Potential Use of Biogas to Initiate Low Carbon Society in Thekelan Village-Indonesia

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Abstract. Thekelan Hamlet is one of the tourist hamlets in Kopeng District, Semarang Regency, Indonesia, which is near the Gunung Merbabu National Park area. Furthermore, the potential of biomass from the livestock and agricultural sectors in this village has not been well utilized. The purpose of this study is to determine the amount of energy use in the Thekelan hamlet, and analyze the potential use of renewable energy (biogas) to substitute conventional electricity. The method used in this research is descriptive qualitative combined with IPCC default methods based on a questionnaire from 40 respondents taken randomly. The result of the research shows that the use of energy sources from fuel wood is 9,830 kg and LPG is 215.5. The number of cattle in the hamlet of Thekelan is 70 heads and 34 goats. The largest GHG emissions are generated from the use of fuel in animal husbandry activities with a value of 0.206 Gg CO₂e/year while the lowest GHG emissions from LFG utilization activities are 0.008 Gg CO₂e/year. The total emissions of all activities are 0.599 Gg CO₂e/year. The use of biogas as an alternative energy is known to be able to reduce GHG emissions by 34.3% because the substitution of fuel wood and LPG is transferred to the use of biogas. This research is expected to be a stimulant and basic data for the realization of low carbon energy conscious villages.

1. Introduction

Basically animal waste that is piled up or just collected in a certain amount of time by itself will form methane gas in a high enough percentage but because it is not accommodated, the gas will evaporate into the air and cause odor around the pile [1]. Biogas can be used as a substitute for fuel, especially kerosene and firewood. On the 14th day of animal manure dumping, gas has formed and can be used to start a stove fire. The gas produced from biogas does not smell like cow dung because it has undergone a process of decomposition of organic matter [2].

Thekelan Hamlet has a potential source of biomass energy derived from cattle dung owned by residents. The biomass energy can be used as fuel or liquid fertilizer. Cow dung biomass contains energy in the form of methane gas which can be used as fuel [3]. Processing of cow manure biomass into fuel is done through the process of energy conversion in a biodigester. Conversion of cow manure biomass energy using biodigester is the result of how to solve problems that involve farmers directly so that biogas is considered as one of the alternatives commonly used by the community [4].
The number of residents living in the Thekelan hamlet is 280 households with 720 residents, the majority of which work in the livestock and agriculture sectors. The location of the village is surrounded by protected forests of Mount Merbabu, making access roads in and out on one road. The harmony of the religious community of the hamlet is very good where 50% of the population are Buddhists, 30% are Muslims and the rest are Christians. Thekelan residents are very familiar with the presence of residents who come to travel or climb Mount Merbabu [5].

Utilization of biomass energy is actually increasing in line with the increase in community needs due to low levels of community income and increasing population. The number of cows in this hamlet is estimated at 500 with the majority breeds of Friesian holstein breeds, in the form of dairy cows. Each house has an average of 3 cows, two of which are dairy cows. The creation of a low-carbon region is the hope of the government, therefore initiation needs to be done immediately so that the village of Thekelan can become a village that is energy independent, environmentally friendly and an example for other villages. The purpose of this research is to find out the number of livestock animals and the use of heat energy sources in the hamlet so that the results of the survey can be used in calculating the estimated GHG emissions generated and analyzing the potential use of renewable energy in the hamlet through biogas.

2. Research Methodology

2.1 Study Area

This research is located in Thekelan Hamlet, Batur Village, Getasan District, Semarang Regency, Central Java Province. Thekelan Hamlet is a hamlet located at the foot of Mount Merbabu precisely in Batur Village, Getasan District, Semarang Regency, Central Java Province. This village has developed into a tourism village with a lot of natural, cultural and potential in the livestock or agriculture sector. Almost every community in this sub-village has livestock such as dairy cows, goats, chickens and pigs. Besides that, the people of Thekelan Hamlet still use firewood as a source of heat energy on a daily basis and some people use LPG as a backup source of heat energy. The amount of livestock manure, burning using wood, and the use of LPG can cause a lot of GHG (Greenhouse Gas) emissions if not controlled. Control of GHG emission levels can be done by utilizing livestock manure as a raw material for biogas where the biogas can also reduce the use of fuel wood and LPG as a source of heat energy.

