urbanization, waste causes a significant challenge in Indonesia. As part of the solution to this challenge is applying the landfill gas (LFG) powerplant. Various efforts are being conducted to implement the LFG powerplant in Indonesia. The literature review was conducted to focusing on the performance sustainability of the LFG powerplant. The explaining power capacity, expected energy supply, actual energy supply, problems, and their cause and impact data are presented. All LFG power plants show technical problems, such as leakage gas pipe, defected gas capture, absence of gas storage and purification equipment, and limited monitoring system. Financial and social challenges exacerbate the technical issues that risk the system’s sustainability, such as unclear funding mechanism, lack of capacity from stakeholders, and conflict with the local community. All of the issues hindered achieving performance targets in the powerplant development, operation, and maintenance phase.

1. Introduction

In developing countries, the management of municipal solid waste (MSW) that is sustainable has become one of the city authorities’ primary challenges [1–3]. As part of urbanization, waste causes a significant increasing challenge in Indonesia. Based on the Ministry of Environment and Forestry (MEF) [4], increasing pressure on final landfills is among the manifestations of the problem. The region/city in Indonesia produces 34,018,221 ton/year. The ministry disclosed that 61.88% of the total waste was already managed. Increasing pressure on the final landfill is among the manifestations of the problem. In waste management strategies, the landfilling issue is dominating globally, as open dumps are still being chosen for the final place to throw 33% of MSW and 37% of MSW is disposed of in landfills [5]. Large volume daily waste influx to be dumped in poorly managed landfills can be found in growing
Indonesian cities [6,7]. Table 1 shows the three cities in Indonesia that produce the highest municipal waste [8].

| City          | 2018  | 2019  | Increasing waste capacity |
|--------------|-------|-------|----------------------------|
| DKI Jakarta  | 21.856| 23.466| 7%                         |
| Surabaya     | 6.243 | 6.294 | 1%                         |
| Semarang     | 4.999 | 5.081 | 2%                         |

One of the solutions to enhance sustainability is integrating landfill gas (LFG) power plants with the waste management system. The integration emits less GHG [9, 10, 11] and reduces the health risks of an open dumping system [12]. LFG from MSW could be utilized as an energy source due to its methane content [13]. It also creates several added values to the waste management system [14], such as reducing dependency on fossil fuel, generating more economic profit [9, 11], and implementing a circular economy [15]. The LFG power plant has been implemented in many places in the world [15, 16]. However, to perform a continuous operation in supplying energy based on this technology in Indonesia is still a difficult task to be fulfilled. Several problems occurred in power plants [7], with many of them at a severe level. These problems lead to a decrease in power plant performance and, in some cases, the end of the operation.

Several studies have been conducted to investigate challenges in utilizing LFG for power generation. [17] calculated potential methane and power generation from MSW in Indonesia’s major cities, such as Medan, Jakarta, Semarang, Yogyakarta, Denpasar, Pontianak, and Makassar. [18] found barriers in implementing LFG power plants in developing countries, such as economic and financial support challenges, regulatory barriers, and limited awareness from community and government institutions. [18] also presented briefly on Indonesia’s Palembang LFG power plant as one of the study cases. However, the explanation disclosed only on technical practice in the Palembang Plant. Therefore, this paper aims to fill the gap by identifying challenges in the implementation of LFG power plants that risk the sustainability of the plant itself. A comprehensive strategy and program could be implemented in the field to provide a solution for various engineering and non-engineering problems. Knowledge of various problems in the LFG power plant and the relevant issues will support an effort to fulfill the demand for a comprehensive solution.

2. Method

This paper provides a literature review to explore sustainability issues of LFG power plants in Indonesia. The review presents data explaining power capacity, expected energy supply, actual energy supply, problems, and their cause, as well as impact. Those will be a basis to present a picture of a lesson learned related to the sustainability of power plant performance. The lesson learned is vital as feedback is needed for the development of the LFG power plant. The workflow of this paper is shown in Figure 1.

Data related to LFG power plants in Indonesia used in this work were gathered from journal articles, proceedings, ministries/government reports, news, and other references. Literature is restricted to references in the last ten years. The discussion section will also include the LFG plant using energy for a non-electricity generation. However, there are not many references found in this phase of writing.
3. Results and Discussion
Some documents show a gap between expected and actual capacity/energy production. Many power plants show lower capacity/energy production or not recorded energy production, as presented in Table 2. For example, Jatibarang LFG’s expected capacity is 983.7 kWe. Nevertheless, actual energy production was only 200 kW (20%). In other locations, such as Supiturang, Manggar, and Banyuroto, actual energy production is unrecorded in energy units but the number of customers. This indicates a lack of infrastructure to monitor the performance of the LFG system. The monitoring system is crucial in sustainability since it would tell technicians if system performance falls short, and then the technician can conduct quick troubleshooting when necessary. In Bantar Gebang LFG, unrepaird broken infrastructure led to reducing the amount of energy production. This made the electricity sales agreement with the National Electricity Company (Perusahaan Listrik Negara/PT PLN) not optimum [6]. The simple stove they used for cooking for each house and region is incomparable. So, assuming energy used per stove is a wrong calculation. Furthermore, energy using for non-electricity generation presents an initial indication of a gap between expected and actual energy production.

