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# Energy Generation through Manure Waste Management: The Case of Indonesian Village

Agil Harnowo Putra[a], Christia Meidiana[a] and Kartika Eka Sari[a]

*Indonesia is a country with the increasing population leading to the increasing energy demand. Consequently, the problem comes up as the fossil fuel reservation decreases. Therefore, two scenarios of manure waste utilization as a source for renewable energy were proposed and assessed in Tegalweru Village. Best scenario is determined based on the criteria of emergy indices. The calculation showed that scenario 2 is the best scenario since it meets more criteria for the sustainability and efficiency.*

**Field of Research:** Environmental Engineering

## Introduction

Worldwide, about 80% of the consumption of energy comes from burning fossil fuels amounted to 10.4 out of 13 TW (Venkateswara, 2008). In Indonesia, almost 71% of energy consumption depends on fossil fuels (International Energy Statistic, 2011). The high dependence on fossils fuels in Indonesia leads to the high GHG emission, especially from transportation and energy sector which is 4.11 % and 18.3 % respectively (International Energy Statistic, 2011). Indonesia belongs to the 10th highest emitter in the world. Therefore, the Government of Indonesia (GoI) committed in Copenhagen COP 17 2009 to reduce the emission up to 26% by 2020. This commitment is proceeded by the enactment of some regulations and laws related to the development and management of renewable energy. Biogas is a renewable energy having potentials in Indonesia. The conversion of livestock manure into biogas offers some benefits since it reduces the depletion of ozone, minimizes the soil and water pollution, increases the energy supply and decreases the dependence on fossil fuels.

To promote the development of biogas as an energy source, some programs have been launched such as Self Sufficient Energy Village (SSEV) and Household Biogas Program called Program BIRU. SSEV Program encourages the local capability to fulfill the village energy demand, while Program BIRU promotes the usage of biogas from livestock manure to substitute the kerosene and charcoal for cooking. The target area of both programs is village since 60% of the population in Indonesia lives in rural areas. Furthermore, these rural areas suffer from the shortage of energy supply which is the main hindrance in the development of rural areas.

The assessment of available bioenergy from livestock manure is required to evaluate

[a]Agil Harnowo Putra, a Christia Meidiana, aKartika Eka Sari, Department of Urban and Regional Planning Brawijaya University, MT.Haryono Street no 167, Malang,65145, Indonesia. Email: agil.harnowo@gmail.com

the current status, to calculate the supply and to estimate the potentials. Therefore, the study aims to find out the potentials of livestock manure waste of Tegalweru Village for energy generation by proposing the best scenario of biogas development in the study area. This study is delivered into four sections. Section 1 explains the renewable energy from livestock manure waste and the process in anaerobic digester to generate biogas from manure waste. It explains also the advantage of biogas as a renewable energy. The materials and methods used in the study are described in section 2. The parameters of the scenarios are presented in this section, too. The next section shows the results including the amount of manure waste and the flow from emergy for each scenario. The last section explains the final results of the emergy analysis which is the best scenario having more criteria for sustainability and efficiency

## 1. Livestock Manure Waste as Source of Renewable Energy

### 1.1 Anaerobic Digestion

Anaerobic Digestion (AD) is a natural process in which microorganism breakdowns organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide and methane) and digestate (a nitrogen-rich fertilizer) (DEFRA,2011). Biodegradation of organic material occurring in nature is principally through the action of aerobic microorganism or bacteria. Complete oxidation of the carbonaceous organic materials results in the production of carbon dioxide ($CO_2$) and water ($H_2O$). Anaerobic microorganism degrade the organic matter in the absence of oxygen with ultimate products are $CO_2$ and methane $CH_4$ (California Integrated Waste Management Board).

AD has a number of advantages compared to other renewables energy technologies. The process produces energy constantly, unlike wind, tidal and solar power, and can be stored in the grid (in the form of gas). It contains energy since the gas generated contains methane. Methane is one of the new renewable fuels suitable for village that needs constant and instant impact from renewable energy. AD supports the sustainable farming sector, where resources are reused on-farm to reduce GHGs and provide secure and sustainable input (DEFRA,2011).

### 1.2 Biogas as an Alternative Energy

Biogas is composed mainly by methane (60-70%) which is able to produce energy in form of electricity and heat. Biogas is produced using bio-digester built close to the source of raw material for biogas i.e cattle manure with equipment which is able to convert the raw materials into biogas.