At present, Thekelan Hamlet already has 2 biogas plants which can be used for 11 houses but in a damaged condition. During the use of biogas, the community can significantly reduce the use of fuel wood and LPG. Efforts to fulfill electricity needs independently are by the use of solar panels. Thekelan Hamlet already has solar panel users in 1 house and Thekelan climbing base camp. The use of biogas and solar panels can improve the welfare of the community because it does not need to pay a lot of costs compared to buying LPG gas and the use of electricity from PLN.
2.2. Data Collection

This research uses descriptive qualitative method that is arranged to explain the real field conditions. Various types of descriptive data are then analyzed deeper to make data generalizations. The direct collection method has been carried out through observation and in-depth interviews. Questionnaire data distributed in writing to be used as a data collection instrument as many as 40 respondents were divided into 5 RTs. The sample in this study was taken using stratified random sampling where each RT was taken 8 respondents. The sample size was calculated using the Slovin formula with 15% error tolerance. Respondents interviewed were the head of the family or one of the parents who understood the conditions of the household.

Some inventory data for animal husbandry and fuel activities use the default data components set by the IPCC [6]. Secondary data obtained in the form of fuel emission factor (FE), heating value of fuel (NK), methane emission factor (Efb for enteric fermentation and manure management), average N excreted (Nex), estimated value of N (Nadj), percentage management Manure (% MMS Nm (kg N), N that evaporates (FNv), emission factor N that evaporates (EfV), N that is lost due to washing (FN Ir), N emission factor lost due to leaching (EF Ir) and percentage of livestock manure% PRP.

2.3. Data Analysis

Calculations of greenhouse gas emissions are carried out based on IPCC GL 2006 which can be seen through equations (1) - (4) for the livestock sector [7] and equation (5) and so on for the use of heat energy sources [8]. Equation (1) is used to calculate methane emissions from enteric fermentation of livestock.

\[
L_{\text{ent}} = (\text{Population} \times \text{EFb}) \times 10^{-6} \tag{1}
\]

\(L_{\text{ent}}\) is methane emissions from enteric fermentation (kg CH\(_4\)/year), population is livestock (tail) population, \(\text{EFb}\) is methane emission factor (kg CH\(_4\)/head/year) and 10-6 is the unit conversion rate from kg to Gg. Equation (2) is used to calculate methane emissions from livestock feed management.

\[
L_{\text{mm}} = (\text{Population} \times \text{EFb}) \times 10^{-6} \tag{2}
\]

\(L_{\text{mm}}\) is the methane emission from Manure management (kg CH\(_4\)/year), the population represents the livestock population (tail), and \(\text{EFb}\) is the methane emission factor (kg CH\(_4\)/head/year).
Then, the researchers calculated the total conversion of methane emissions from enteric fermentation and manure livestock management to carbon dioxide (CO\textsubscript{2}e) emissions by multiplying the Lent and Lmm values with a conversion factor of 23. Equations (3) - (4) are used to calculate nitrous oxide (N\textsubscript{2}O) emissions directly from livestock management.

\[ \text{Nm} = (\text{Population} \times \text{Nex} \times \text{Nadj}) \times (%\text{MMS}/100) \]  
\[ \text{L}(\text{N}_2\text{O})_{\text{dir}} = (\text{Nm} \times \text{EF} \times (44/28)) \times 10^{-6} \]

Nm is nitrous oxide emissions (kg N), Nex is the average N excreted (kg N/head/year), Nadj is the estimated value of N (unit) and % MMS is the percentage of managed manure (%). The Nm value obtained will be used in direct nitrous oxide emission calculations based on the following equation.

\[ \text{L}(\text{N}_2\text{O})_{\text{dir}} = (\text{Nm} \times \text{EF} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{Ndep}} = (\text{Nm} \times \text{FNv} \times \text{EFv} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{Ir}} = (\text{Nm} \times \text{FN Ir} \times \text{Ef Ir} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{dir}} = (\text{Nm} \times \text{EF} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{total}} = (\text{L}(\text{N}_2\text{O})_{\text{dir}}) \times 296 \]