| LFG Powerplant  | Site Location         | Year In Operation | Expected Capacity/Energy | Actual Energy Production                  |
|-----------------|-----------------------|-------------------|--------------------------|-------------------------------------------|
| Bantar Gebang   | Bekasi – West Java    | N/A               | N/A                      | 2016 – 2017: 23,112 – 333,272 kWh/month   |
| Benowo          | Surabaya – East Java  | 2001              | 2 MW                     | N/A                                      |
| Supiturang      | Malang – East Java    | 2021              | 0.0656 MWe               | Recently 100 households are listed as the user of the energy for cooking |
| Manggar [19]    | Balikpapan            | 2019              | N/A                      | Recently 165 households are listed as the user of the energy for cooking |
| Jatibarang [19] | Semarang – Central Java | 2019 [3]          | 0.9837 MWe               | 200 kW [3]                               |
| Banyuroto [19]  | Kulon Progo – Yogyakarta special province | 2019          | 0.0031 MWe               | Recently 14 households are listed as the user of the energy for cooking |
Half of the LFG plants analyzed in Table 2 are using the gas directly for cooking. Direct use for cooking is viable due to the low cost and practicality. However, direct usage of LFG still requires purification installation before the customers utilize the gas. This could protect customers’ equipment from corrosion and any defect caused by impurities. This concern became one of the sustainability issues in Benowo and Talang Agung LFG [6].

Further review shows a more detailed picture presenting various problems faced by the LFG power plants in Indonesia. The compilation is presented in Table 3. Besides the aforementioned technical issues, financial problems appeared in seven LFG power plants, i.e., Bantar Gebang, Bagendung, Suwung, Batulayang, Suburban, Tamangappa, and Puuwatu LFG. According to [20], landfill management costs around US$ 2.5–16.1/capita-year, yet, the landfill management entity is only able to collect 4-19% of the total cost. The LFG funding through Public-Private Partnership (PPP) also faces a financial challenge as the investment is still considered high risk and low return [21]. Thus, investment for LFG power plants usually depends on government financial support or international schemes, such as Clean Development Mechanism (CDM). That being said, LFG in Suwung, Batulayang, Suburban, Tamangappa, and Puuwatu were discontinued due to an unclear scheme proposed by the National Commission for the CDM funding [22].

Table 3. A problem in Development, Operation, and Maintenance of Landfill Gas Powerplant in Indonesia.

| LFG Powerplant | Problem/Disturbance | Cause | Impact |
|----------------|---------------------|-------|--------|
| Bantar Gebang [6] | Part of landfill gas well pipes are defect | Lack of maintenance, improper installation | Defect in gas capture components |
| | Delay in budget allocation for operation and maintenance | Administration problem in taking over the process | N/A |
| | Lower gas production than expected and broken equipment | N/A | Electricity sales did not perform optimally |
| Benowo [6] | There is no expansion on the gas capture area | N/A | Risk of gas production decrease |
| | There are no gas storage and purificator | N/A | Defect risk on components using gas |
| Talang Agung [6] | There is no expansion on the gas capture area | N/A | Risk of gas production decrease |
| | There are no gas storage and purificator | N/A | Defect risk on components using gas |
| Bagendung [6] | A severe defect on many pipes | High investment cost without proper financial scheme | |
| | Abandoned facilities | No adequate capacity of local stakeholders | Not in operation anymore |
| | | No support from the local community | |
Lack of technical installation causing a gas leak

There is no maintenance

| Location       | Problem                                                                 | Outcome                                      |
|----------------|--------------------------------------------------------------------------|----------------------------------------------|
| Batulayang [19]| The unclear schemes proposed by National Commission for Clean Development Mechanism (CDM) | Project is discontinued                      |
| Suburban [19]  | N/A                                                                      |                                              |
| Tamangappa [19]| N/A                                                                      |                                              |
| Puuwatu [19]   | N/A                                                                      |                                              |

In Bantar Gebang, a transition from a private entity to Integrated Waste Management Unit (Unit Pengelola Sampah Terpadu/UPST) left a vacuum period of management. During the vacuum period, there was a delay in budget allocation for operation and maintenance, which further led to defect in gas capture components [6]. LFG plant in Bagendung also faced financial difficulties as the system has high investment costs and low gas production. This financial condition got worse as there was no incentive and an unclear funding mechanism from the government [6]. Additionally, social issues such as lack of capacity from local stakeholders and lack of support from the local community added to financial and administrative issues in Bagendung LFG. In the end, Bagendung LFG is not in operation anymore. Despite the project being discontinued, the LFG project in Puuwatu developed the community's social capital during its operation [23]. There is active participation from the local community in maintaining the system. System operation had been strengthening social capitals, such as networking and trust among community members. However, stakeholders' community building and development are still limited, i.e., technical and management training.

This finding seems to be in line with what happened in several places, especially in developing countries, which stated that technical maintenance problems and the ability of the community to manage had hampered the sustainability of landfill gas power plants [16]. Even if the powerplant is operational, poor manageability can lead to low revenue and thus stop the plant operation [24]. The operation of a landfill gas powerplant depends not only on the strength of the technology but must be supported by many aspects described above. In the end, sustainability must be considered thoroughly, primarily by increasing the powerplant facility's management capacity. Otherwise, those aspects still hinder the sustainability of some power plants. Therefore, the environmental burden reduction cannot be achieved.

4. Conclusion

Various efforts are being conducted to implement the LFG power plant in Indonesia. This study aims to explore challenges faced in implementing LFG power plants that risk the system's sustainability. The target to reducing environmental burdens by having LFG was not met because the sustainability of the power plant could not be achieved. A review of kinds of the literature identified that sustainability issues on LFG in Indonesia are driven by technical, financial, and social issues. Future studies are needed to explore improvement and efforts by stakeholders to address this sustainability challenge.

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