Technical and social assessment of biogas in Yogyakarta and Gorontalo, Indonesia

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Abstract. As an agriculture country, Indonesia tries to diversify its energy sources to biogas, especially to reduce fossil energy in household sector. However, biogas plants in Indonesia are barely evaluated after the installation. Therefore, this study was conducted to fill this gap. This study investigated technical and social conditions of biogas implementation in Plosokerep and Wonolelo Village, Yogyakarta and Tanjung Harapan and Dumati Village in Gorontalo. Three out of four communal biogas plants assessed in this study are still operating. Yet, sustainability of the plants faces several challenges, i.e. poor biogas installation (e.g. missing water trap and leaking gas holder), missing system for equal biogas distribution, missing supply chain for biogas spare parts, and week polycentric local governance. Several recommendation to improve this condition are installation of biogas monitoring in distribution pipeline, regular and monitoring and assistance, development of supply chain network with commercial entities, and distribution of power and responsibility to ensure operation of the system if one of stakeholder failed to perform.

1. Introduction
Indonesia is a large archipelago country with more than 13,000 islands spread between Indian and Pacific Ocean. Indonesia is blessed with numerous energy resources from coal, oil, natural gas, and renewable energy sources. Over the years, Indonesia depends its energy supply from fossil sources. By 2017, all combine fossil fuel accounted for 72.3% of Total Primary of Energy Sources (TPES) [1]. Fossil energy consumption emits more greenhouse gas emission which harms the environment. It also creates vulnerability in the country since fossil energy reserve keep decreasing yet the demand is increasing.

Biomass accounted for 18.6% of TPES in 2017. Yet, it dominated with traditional wood-fuel and charcoal. Bio-energy can be harvested from other type of biomass, such as agriculture product (e.g. palm oil, coconut oil, corn, etc), organic waste (e.g. bagasse, rice husk), city waste, and animal manure. From cow manure, there is 535 MWe of potential bio-energy [2]. This value is relatively small compare to the other biomass. Nevertheless, growing population of livestock is opportunity to implement energy conversion technology using biomass.
Bio-digester is one of technology to convert organic waste into biogas and digestate. Biogas is flammable and can be utilized as fuel for cooking or electricity generation. Meanwhile, another product, called digestate, can be used as organic fertilizer. With digester technology, organic waste, such as agricultural waste and manure, are degraded. farming and circular economy. Additionally, digester reduces emission of greenhouse gas in form of methane (from manure) and carbon dioxide (from fossil energy usage).

Yogyakarta Province, which located in southern area of Java Island, Indonesia, does not have any energy resources except renewable energy. By 2005, total energy demand in the province was still supplied from fossil fuel, like oil (74.71%) and LPG (7.32%), which is distributed from other provinces [3]. Energy demand specifically in household sector accounted for 32.24 % of total energy consumption, while 66% of it came from cooking. By 2014, there are 40% of village in Yogyakarta that still using wood for cooking, while the rest were using LPG [4].

On the other hand, Gorontalo Province is located in Sulawesi Island. Like Yogyakarta, Gorontalo has several renewable energy potentials, such as hydro, wind, solar, biomass, and geothermal energy. Yet, energy audit and project energy demand recording in Gorontalo have not been made. After national program to shift from kerosene to LPG, many households and restaurants in Gorontalo depend on 3-kg LPG bottle. 3-kg LPG bottle is still subsidized by the Government of Indonesia (GoI) and in Gorontalo, its supply is scarce sometimes. Biogas implementation is able to reduce GoI subsidy load and dependency on LPG supply.

Implementation of household-scale digester in Indonesia started in 2009 when Indonesia Domestic Biogas Program (IDBP) is initiated. The program is a collaboration program between Ministry of Energy and Mineral Resources (MEMR) and Netherlands Development Organization (SNV). As time goes by, implementation of biogas technology in Indonesia not limited to household scale only. It grows into communal-scale of biogas, either for cooking or for electricity generation.

However, biogas implementation in Indonesia faces many challenges. Biogas digester in Yogyakarta performed below its feasibility study. The low performance of digester was caused by missing monitoring of feedstock quality, procedure for feedstock mixing and regular maintenance monitoring [5]. On the other hand, biogas implementation in Indonesia hard to sustain in technical, economic and institutional aspect due to unavailability of water in several area to mix the feedstock, lack of industry to support biogas industry, and its implementation highly depend on local government policy[6].

This study tried to answer inquiries on sustainability of biogas implementation in Indonesia. Field study and interviews are done in Yogyakarta and Gorontalo to compare condition of biogas plants in technical and social aspect. Qualitative content analysis was performed to analyse the data. In the end of this study, room for improvement would be determined so that sustainability of biogas system can be achieved.

