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Factors Influencing the Biogas Acceptance in Rural Area

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Abstract. This study addresses how utilization of information such as livestock population, village maps and geographic information system (GIS) can be utilized to evaluate biogas production from livestock manure in rural areas. Cluster analysis was used to identify the appropriate locations for construction of anaerobic digester. The factors influencing the acceptance of biogas development were also analysed using regression analysis. The logistic regression model was employed for data analysis. The model was used furthermore to calculate the probability of acceptance of biogas development in the area of study. Calculation of potential biogas production is approximately about 24,560.64 MJ/day of energy can be produced. The determinants for biogas development acceptance ranges between 10% and 74.6%. The study was based on primary data that were elicited using open and closed-ended questionnaires. Empirically, the result indicated that number of cattle owned, age of household head, family size, land availability and knowledge are factors that have statistical significance (p < 0.05). Family size, land availability, knowledge positively influence the acceptance of utilization of biogas technology, while age of farmer and cattle ownership is inversely proportional to the acceptance. The model shows that if all factors drive, the probability can be increased up to 74.6% indicating that the use of livestock manure can be successfully developed in the area.

1. Introduction

Urbanization and technology development causes increasing world's energy demand resourced mostly from fossil fuel, while the world is facing the decrease of fossil fuel resource stock. Intensive use of fossil fuel leads to negative environmental effects paying pro-environmentalist’s attention to seek solution. Eventually, renewable energy sources should be increased since its usage has a low environmental impact [1]. One of the promising renewable energy sources is the biomass energy source. Biomass includes woody plants, herbaceous plants/grasses, aquatic plants, and manures [2]. Treatment of manure using anaerobic Digester (AD) generates biogas. Utilization of biogas, primarily composed of methane and carbon dioxide gas, is growing fast in many countries [3]. Its application offers some advantages such as flexibility of scale, higher affordability, lower greenhouse gases (GHGs) emission and higher sustainability [4, 5]. AD constructed according to the level of technology and economic aspect is suitable for farmers in developing countries [6]. Construction of AD in rural areas is deliberated for the high cost. However, the construction of communal AD may overcome this hindrance because it increases farmer's affordability [7]. According to [8] biogas utilization can decrease GHGs concentration in the atmosphere since it converts methane to carbon which has global warming potential (GWP) 21 times less than methane. Carbon released during biogas production is assumed to be neutral
to GHGs concentration in the atmosphere since it is a natural process [9]. Biomass, as a source for biogas, is abundant and can be produced anywhere so that its usage can reduce foreign oil dependency. Moreover, biogas energy can be converted to electricity and thermal energy [10]. The risk of price volatility in biomass energy is much less compared to non-renewable energy mix [11]. Despite its advantages, Indonesia is still far behind valuing its biogas energy. To meet the ongoing energy crisis, initiatives are required in order to develop the use of biogas technology. However, biogas energy is a geographically dependent renewable resource that determining the appropriate site for AD construction is also very crucial [11]. Some previous studies have focused on site selection for ADs so far [12-15]. Furthermore, there are other factors influencing biogas development. Therefore, in this study, determining the driving forces influencing the households’ decision to adopt the AD is a prerequisite.

2. The Materials and methods

2.1. Area of Study and data collection

The study was conducted in a village, well known to be dominated-livestock asset. A random sampling technique was used for selecting the households to be surveyed consisting of non-biogas farmers (households not using the biogas plants, either willing to do so or not). Primary data related to the household socio-demographic and economic characteristics, including the motivation of using biogas plants were collected from 305 households. The head of the household was the respondent. The data collection was carried out through a household survey based on a questionnaire in the village areas from May to July 2019. Data were analysed by using statistical techniques (descriptive statistics, cross-tabulation, frequency tables, means t-test, and logistic regression) with SPSS. Secondary data were collected from different Government offices, NGOs and private entrepreneurs who actively promoted biogas activities in the local area, Indonesia Bureau of Statistics (IBS), and scientific research papers.

2.2. Energy Calculation

Calculation of biogas energy is conducted since there is no field measurement of biogas generated by the manure samples for equipment unavailability. Some assumptions are applied for the calculation as follows:

1. Gas production per unit mass of manure. According to [16], potential gas produced per unit mass of cow or bull manure is 0.023-0.040 m³. A value of 0.040 m³/kg manure is used in this study based on an interview with local staff.

