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The Determinant Factors of Biogas Technology Adoption in Cattle Farming: Evidences from Pati, Indonesia

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ABSTRACT. Even though biogas technology has been introduced in Indonesia since 1990's, the rate of biogas adoption in Indonesia runs slowly. It is therefore important to understand the factors encouraging or discouraging potential adopters in building biogas digesters. The development of the livestock sector, especially cattle farming, in Indonesia can be seen as an opportunity to increase the rate of biogas adoption. This study investigated the factors influencing cattle farmers' adoption biogas technology. A cross-sectional research survey was carried out by using structured questionnaires as the primary tool to collect data from both biogas adopters and non-biogas adopters in Pati regency, Indonesia. The socioeconomic characteristics of potential biogas adopters play an important role to ensure the adoption of biogas technology sustainable. A higher social status influences individual to adopt biogas relatively earlier than other members of a social system. Higher income and education also enable traditional farmers to either finance biogas digesters with their own money or access aid from the government or other agencies. Amongst other attributes of innovation, the advantages of installing biogas digester can be seen to speed up the rate of biogas adoption. Having a biogas digester was perceived as a better option and generated more benefits as compared to previous technologies or methods.

Keywords: adoption, biogas technology, cattle farming, determinant factors

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1. Introduction

The adoption of biogas technology has remained low despite Indonesia as an agriculture country has an abundance of organic resources for biogas production. It is roughly estimated that the installed capacity of biogas utilization in Indonesia is less than 1% of the existing biogas potential (Widodo *et al.* 2009). Furthermore, less than 50% of installed biogas digesters in developing countries including Indonesia were operational due to many factors such as inadequate technical support, inappropriate technologies, and lack of institutional capacity of the main stakeholder (Bond and Templeton, 2011; Lohri *et al.* 2013).

Biogas technology is a technology to convert organic waste including livestock manure into biogas through the process of anaerobic digestion. Biogas, a flammable gas, is mainly composed from methane (50-75%) and carbon dioxide (25-45%) and typically has a calorific value of 21–24 MJ/m^3 (Bond and Templeton, 2011).

Literature shows that biogas technology offers benefits in many aspects. The adoption of biogas technology offers economic benefits in terms of reducing households' expenditure, increasing income generation and creating job opportunities (Haryanto *et al.* 2017; Jian, 2009; Chakrabarty *et al.* 2013). Socially, utilizing biogas improves sanitation and promotes gender equality (Massé *et al.* 2011; Kabir *et al.* 2013). Further, the adoption of biogas technology plays an important role in mitigating greenhouse gas emissions from animal husbandry (Clemens *et al.* 2006).

In addition, biogas technology is an effective way in supporting sustainable livestock farming by converting livestock waste into sustainable energy and organic fertilizer (Massé *et al.* 2011). Since biogas can be produced from locally available organic materials, it can be used to fulfill energy needs and to reduce the usage of fuel wood in rural areas. In Indonesia, 69% of rural population is estimated using fuel wood for

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energy purposes thus facing potentially severe health impacts due to fuel wood use (Huboyo *et al.* 2014).

Promoting sustainable cattle farming becomes increasingly important since the Indonesian government has targets to reduce its dependence on imports and to achieve self-sufficiency in milk and beef production by 2020 and 2026. On the one hand, developing the livestock sector will improve the welfare of rural people, since about 63% of poor people in Indonesia live in rural areas and most of them work as farmers (GOI 2016). On the other hand, the animal husbandry sector has adverse impacts on the environment due to improper waste management.

The environmental problems like water and air pollution lead to complaints from people dwelling close to farm areas, and triggers social tensions within the community. In many cases, cattle farming in Indonesia are situated in densely populated. A majority of the farms are concentrated in Java Island where over half of Indonesian's population lives (GOI 2016).