Then calculate nitrous oxide emissions from livestock manure management indirectly (indirect) through equation (5) - (9). In calculating nitrous oxide emissions from livestock manure management indirectly (indirect), the first calculation uses equation (5) to find the value of Nm.

\[ \text{Nm} = (\text{Population} \times \text{Nex} \times \text{Nadj}) \times (%\text{PRP}/100) \]

Nm is nitrous oxide (kg N) emissions and % PRP is the percentage of livestock manure in the PRP (%). Then the value of Nm is used in the calculation of L (N\textsubscript{2}O)\_Ndep in equation (6), L (N\textsubscript{2}O)\_Ir in equation (7) and L (N\textsubscript{2}O)\_dir in equation (8).

\[ \text{L}(\text{N}_2\text{O})_{\text{Ndep}} = (\text{Nm} \times \text{FNv} \times \text{EFv} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{Ir}} = (\text{Nm} \times \text{FN Ir} \times \text{Ef Ir} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{dir}} = (\text{Nm} \times \text{EF} \times (44/28)) \times 10^{-6} \]

\[ \text{L}(\text{N}_2\text{O})_{\text{total}} = (\text{L}(\text{N}_2\text{O})_{\text{dir}}) \times 296 \]

Total L (N\textsubscript{2}O) is total converted nitrous oxide emissions (Gg CO\textsubscript{2}e/year), figure 296 is a multiplication factor for conversion from N\textsubscript{2}O to CO\textsubscript{2}. Equation (11) is used to calculate carbon dioxide emissions from the use of heat energy sources.
\[ \text{CO}_2 \text{ Emission} = \text{Consumption} \times \text{FE} \times \text{NK} \times 10^{-9} \] (11)

The intended consumption is fuel consumption (kg/year), FE is the emission factor (gr CO\textsubscript{2}/MJ), NK is the calorific value (MJ/kg) and 10\textsuperscript{-9} is the unit conversion from gr to Gg.

3. Result and Discussion

Through the results of a survey that has been carried out, it is known that the number of dairy cattle is 70 and goats are 34. In addition, data on the use of fuel wood and LPG obtained are the average use of fuel for one month in units of kilograms (kg). In general, Thekelan Hamlet residents generally use firewood as a source of heat energy compared to LPG. This is done because people in rural areas generally choose the type of fuel that is easy to obtain. Firewood is more widely used by the community because fuel is easier to obtain because it is close to a settlement especially the community does not need to pay to get it.

3.1 Analysis of Greenhouse Gas Emissions

Greenhouse gas emission analysis is performed using the calculation of CO\textsubscript{2} emissions by default methods based on IPCC GL (2006). Calculation of CO\textsubscript{2} emissions from livestock is categorized into 3 parts, including CH\textsubscript{4} emissions from enteric fermentation and livestock manure and N\textsubscript{2}O emissions from livestock manure. CH\textsubscript{4} and N\textsubscript{2}O emissions are converted to CO\textsubscript{2}e emissions and a total GHG emission is obtained.

| Emission Category                             | GHG Emission (Gg CO\textsubscript{2}e/year) |
|-----------------------------------------------|--------------------------------------------|
| Dairy Cows                                    |                                            |
| CH\textsubscript{4} emissions from enteric fermentation | 0.09016                                    |
| CH\textsubscript{4} emissions from faeces      | 0.04347                                    |
| Direct N\textsubscript{2}O emissions          | 0.03126                                    |
| Indirect N\textsubscript{2}O emissions        | 0.00474                                    |
| Total                                         | 0.16962                                    |
| Goat                                          |                                            |
| CH\textsubscript{4} emissions from enteric fermentation | 0.00391                                    |
| CH\textsubscript{4} emissions from faeces      | 0.00017                                    |
| Direct N\textsubscript{2}O emissions          | 0.00633                                    |
| Indirect N\textsubscript{2}O emissions        | 0.00767                                    |
| Total                                         | 0.01808                                    |