Some of the reasons why biogas is feasible to be utilized as an alternative energy are as follows:

1. Biogas can reduce GHG emissions
   Waste and cattle manure, urine and other waste from cattle manure can be used as raw materials in the process of anaerobic digestion to reduce emission of biogas generated by the gas methane (CH4). According to the IPCC National Greenhouse Gas Inventories the amount of 9125 kg/year cattle manure has potentials of of 26 kg/year methane. Therefore the process

of anaerobic digestion can reduce the levels of CH4, that was brought by the raw material i.e. feces of cattle, with the range between 35.2%-40.2%, If all the cattle manure is used for biogas, the total amount of CH4 can be reduced is 9.89 tons per year. Furthermore, residue from biogas process can be used as compost for organic farming by local farmers.

2. Biogas can develop a system of eco-village or the environmentally friendly village
   Most villages Indonesia still use fossil fuels in the form of firewood for their energy needs. The development of eco-village through the utilization of biogas can reduce the dependence on fossil fuel.

3. Accelerating the sustainable development of agriculture
   Sustainable agricultural development is critical in the effort to maintain and to increase the production of the agricultural sector. The development of biogas can support the good agricultural system which emits low GHG such as methane.

4. Promote low-carbon circular economy development
   Biogas development in villages can form a circulation economy with weak carbon value, because the process of anaerobic digestion are biogas processing done at the time capable of reducing harmful gases like nitrogen (NH3-N), phosphorus (P2O5) and potassium (k2O) at 563-1163 mg/kg. 667-847 mg/kg and 1130-1300 mg/kg respectively.

5. Social benefits
   Social benefits gained from the development of biogas in the rural areas is the presence of visible public participation to build and to run the biogas installation. The development and maintenance process should be done by the community so that the community has sense of belonging and courage to manage it. In addition, the cooperation between the biogas farmer and non-biogas farmer will rise.

### 1.3 Sustainability and Efficiency of Manure Management

Management of livestock manure is able to increase the efficiency and usefulness of livestock manure waste. Livestock manure waste is useful to substitute the fossil-fuel-based-energy source commonly used in the village such as kerosene, charcoal, and woods for cooking. Nowadays the manure waste is already widely used for its sustainability and efficiency. Furthermore, waste from livestock manure can be used for organic fertilizer in the agriculture sector. The sustainability and efficiency of cattle dung utilization for biogas can be evaluated using emergy analysis as proposed by Zhou (2009) and Zhang (2010).

Zhou (2009) used emergy analysis to determine the level of efficiency and sustainability of biogas projects in China. He applied several factors such as cattle dung, natural factors, workers, the level of construction and maintenance costs on emery analysis to determine the sustainability and efficiency. Meanwhile Zhang (2010) proposed the utilization of biomass for sustainable energy and evaluated it using emergy analysis.

## 2. Material and Method

Primary data about the availability of manure waste were collected through field surveys. Questionnaires were distributed and direct interviews with the households in were conducted.

Meanwhile, secondary data on population statistic, structure, distribution as well as agriculture pattern is collected from the document officially released by the authority (local government, related department and offices). The study was conducted in Tegalweru Village in Dau District of Malang Regency, East Java Province. The village is located about 10 km away from Malang City.

Two scenarios were proposed and assessed for the utilization of manure waste in Tegalweru Village. The sustainability and the efficiency was calculated using emergy analysis. The scenarios were determined based on the supply energy in Tegalweru Village. There were two conditions which were the baseline condition (scenario 1) and the optimal condition (scenario 2). Scenario 1 was the baseline scenario where the manure from the existing number of cattle (10 heads) was utilized for the energy source. Scenario 2 assumed that manure waste from the available cattles in the village (727 heads) was utilized for biogas source and the biogas residue was used for organic fertilizer . Table 1 shows the description of each scenario:

**Table 1: Scenario Description**

| Scenario | Description |
|---|---|
| 1 | Baseline scenario, where the manure waste from cattle dung used for biogas<br>Baseline scenario was a BAU (business as usual) scenario. |
| 2 | Optimal scenario, where all the potential cattles manure was utilized to produce biogas. Furthermore, biogas residue was used for organic fertilizer. |

Emergy is an abbreviation of the word energy memory that can be defined as the energy that is available and has been previously created for a process either directly or indirectly, whereby such a process would later form a product or service that can be expressed in units of energy (Odum, 1996). The calculation is done by combining emerge in natural resources and the economy having unit of sej (Solar Joules Equivalent). In this study, the calculation of emergy indices is limited to EIR, EYR, ELR and ESI . This calculation was conducted to find out the level of efficiency and effectiveness of waste utilization of livestock excrement in Tegalweru village.