2. Manure generation. The average manure generation in the village is 32 kg/head/day according to interview with farmers (67%).

3. Biogas caloric value. The typical biogas caloric value is 20 – 26 MJ/m³ biogas [17]. Value of 26 MJ/m³ is used in this study.

Using those assumptions, total potential biogas production in the village is calculated using equation (1):

$$E_{tot} = N \times W \times C_g \times e$$

Where $E_{tot}$ is total potential biogas production in MJ, $N$ is the number of cattle, $W$ is manure weight in kg, $C_g$ is a constant describing potential gas value which is 0.04 m³/kg manure and $e$ is biogas calorific value (26 MJ/m³ biogas).

2.3. Empirical modelling of biogas plants adoption

Adoption of biogas technology in this study is the dependent variable defined as production and consumption of biogas from a small-scale bio-digester by a household. The logistic model was applied to investigate the biogas technology adoption process. Both logit and probit are well-recognized approaches in adoption studies [18]. The choice of whether to use a probit or logit model is a matter of computational convenience [19]. Logistic regression is used when the dependent variable is dichotomy and the independent variables are of any type. It applies Maximum Likelihood Estimation (MLE) after
transforming the dependent variable into a logit variable [20]. It estimates the odds of a certain event occurring. The dependent variable is a logit, which is the natural log of the odds showed by equation (2).

\[ \ln \frac{P}{1-P} = a + bX \]  

(2)

Extracting P from this equation, it comes out that equals to equation (3).

\[ P = \frac{e^{a+bX}}{1+e^{a+bX}} \]  

(3)

where P is the probability of the event occurring, X are independent variables, e is the base of the natural logarithm and a and b are the parameters to be estimated by the model. The empirical form of the model used in the study is as presented by equation (4).

\[ \Pr(Y) = \frac{1}{1+e^{-(a+bX)}} \]  

(4)

where Y is the logit for the dependent variable. The logistic prediction equation for the present study is calculated using equation (5).

\[ Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n \]  

(5)

Where b_0 is a constant term, X_1, X_2, \ldots, X_n are independent variables likely to affect the probability of adopting the biogas technology, and b_1, b_2, \ldots, b_n are the coefficients to be estimated. The dependent variable was modelled as: Y = acceptance of biogas technology = P(Y) = \{1 if the farmer household chooses to produce and use biogas technology, and 0 otherwise\}.

3. Results and discussion

3.1. Socio-Economic Characteristic of the Farmers and the Acceptance of Biogas Technology

There are 507 HHs of non-biogas farmers in the village who were surveyed using questionnaires and the results were computed and are shown in figure 1.
The result from descriptive analysis describes the relationship between some aspects including environment, economic, technical, and social aspects toward biogas acceptance. Environmental aspect refers to land availability. The economic aspect is comprising of subsidies, income-generating and cow ownership. Technological reasons associated with training and experience. Finally, the social aspect consists of age, education level and family size. The acceptance of biogas is generally proportional to the age, although it tends to decrease when the age reaches 50. It indicates that the old farmer has less interest to adopt the biogas. Cow ownership in the village ranges between 3 and 10 heads. Farmers with cow ownership not more than 3 accept the biogas at most. The acceptance declines along with the increasing cow ownership. Farmers having higher education levels accept biogas less than the others because with the higher-level education they earn better and afford better the price for liquid petroleum gas (LPG) consumption. It explains also why the income inversely proportional to biogas acceptance. The relation between family size and acceptance is directly proportional. It may be caused by the opportunity to save the fuel expenses because commonly more family size relates proportionally to family size. Training about biogas technology and experience of biogas adoption (production and usage) shows the same trend where farmers with both items tend to accept more than those having neither training nor experience. Subsidies play an important role since it can support the farmers to construct the AD. Therefore, the availability of subsidies may increase the biogas acceptance. Moreover, the acceptance is proportional to land availability. The majority of farmers having land space less than 14 m² do not have an interest to adopt biogas technology because there is a requirement of a minimum land area of 14 m² for the smallest AD capacity.