2. Methodology

This study conducted in two villages in Yogyakarta, i.e. Plosokerep and Wonolelo; and two villages in Gorontalo, i.e. Dumati and Tanjung Harapan. Plosokerep village is located on the slope of Merapi Mount and has cold weather that perfect for dairy cow farming. Koperasi Samesta is a communal dairy cow farm that integrated with biogas plant. Contrary to Plosokerep, Wonolelo village has weather that similar toa low-land so the average temperature is hotter than Plosokerep. Most of residents of Wonolelo are farmers and some of them have communal cattle farming integrated with biogas plant. The large people in the semi-arid low-lands of Dumati and Tanjung Harapan, Gorontalo province, work in agriculture and livestock sectors. Some of them also have communal biogas plants.

To understand impact and current condition of biogas plants in the selected areas, interviews were run towards users, operators, and management team. In total there were 13 respondents. Questions for the interview were divided into three parts. The first part gathered information about biogas condition after installation, maintenance routine, constraints when operating biogas plants, and impacts of biogas implementation. In the second part, data were obtained on women involvement in operation and management of biogas. Women has important role in biogas implementation because they usually the one who manage energy and cooking expense in household [7]. The last part of questions dealt with
management organizational in biogas implementation. Interview recordings were then transcribed, coded and themed for analysis using thematic analysis. Thematic analysis was used due to its flexibility in analyzing interview transcripts. With thematic analysis, unexpected result from the interview still can be coded [8]. Thematic analysis was performed in five steps, i.e. (1) understand and get familiar with the data; (2) develop general code; (3) put general codes into suitable themes; (4) evaluating themes; (5) summarize data [9]. To ensure validity and reliability of the result, data collection and interviews were executed with triangulation too. This means the same questions were asked to all the interviewees. Moreover, literature review was done to get confirm the result. By the end of this study, recommendation also developed from the triangulation to improve performance of selected biogas plants.

3. Results
Two out of four biogas plants that being assessed are not operating anymore. These inactive plants are caused technical and social problems, such as lack of public participation, too low pressure of biogas, too many losses on distribution, and so on. Table 1 summarized current condition of biogas in Plosokerep, Wonolelo (Yogyakarta), Dumati and Tanjung Harapan (Gorontalo).

| Location                  | Biogas Type                          | Current Condition       |
|---------------------------|--------------------------------------|-------------------------|
| Plosokerep Village, Sleman, Yogyakarta | Medium size and communal digester to process manure from 40 cows | Biogas used to be fuel for cooking |
| Wonolelo Village, Bantul, Yogyakarta | Medium size and communal digester to process manure from 40 cows | Currently use for cooking |
| Dumati Village, Gorontalo  | Small size and communal digesters to process manure from 2 cows | Currently use for cooking |
| Tanjung Harapan Village, Gorontalo | Medium size and communal digesters to process manure from 20 cows | Biogas used to generate electricity |

Biogas in Yogyakarta, i.e. in Plosokerep and Wonolelo, have the biggest capacity among all assessed plants. Both plants are able to process 40-cows capacity from farmers group in the area. Unlike in developed country, farmers in Indonesia usually have less than 10 cows. Thus, for communal biogas plants, the cows are kept in communal place. Despite it is built in the same size, biogas in Plosokerep is not operating due to many losses of biogas in distribution. Cows in Plosokerep are owned by farmers outside the area but the biogas are distributed to 20 households nearby. The closest household located 800 meters away from the plants and built in higher place elevation. Similar problem about low pressure of biogas also occurs in Wonolelo, Yogyakarta. On the other hand, Dumati biogas plant has the smallest capacity among all plants assessed. The plant was built to process manure only from 2 cows. Despite the size, this biogas plants are still operating to cook “pia”, the specialty pastry from Gorontalo. While, biogas in Tanjung Harapan is the only used for electricity generation. This utilization was selected since people in the area did not have access to grid electricity. The system is not working because the generator was not working properly. Additionally, operation of the system highly depends on the sole worker who left the village.