**Table 2: Energy Index**

| ***Index*** | ***Abbreviation*** | ***Formula*** | ***Criteria*** |
|---|---|---|---|
| Emergy Investment Ratio | EIR | EIR= NP+RP/RR+NR | Lower was better |
| Emergy Yield Ratio | EYR | EYR= Y/NP+RP | Higher was better |
| Environmental Loading Ratio | ELR | ELR=(NP+NR)/(RR+RP) | Lower was better |
| Environmental Sustainability Index | ESI | ESI = EYR/ELR | Higher was better |

Source: Odum,HT 1996

## 3. Results

The existing amount of manure and energy uses, as well as its supply and potentials were calculated from the available data. The dung is totally from cattle since there is no other livestock beside cattle. Table 3 shows the salient features of biogas management in Tegalweru Village.

**Table 3: Salient Features of Biogas Management in Tegalweru Village**

| Parameter | Amount |
|---|---|
| Number of farmer (with cattle) | 136 |
| Total Number of cattle | 1080 |
| Total dung [kg/day] | 27000 |
| Number of farmer- biogas | 6 |
| Volume biogas generated $m^3$/day | 44 |
| Number of farmer-non biogas | 130 |

### 3.1 Emergy Flow

Input from energy analysis in the form of a biogas system diagram are free resources, renewable purchased inputs and non-renewable purchased inputs. Free resources consists of sunlight, wind, rain, earth cycle, flushing sewage and solid manure. While the renewable purchased input such as human labor and water. Non-renewable purchased sources in the biogas system consists of the construction and maintenance costs to get the output in the form of biogas, biogas slurry and biogas residue for scenario 1 and organic fertilizer for scenario 2. Two scenarios in the study had the different emergy flow, the difference between that scenario lies in the amount of manure that used as biogas.

The first is the utilization of biogas corresponding with the BAU (Business as Usual) condition in Tegalweru village. The second scenario is a condition in which manure waste from all cattle (1080 heads) will be utilized and the residue will be used for organic fertilizer.

Figure 1 illustrates the emergy system diagram of biogas in the Village Tegalweru according to Odum's rules. Emission which can be reduced by the use of biogas is not calculated by emergy analysis. The calculation is done separately. More detail of emergy flow diagram of the system is described in Figure 1.

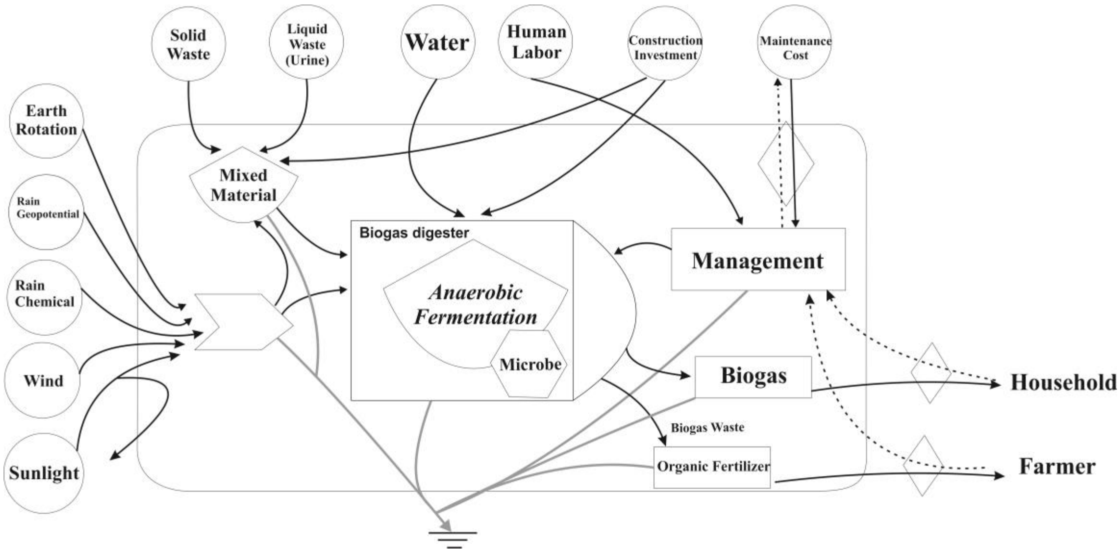


**Figure 1: Emergy System Diagram Scenario 1**

Figure 2 illustrates emergy system diagram of biogas in the Tegalweru Village according to Odum's rules. Emission which can be reduced by the use of biogas is not calculated by emergy analysis. The calculation is done separately, and one additional product that will come out of the scheme is organic fertilizer. More detail of emergy flow diagram of the system is described in Figure 2