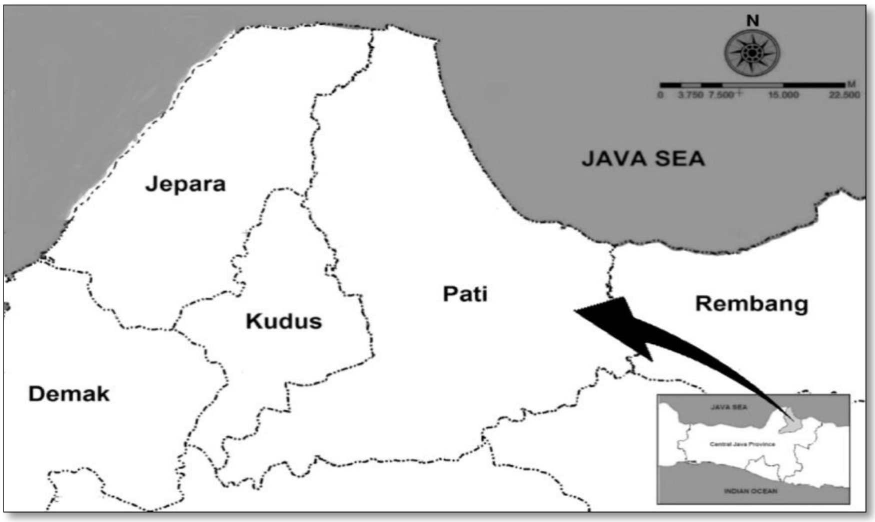

Fig.1. The location of sampling sites

Previous studies have revealed that the decision to adopt biogas technology was affected by several determinant factors including demographic and socioeconomic factors (Kabir *et al.* 2013; Mwirigi *et al.* 2009, Qu *et al.* 2013; Walekhwa *et al.* 2009). Meanwhile, Rogers (1995) stated that the rate of adoption is determined by five attributes of innovations namely relative advantage, compatibility, complexity, trialability and observability.

The objective of this study is to investigate the factors affecting the households of cattle farmers adopting biogas technology. Thus, understanding the determinant factors of biogas adoption is crucial for developing strategies for biogas dissemination particularly in cattle farming.

2. Materials and Methods

2.1 Study site

This study was based on a survey carried out in Pati regency, Indonesia from March to October 2016. Pati regency lies in the northern coast of Java Island, Indonesia ($6^{o}25'$–$7^{o}00'$S, $100^{o}50'$–$111^{o}15'$E). It is located mostly in lowland areas with elevations ranging from 1 to 624 meter with annual rainfall ranging from 11 to 883 mm. The total area of the study was about 150,368 hectares (ha) consisting of 114.280 ha (76%) agriculture land and 36,088 ha (24%) non agriculture land. This area has more than 1.2 million citizens and most of whom work in the agriculture sector followed by the trading sector.

2.2 Research Design

A field survey research was chosen as the design of this research with qualitative and quantitative approach (mix method). Survey research is a specific type of field study that involves the collection of data from a sample of elements drawn from a well-defined population through the use of a questionnaire (Visser *et al.* 2000).

2.3 Sampling procedure

In order to investigate the factors affecting farmers in adopting biogas technology, a cross-sectional research survey was used to compare differences between households with and without biogas digesters. The Slovin's formula (Eq. (1)) was applied to determine a sampling size.

$$n = \frac{N}{1 + Ne^2} \quad \textbf{(1)}$$

where:

- n is the sampling size
- N is the number of biogas adopters as population
- e is the margin of error (0.05)

Based on the Slovin's formula, 66 households with biogas digester (biogas adopters) were selected at random and interviewed using questionnaires. For comparison purposes, the study took equal sample size between biogas adopters and non-biogas adopters (households without biogas digesters). Thus, to investigate the determinant factors, the study involved a total of 132 sample households consisting of 66 biogas adopters and 66 non-biogas adopters. One nearest neighbor for each sample biogas adopters was selected purposefully to determine non-biogas adopters.

Table 1
Definition of socio-economic characteristic

Characteristic	Definition
Age	age of household head in years
Family size	total number of people in the household
Education	educational level of household head in years
Experience	experience in raising cattle in years
Income	total monthly income in Rupiah
Cattle	number of cattle owned by farmer in head of cattle

2.4 Data collection and analysis

As typical a research survey, structured questionnaires were used as the primary tool for data collection. The first part of questionnaire was used to provide data regarding the socio-economic characteristic of respondents including age, family size, education level, working experience, income level and number of cattle owned by farmer (Table 1). The second part of the questionnaire was used to collect data related to respondents' reasons to adopt or not to adopt the technology.

The questionnaires were presented to a cattle farmer, a representative of local NGO, and a researcher from Development Planning Agency of Pati regency to determine the suitability of the questions in collecting the data required. All the comments were considered and the final sample questionnaires are ready for data collection. Later, the data from respondents were collected and analyzed with descriptive statistics.

Other primary data were collected through direct observations and interviews. Direct observation plays an important role investigating the performance of biogas installed and the management of biogas digesters. Interviews were conducted to collect qualitative data regarding the motivation to adopt or not to adopt the technology and the status of the technology. Interviews also were used to get in-depth explanations for the answer given by respondents.

3. Result and Discussion

3.1 Status of the technology

Biogas digesters with a capacity of 6 m^3 was seen as the most popular size in the study location, making up 47% of total digesters, followed by 9 m^3 and 4 m^3 digester with accounting for 29% and 17%, respectively. Few communal biogas digesters have also been installed with volumes of 18 m^3, 25 m^3 and 30 m^3. Communal digesters were designed to dispose waste from several farms (households) and to share biogas. Therefore, communal digesters have larger volume compared to individual digesters.