The total GHG emissions produced from dairy cattle are greater than goats. This happens because the number of dairy cattle is double that of goats. However, indirect N\textsubscript{2}O emissions from goats are greater than dairy cows. Overall GHG emissions from the livestock sector are 0.18770 Gg CO\textsubscript{2}e/year.

| Fuel Type  | GHG Emission (Gg CO\textsubscript{2}e/year) |
|------------|--------------------------------------------|
| Firewood   | 0.19817                                    |
| LPG        | 0.00772                                    |
| Total      | 0.20589                                    |

Through Table 2, it is known that GHG emissions in the heat energy use sector. Emissions generated from the use of fuel wood are 0.19817 Gg CO\textsubscript{2}e/year while the use of LPG is 0.00772 Gg CO\textsubscript{2}e/year with total emissions produced by 0.20589 Gg CO\textsubscript{2}e/year. Estimates of total GHG emissions from both the livestock sector and the use of heat energy sources can be seen through Table 3.
### Table 3. Total GHG emissions in Thekelan sub-village

| Emission Category | GHG Emission (Gg CO$_2$e/year) |
|-------------------|---------------------------------|
| Livestock         | 0.18770                         |
| Fuel              | 0.20589                         |
| **Total**         | **0.39359**                     |

Based on Table 3 it can be seen that the overall estimation of GHG emissions in the Thekelan sub-village is 0.39359 Gg CO$_2$e/year. After calculating emissions from livestock and the use of heat energy sources, it can be predicted how much influence the use of biogas in order to reduce GHG emissions and reduce the use of fuel wood & LPG.

#### 3.2 Utilization of Biogas as Alternative Energy

Biomass is an alternative energy resource that can be renewed again. Biomass can mean anything that comes from animals and plants and various other organic compounds. This abundant potential of biomass has not yet been fully developed. Though the supply of energy sources can be sustainable and renewable. Biomass energy is also considered as one of the clean energy recommended as fuel. The process of converting biomass into biogas through an anaerobic process where carbohydrates (C$_6$H$_{12}$O$_6$), fat (C$_{12}$H$_{24}$O$_6$) and protein (C$_{13}$H$_{25}$O$_7$N$_3$S) are converted to CH$_4$.

| Fuel Type | Biogas Production (kg/month) | Remaining Needs (kg/month) | Residual GHG Emission (Gg CO$_2$e/year) |
|-----------|------------------------------|----------------------------|----------------------------------------|
| Firewood  | 3,960.222                    | 5,869.778                  | 0.1183                                 |
| LPG       | 792.0444                     | 0                          | 0                                      |

The biomass that is converted into biogas can certainly replace firewood and LPG as fuel and possibly also space heating. Assuming that each day's dung production is 19.5 kg for cattle and 0.98 for goats, then 1,365 kg for cattle and goats are produced and 33.32 kg for dung. Biogas that can be produced by cattle and goats per kg of manure is 0.038 and 0.028 m$^3$. Therefore, the potential for biogas that can be produced is 51.87 m$^3$/day for cattle and 0.93 m$^3$/day for goats. If the total is obtained the value of 1.584 m$^3$ of biogas per month. Several types of fuel such as firewood and LPG are known to be equivalent to biogas. The value of 1 kg of firewood is equal to 2.5 m$^3$ of biogas and the value of 1 kg of LPG is equal to 0.5 m$^3$ of biogas. The use of biogas can save fuel wood up to 5,869 kg/month and cover all LPG needs. In addition, the use of biogas will only emit 0.1183 Gg CO$_2$e/year from the original 0.19817 Gg CO$_2$e/year. The use of biogas has been proven to reduce GHG emissions so that low carbon villages can be realized.

#### 4. Conclusion

GHG emissions from the livestock sector are 0.18770 Gg CO$_2$e/year while from the use of heat energy sources is 0.20589 Gg CO$_2$e/year. Utilization of biogas produced from 70 cows and 34 goats can replace 3960 kg/month of firewood or 792 kg/month of LPG. In addition, the use of biogas can also reduce greenhouse gas emissions by 0.0798 or by 40% from the emissions of combustion of firewood and eliminate direct emissions from the use of LPG.

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