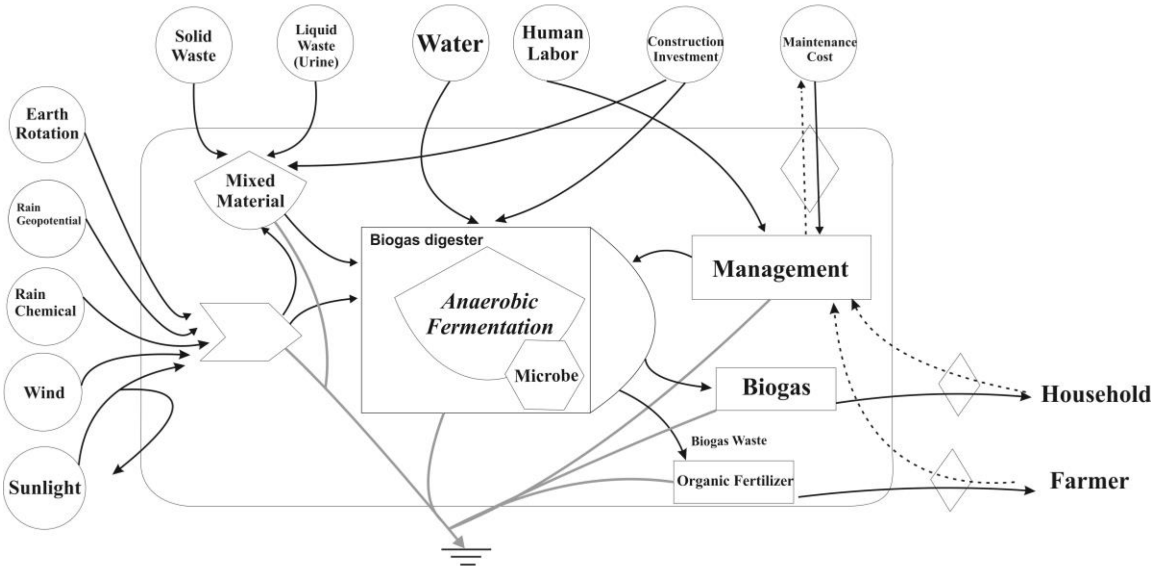


**Figure 2: Emergy System Diagram Scenario 2**

Calculation of the total energy are shown and presented in emergy table. Table 6 shows the results of the calculation of emergy of biogas systems in each scenario. Transformity used in the study were taken from the literature and several previous studies. Each scenario was evaluated in 3 parts, namely, input, process and output.

Table 4 shows that scenario 1 has a total solar emergy of 5.71E+17 seJ and requiring the total emergy investment of 2.04E+15 seJ. Energy input of scenario 1 is the lowest, due to the low utilization of manure that affects the quantity of labor,

finance and other inputs. As the main ingredient in biogas systems, solid manure and urine and sewage flushing has much less contribution which is only 0.07%
Table 5 shows that scenario 2 has the total solar emergy of 2.44E+19 seJ which has more amount compared to scenario 1. It requires emergy investment of 2.18E+15 seJ. Solid manure, urine and sewage has contribution of 0.07% in the biogas system.