In accordance to the digester design, most biogas users in the study location opted for concrete-fixed dome design. Of 66 biogas digester, 63 digesters use concrete-fixed dome design while the rest use fiberglass dome design.

Prior to using biogas technology, farmers applied dry lot system to manage their manure while the rest dumped waste into river. These are considered simpler and cheaper treatment methods compared to others. Dry lot is a manure management system whereby manure, in particular cow dung, is stacked in uncovered areas with or without pavement and the accumulated dung will be removed periodically (IPCC 2006). Farmers use collected dung to fertilize their own land or sell it to other farmers. This type of manure management is still applied by non biogas adopters.

Fig.2. (a) Dry lot manure management system, and (b) manure dumped to rivers

Fig. 3. (a) Fiberglass digester, (b) the construction of a 30 m^3concrete-fixed dome digester, (c) a finished 30 m^3 concrete-fixed dome digester

The construction of 52 biogas digesters was fully funded by the government. The incentives were allocated to a group of farmers instead of individual farmers. The group then selected a member's farm as the location for the biogas digester. Other biogas digesters (11 digesters) were constructed under Indonesian Domestic Biogas Program (IDBP). With assistance from an international Non Governmental Organization (NGO) called SNV/Hivos, a local NGO called Yayasan Rumah Energy has been running biogas projects in Pati since 2011. Different from the government's projects, IDBP gives subsidy partially and obligates farmers to contribute towards the construction cost. Therefore, the willingness and the ability to pay for biogas projects are the crucial factors for selection.

3.2 Socio-economic characteristic

Table 2 shows descriptive statistics of respondent's socio-economic characteristic. In general, compared to non biogas adopters, the adopters are: younger and have higher family size, level of education, working experience, income and number of cattle.

Table 2
Mean value of socio-economic characteristic

Characteristic	Adopters	Non Adopters	Total sample
Age	46.5	47.6	47.05
Family size	3.7	3.3	3.5
Education	12.4	7.6	10.0*
Working experience	18.3	16.9	17.6
Income	2.4	1.1	1.75*
Cattle	5.2	1.9	3.55*

* Indicating the difference in mean values between adopters and non-adopters is statistically significant at $P<0.05$ (t-test used for the differences in means).
Source: survey data

Having higher level of education means that biogas adopters had more years of formal education than non biogas adopters. Statistically, there was a insignificant mean difference in age, family size and working experience between biogas adopters and non adopters. Meanwhile, a significant statistical difference ($p<0.05$) was found in education, income and number of cattle between two groups.

The findings of this study showed that the biogas adopters had significantly higher social status than non adopters. All respondents come from the Javanese tribe and in Javanese's culture, some socioeconomic characteristics (e.g. the possession of wealth and level of education) closely relate to social status. In this study, the possession was measured from the number of cattle owned by farmers and level of income.

Farmers who have higher social status find it easier to adopt the technology than the other farmers in the same area. Due to their social status, some cattle farmers were selected as leaders of farmer groups and their farms were typically chosen as the place for building biogas digesters. Becoming the leader of the farmer group enables them to have good relations with the government and thus receive information regarding biogas programs more easily and quickly. Having enough information and support from the government is an effective way for early adopters to deal with the uncertainty and the risk of adoption the innovation.

Having good income increases the willingness and ability to pay in biogas project and encourages potential adopters to join the biogas projects. Under IDBP, a household spent 2-3 million Rupiah or about 30% of the total construction cost to build a digester with a capacity of 4 m^3 or 6 m^3. The decision to spend money for adopting the technology is seen as very risky because on average, a farmer's monthly income is less than 3 million Rupiah (Table 2).

3.3 Reasons not to adopt the technology

This part presents the reason why households decide not to adopt biogas technology. The farmers had not adopted the technology because of various reasons that were: lack of funding (53%), unavailable space for building digester (33%) and others (14%). The "other" reasons included the idea of biogas technology having never crossed their minds, the perception that it was a lot of work and the investment not being economically feasibility. Funding becomes the main obstacle of adopting biogas since cost of biogas constructions is unaffordable for traditional farmers. Unavailable space means farmers have very limited land or they allocate their land for other purposes. In order to build a 6 m^3 biogas digester, the potential users have to allocate about 24 m^2 of land.

Due to the distance from the city centre, population growth and economic development, some villages that are located close to city centre change slowly from rural areas to rural-urban areas. Many human settlements and industries have been established in the past several years causing the land price in the villages to increase. Using their land for expanding farms or building house results in more benefits for farmers than using the land being used for the building of biogas digesters.

3.3 Reasons to adopt the technology

About 44% of adopters (29 households) stated that they had adopted the technology because it was fully subsidized by the government (economic factor). Without a full grant from the government, the respondents did not want to build biogas digester even though they realized the benefits and they were able to finance the construction cost with their own money. The investment for building biogas digester is quite high and it is more profitable to invest in expanding their farm or in buying agricultural land rather than investing in building biogas digester.