3.2. Potential Biogas Production

The total potential biogas production was calculated using Eq. 1 and it shows that about 24,560.64 MJ/day energy can be produced by utilizing the manure waste for feedstock of AD in the village. The potential energy can be distributed to the villagers (farmer and non-farmer households) for cooking. The energy conversion into heat is more reasonable that electricity for robustness reasons.
3.3. Factors Influencing Biogas Acceptance in the Village

The result attained from the logistic regression analysis indicated that estimated values and observed data using the model fitted reasonably well. The goodness-of-fit test comparing the observed values to the expected (fitted or predicted) values showed that the log's odds of acceptance were concurrently associated with the independent variables. Five iterations were used to reach the maximum log-likelihood. Iterations stopped when the log-likelihood was 186.825 without any other differences between iterations 4 and 5. The Cox and Snell R-square was 42.8% and the Nagelkerke R-square was 57.80%, which is adequate for supporting the model's quality. One method to validate the goodness-of-fit of the regression model is the Hosmer and Lemeshow test (H-L test). The value from the H-L test is 3.317. The significance value is 0.913 which is more than 0.05 indicating that the model was fit for the data.

Using the Wald test, six variables out of nine variables were statistically significant (p < 0.05) in influencing the acceptance of biogas adoption in the farmer households (see Table 1). These variables include cow ownership, age, family size, land availability (1), land availability (2), and training. There are two categories for land availability to accommodate the minimum land space for individual AD (14-20 m²) and communal AD (> 20 m²).

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.134</td>
<td>1.209</td>
<td>.879</td>
<td>1</td>
<td>.348</td>
<td>3.108</td>
</tr>
<tr>
<td>Cow</td>
<td>-.302</td>
<td>.093</td>
<td>10.630</td>
<td>1</td>
<td>.001</td>
<td>.739</td>
</tr>
<tr>
<td>Age</td>
<td>-.044</td>
<td>.019</td>
<td>5.543</td>
<td>1</td>
<td>.019</td>
<td>0.957</td>
</tr>
<tr>
<td>Family size</td>
<td>.333</td>
<td>.189</td>
<td>3.100</td>
<td>1</td>
<td>.078</td>
<td>1.395</td>
</tr>
<tr>
<td>Land Availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land (1)</td>
<td>3.152</td>
<td>1.085</td>
<td>8.439</td>
<td>1</td>
<td>.004</td>
<td>23.392</td>
</tr>
<tr>
<td>Land (2)</td>
<td>1.444</td>
<td>.371</td>
<td>15.150</td>
<td>1</td>
<td>.000</td>
<td>4.236</td>
</tr>
<tr>
<td>Knowledge</td>
<td>1.230</td>
<td>.363</td>
<td>11.501</td>
<td>1</td>
<td>.001</td>
<td>3.422</td>
</tr>
</tbody>
</table>

Based on Table 1, the result of regression analysis is:

\[ Y = 1.134 - 0.302x_1 - 0.44x_3 + 0.333x_5 + 3.152x_6 (1) + 1.444x_6 (2) + 1.230x_7. \]

where \( x_1 \) is the number of cattle, \( x_3 \) age, \( x_5 \) is family size, \( x_6 \) is land availability, and \( x_7 \) is knowledge.

Using Eq. 3, the probability of farmer's acceptance of biogas technology was calculated. The model shows that if all factors drive, the probability increases up to 74.6% indicating that the use of livestock manure can be successfully developed in the area.

4. Conclusion

The main purpose of this study is to analyze the factors affecting the adoption of biogas technology in rural areas. Biogas offers a good potential energy option through its several advantages. Calculation for potential energy production is conducted. The total energy potential generated in the village is 24,560.64 MJ/day and can be distributed to other households for energy demand of 2,147.34 MJ/day. A logistic regression model used to analyze the farmer household's acceptance toward biogas technology showed that some factors play an important role in farmer's decision to adopt biogas plant. The factors are identified as a trigger to encourage the farmers to use the manure waste as input for AD. The factors positively influence knowledge, family size, land availability, subsidies, training and experience.
Meanwhile, the factors negatively correlated with the farmer's decision to adopt biogas technology are cow ownership, income, education level and age. The probability of biogas technology acceptance can be up to 74.6% if all factors drive in the village.

References

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