Data for this study was collected by doing face to face interviews with users, operators and management team of selected biogas plants. The data then investigated using thematic analysis. General codes from the interviews are “crosscutting”, “technical”, and “social” aspect. Impact of biogas was put into cross cutting aspect since it was perceived by community (social) yet caused by
technical performance. From the interview, technical aspect of biogas mostly about challenges during implementation of biogas while in the social aspect can be divided into organizational and women involvement. There were new codes during the analysis which are “implementation enabler”. Implementation enabler are positive public perception on biogas which makes people willingly to utilize it. Detail on this result is presented in Table 2.

| Assessment Result | Plasokerep Village, Sleman, Yogyakarta | Wonolelo Village, Bantul, Yogyakarta | Tanjung Harap Village, Gorontalo | Dumati Village, Gorontalo |
|-------------------|----------------------------------------|--------------------------------------|---------------------------------|--------------------------|
| Impact biogas     | • Biogas utilized to cooking meals and boiling water | • Biogas for cooking | • Biogas utilized for electric lights until 12 o’clock at night. | • Biogas for cooking |
|                   | • Sludge utilizes as organic fertilizer for sale | • Sludge utilizes as organic fertilizer for own consumption and for sale sometimes | • Sludge utilizes as organic fertilizer for own consumption and for sale sometimes | • Sludge utilizes as organic fertilizer for own consumption and for sale sometimes |
| Enabler           | • Public feel an advantage that biogas is free | • Biogas stove is sturdy and easy to maintain | • Public feel an advantage that biogas is free | • Biogas connected to business |
|                  | • Biogas connected to business | • There is no serious problem on biogas pipeline so far | | |
|                  | • Sludge production and sales are well recorded | • Cooking using biogas is slightly faster than LPG by 2 minutes | | |
|                  |                                         | • There is monitoring activity and constant demand on biogas fertilizer from Regional Ministry of Agriculture | | |

Table 2. Technical and social assessment results of biogas implementation in Yogyakarta and Gorontalo
| Technical | Challenges |
|-----------|------------|
| - Biogas users located too far from the plant |
| - No velocity pump or compressor installed in the system |
| - Cows owners are from different area |
| - Biogas is not distributed fairly |
| - Some users located dispersed and too far from biogas plant |
| - Lack of fresh water during dry season |
| - Biogas is wet due to lack of water trap in the system |
| - Technical troubles on biogas generator |
| - Lack of knowledgeable operator |
| - Leak of gas holder |
| - There is public perception that biogas cause bad odour |
| - Biodigester capacity is too small |
| - Biogas is wet due to missing water trap. It results in rusty stove and feedstock mixer |

| Women involvement | Women become part of management but not in technical team |
|-------------------|---------------------------------------------------------|
| - Women become part of management but not in technical team. |
| - In technical works, the responsibilities are borne to men in the community |
| - Women works in technical work if men in the family unable to do so |
| - Men were responsible on the technical works while women only users of biogas |
| - Women become part of management but not in technical team |
| - Women actively manage the pia business |

| Organizational | Training and technical assistance on biogas operation and maintenance only held in the beginning of project |
|----------------|--------------------------------------------------------------------------------------------------------|
| - Training and technical assistance on biogas operation and maintenance only held in the beginning of project |
| - Depend on sole operator |
| - Training and technical assistance on biogas operation and maintenance only held in the beginning of project |

In Plosokerep, biogas digesters are owned by a farmer group. Members of the farmer group are people from other area in Sleman, Yogyakarta. Main objective of the biogas installation in Plosokerep is to produce bio fertilizer. Thus, biogas from this digester distributed to household near the farm location. Biogas stove and its installation built to local households for free but there was monthly fee for operation and maintenance. At first, biogas well distributed to 5 households. This utilization reduced LPG expense up to 2 bottles (each 3 kg LPG per bottle) every month. Yet, biogas distribution was interrupted since up to 20 households are now connected to the systems. Extension of biogas users without addition the upstream production leads to lower amount of biogas received. Nowadays, biogas only works well during midnight when there are rarely activities in the household. Because of that, the users prefer to use LPG again. Nevertheless, bio fertilizer production in the farmer group is still going on.
Biogas in Wonolelo village also has similar problem. Biogas digester built for a farmer group. In the beginning of the installation, all members of farmer group which consist of 20 households were connected to a biogas digester. Problem appeared when households which located far from the digester did not received biogas as much as households near the digester. Because of that, households which located far from the digester were stop using biogas. Currently, only 9 households using biogas. In Wonolelo, biogas utilization reduces LPG consumption up to 2 bottles of LPG.

Both locations, Plosokerep and Wonolelo, do not have velocity pump to distribute biogas to users who live far from the digester location. Another technical challenge in communal digester is how to distribute biogas equally. Unlike electricity where each household has electricity quota, installation of biogas in communal system do not have any measurement system. From interview, biogas users in Wonolelo complaints that biogas stove is easily clogged and corroded. This caused by missing water trap in distribution system of biogas. High water content in biogas also makes pipe distribution clogged.

In all locations, technical assistance or training was held in the beginning of project. Limited transfer knowledge and technology could make users have no sense of belonging and responsibility. The lack knowledge and understanding after biogas installation means that they tend fixing technical problem by knowledge-based activities [10]. In Wonolelo, to solve problem on missing water trap, men of farmer group usually clean the pipe distribution once in couple months or if any fault report from biogas users. On the other hand, women who use biogas stove learn autodidact to clean the stove using formic acid, clothes and brush.