Giving an incentive to farmers increase the rate of biogas adoption, as indicated by the number of digester installed due to the incentive. However, giving an incentive creates high dependency among farmers. The farmers tend to wait for incentive from the government and they have low willingness to invest in pay for the innovation. In addition, the policy from the government to give full subsidy discourages other actors like NGO to get involved in the biogas sector and offers different schemes of funding to potential adopters. This study found that there is no biogas project under IDBP in areas where the government has built a number of fully subsidized bio-digesters.

21 adopters (32% of total adopters) stated that improving farm's sanitation and preventing pollution (environmental factors) is the primary reason to adopt biogas. Farmers received complaints from their neighbors because their waste creates air pollution (bad odor) and contaminates agricultural land. The technology offered better solutions than previous waste management systems in terms of tackling waste problems and reducing complaints. After adopting the technology, cattle farmers feel more comfortable to run their business because they avoid complaints from their neighbors.

Even though all respondents received economic benefit in terms of reducing energy expenditure, only 16 households (24% of total adopters) placed this benefit as the main reason to adopt biogas. Before using biogas, 39 households used 3 kg cylinders of LPG (liquefied petroleum gas) as their primary source of energy for cooking. As a result of shifting from LPG to biogas, the households can save 38,750 Rupiah per month, on average. 27 households used fuel wood for cooking prior to using biogas. The fuel wood user also can save their money by replacing fuel wood with biogas. However, the amount of saving is difficult to calculate because of two main reasons. First, in certain periods farmers collect fuel wood from their backyard for free. Second, the price and quality of fuel wood fluctuate depending on the season and type of wood.

Roger's theory regarding the attributes of innovation is relevant to the study's findings. In this study, relative advantage was the most important attribute determining the rate of adoption when compared to other attributes. Relative advantage is *"the degree to which an innovation is perceived as being better than the idea it substitutes"* (Rogers, 1995). Environmentally, the adoption of biogas was perceived as better than the previous option (dumping) to treat waste and to overcome the negative impacts of the waste. Later, using biogas for cooking enables farmers to spend less money compared to using LPG or fuel wood.

According to respondents, operating biogas digesters in particular communal digesters is more complex and difficult than previous methods. The best example was the case of a communal biogas digester with the size of 25 m^3. Technically, the biogas digester was designed to treat 600 kilograms of substrate every day consisting of cow dung and water in the same proportion (1:1) in order to produce biogas for 7 households.

In reality, the group of farmers had insufficient information on properly operating and managing a communal digester. The farmers decided to adopt the technology due to the benefits of installing biogas digester and they did not really care for the difficulties in managing it. Later, one respondent, the person in charge of operating the digester, realized the difficulty in collecting both 300 Kilograms of cow dung and water every day for mixing. In addition, unclear task division and poor mutual understanding among members were crucial problems.

Having limited technical and managerial skills in biogas became barriers for adopters to ensure the sustainability of operating biogas digesters. Because of that, about one year after the construction of the digester, the respondent decided to stop sharing biogas with other households and used the biogas only for himself. This was a situation that the members of farmer group had not foreseen when they had accepted the technology from the government.

In observability perspective, the rate of adoption will increase if the technology shows good performance and conversely the rate of adoption in certain areas will decrease or the technology will be rejected if it shows bad performance. However, relative advantage of installing biogas digester was a more important factor than observability. In Bageng village, 2 fiberglass digesters were constructed in 2015 and their performance was not meeting expectations. Due to technical fault, the fiberglass digesters only produced very low amount of biogas and one of them was only operated for a few months. Surprisingly, when the government offered the incentives one year later, potential adopters did not mind adopting fiberglass digesters because the digester was free and they did not spend money at all.

4. Conclusion

The adoption process of biogas technology closely relates to socioeconomic characteristic of adopters especially the social status of adopters. Therefore, biogas programs have to be integrated with other development programs such as poverty alleviation, gender equality and education.

Receiving the relative advantage of the biogas adoption was the most determinant attribute to influence farmer to adopt biogas. However, the type of relative advantage perceived by adopters varies including low initial cost for building digester, savings and an increase in comfort.

Giving incentive to eliminate initial cost seemed to be the only one strategy implemented by the government since the initial cost for building digester was very high. It is important to decrease the dependency toward the government's grant and increase the ability of farmer to finance digesters on their own money.

Therefore, the government should provide other types of active support (e.g. funding, training and technical assistance) to promote biogas technology. The government should encourage and attract the private sector to be involved in promoting biogas technology by providing facilities such as tax and custom exemption, laws in order to make the biogas sector commercially sustainable and market oriented.

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