Despite technical training that given to men and women, there is gender-based responsibility division in all biogas locations. Women responsible on managing biogas production and utilization, while men work in upstream and technical activities, such as putting feedstock into the digester, cleaning clogged feedstock channel and biogas pipe distribution.

Nevertheless, biogas still works well in Plosokerep, Wonolelo and Dumati village because it is integrated to business or productive activities. Monitoring activities from management team or responsible government office is performed although it does not occur regularly.

In Tanjung Harapan where biogas stop operating, monitoring from authority is missing. This get worse as polycentric governance for biogas installation is failed. Biogas in Tanjung Harapan highly depend on sole operator who knows the system well. As the operator leaving for another job, farmer group in Tanjung Harapan tried to repair leaking gas holder and biogas generator. While the gone operator is the one who understand biogas generator, the effort to repair gas holder finished prematurely due to hard time on finding the suitable spare part or material.

4. Discussion

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where Many reports identified various barriers to biogas implementation; some of them are technical and social aspects. In technical aspects, poor construction and material quality and inexperienced workers become obstacles in biogas projects [11]. Social barriers such as lack of information and socialization about biogas operational and poor owner’s responsibilities [12]. In this study, challenges for sustainable biogas implementation are poor biogas installation, e.g. missing water trap and leaking gas holder; missing system for equal biogas distribution, missing supply chain for biogas spare parts, and weak polycentric governance.

Fixed dome digester construction is standardized in Indonesian National Standard (Standard Nasional Indonesia (SNI)) No 7826:2012. However, this standard does not include how distribution pipeline should be. Design for biogas distribution seems lack of proper calculation on how many households can be connected in the system. Standard biogas supply for cooking stove range from 0.380 m³/hour until 0.500 m³/hour [13]. Daily biogas production from one digester should be divided to number of connected households. If biogas flow falls lower than the minimum standard, there should be no new connection unless there is more feedstock input.

Another challenge for communal biogas implementation is how to ensure fair distribution between biogas users (households). In current practice, household which located far from the digester receive less biogas than the nearby households. One alternative solution for this problem is by installing gas
distribution system. The distribution system consists of gas holders, manometer, manual valves and pressure valves [14]. Manometer is placed between gas holders and the distribution line. There should be minimum allowable working pressure for gas holder so if the pressure drops below that; distribution of biogas to household are closed by using manual valves. Installation of pressure valves are aims to ensure no back flow and favorable to minimize pressure drop in distribution pipeline [14]. Additionally, gas counter should also be installed before biogas stove so amount of biogas utilization for each household can be monitor [15]. Therefore, amount of money which need to be paid by the household should be equal to their gas usage every month. However, the unit price of biogas (USD/m³) to be paid by the households have to meet users’ economic capability. Thus, this monitoring installation does not work counter-productive for implementation of biogas.

Renewable energy supply chain consists of numerous stakeholders, such as government, researcher, commercial entity, philanthropy organizations or investors, labours and users [16]. From this study, operators and users have hard time in troubleshooting and repair biogas system. In current practice, commercial role seems to be missing in providing renewable energy spare parts. Limited assistance and knowledge transfer also restrict users and operators’ alternatives of solution. To improve this condition, technical assistance should be conduct not only in the beginning of the project but regularly. In addition, network between investors, commercial and users need to develop to ensure sustainability of the implementation.

Tanjung Harapan, users highly depend the operation of biogas on one sole operator who also responsible as leader of the village. The operator was the one who got training from philanthropic organization. This condition reveals a poor polycentric governance. Polycentric governance involves distribution of power, multiple authority and overlapping responsibility to all stakeholders [17]. Thus, there would be another stakeholder who will cover the responsibility if one of the stakeholders failed.

5. Conclusion

Biogas implementation in Indonesia has been deployed to reduce dependence on fossil energy resources, especially in household sector. Farmers in Indonesia usually have small amount of livestock. Therefore, communal biogas plants emerged. Three out of four communal biogas plants assessed in this study are still operating. Yet, sustainability of the plants is facing challenges, i.e. poor biogas installation (e.g. missing water trap and leaking gas holder), missing system for equal biogas distribution, missing supply chain for biogas spare parts, and weak polycentric local governance.

Several recommendations to improve this condition are installation of biogas monitoring in distribution pipeline, regular monitoring and assistance, development of supply chain network with commercial entities, and distribution of power and responsibility to ensure operation of the system if one of the stakeholders failed to perform.

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