**Table 4: Emergy Flow Supporting Biogas System of Scenario 1**

| No | Item[a] | Raw data | Units | Transformity (sej/unit) | References | Solar Emergy (sej/yr) |
|---|---|---|---|---|---|---|
| | | | ***Local Resources*** | | | |
| 1 | Sunlight | 2.07E+09 | J | 1.00E+00 | Odum HT, 1996 | 2.07E+09 |
| 2 | Wind, Kinetic Power | 2.54E+08 | J | 1.50E+03 | Odum HT, 1996 | 3.80E+11 |
| 3 | Rain, Geopotential | 3.09E+09 | J | 1.05E+04 | Odum HT, 1996 | 3.25E+13 |
| 4 | Rain, Chemical | 1.55E+11 | J | 1.82E+04 | Odum HT, 1996 | 2.82E+15 |
| 5 | Earth Cycle, Earth Rotation | 1.67E+08 | J | 3.44E+04 | Odum HT, 1996 | 5.74E+12 |
| 6 | Manure waste | 8.32E+11 | J | 2.70E+04 | Wei,XM *et all,* 2009 | 2.25E+16 |
| 7 | Urine and total liquid waste | 5.87E+05 | J | 3.80E+06 | Geber U, *et all*, 2001 | 2.23E+12 |
| 8 | Human Labor | 3.66E+07 | J | 4.63E+06 | Meidiana,2012 | 1.70E+14 |
| | Total (R) | | | | | 2.53E+16 |
| | | | ***Non-Renewable Resources*** | | | |
| 9 | Grass | 1.48E+05 | kg | 3.68E+12 | Jiang,MM,2009 | 5.44E+17 |
| 10 | Ground Water | 1.18E+02 | m3 | 3.23E+11 | Buenfil, 2001 | 3.82E+13 |
| | Total (N) | | | | | 5.44E+17 |
| | | | ***Economy Input*** | | | |
| 11 | Construction Investment | 2.50E+02 | $ | 5.50E+12 | http://www.cep.ees.ufl.edu | 1.38E+15 |
| 12 | Maintenance Cost | 3.00E+01 | $ | 5.50E+12 | http://www.cep.ees.ufl.edu | 1.65E+14 |
| | Total (F) | | | | | 1.54E+15 |
| | | | ***Yield*** | | | |
| 13 | Biogas | 5.33E+07 | J | 2.48E+05 | Wei XM,*et all* 2009 | 1.32E+13 |
| 14 | *Digestate (liquid)* | 1.29E+08 | J | 5.77E+06 | Geber U, *et all*, 2001 | 7.42E+14 |
| 15 | *Digestate (solid)* | 2.05E+09 | J | 2.70E+04 | Wei XM, 2009 | 5.54E+13 |
| 16 | *N Fertilizer* | 1.29E+09 | kg | 4.62E+09 | Odum HT, 1996 | 5.95E+18 |
| 17 | *P Fertilizer* | 2.21E+08 | kg | 1.78E+10 | Odum HT, 1996 | 3.94E+18 |
| 18 | *K Fertilizer* | 6.39E+08 | kg | 1.74E+09 | Odum HT, 1996 | 1.11E+18 |
| | Total (Y) | 4.38E+09 | | | | 1.10E+19 |

**Table 5: Emergy Flow Supporting Biogas System of Scenario 2**

| No | Item[a] | Raw data | Units | Transformity (sej/unit) | References | Solar Emergy (sej/yr) |
|---|---|---|---|---|---|---|
| | | | ***Local Resources*** | | | |
| 1 | Sunlight | 9.91E+10 | J | 1.00E+00 | Odum HT, 1996 | 1.67E+11 |
| 2 | Wind, Kinetic Power | 7.25E+09 | J | 1.50E+03 | Odum HT, 1996 | 1.83E+13 |
| 3 | Rain, Geopotential | 8.83E+10 | J | 1.05E+04 | Odum HT, 1996 | 1.56E+15 |
| 4 | Rain, Chemical | 4.43E+12 | J | 1.82E+04 | Odum HT, 1996 | 1.36E+17 |
| 5 | Earth Cycle, Earth Rotation | 4.77E+09 | J | 3.44E+04 | Odum HT, 1996 | 2.76E+14 |
| 6 | Manure waste | 3.33E+13 | J | 2.70E+04 | Wei,XM *et all,* 2009 | 8.98E+17 |
| 7 | Urine and total liquid waste | 2.35E+04 | J | 3.80E+06 | Geber U, *et all*, 2001 | 8.93E+10 |
| 8 | Human Labor | 8.72E+08 | J | 4.63E+06 | Meidiana,2012 | 4.04E+15 |
| | Total (RR) | 3.79E+13 | | | | 1.04E+18 |
| | | | ***Non-Renewable Resources*** | | | |
| 9 | Grass | 5.91E+06 | J | 3.68E+12 | Jiang,MM,2009 | 2.18E+19 |
| 10 | Ground Water | 4.73E+06 | kg | 3.23E+11 | Buenfil, 2001 | 1.53E+18 |
| | Total (N) | 5.91E+06 | | | | 2.33E+19 |
| | | | ***Economy Input*** | | | |
| 11 | Construction Investment | 1.00E+04 | $ | 5.50E+12 | http://www.cep.ees.ufl.edu | 5.50E+16 |
| 12 | Maintenance Cost | 1.20E+03 | $ | 5.50E+12 | http://www.cep.ees.ufl.edu | 6.60E+15 |
| | Total (F) | 1.07E+07 | | | | 6.16E+16 |
| | | | ***Yield*** | | | |
| 13 | *Biogas* | 1.21E+13 | J | 2.48E+05 | Wei XM,*et all* 2009 | 3.00E+18 |
| 14 | *Biogas slurry* | 5.14E+09 | J | 5.77E+06 | Geber U, *et all*, 2001 | 2.97E+16 |
| 15 | *Biogas solid* | 7.59E+09 | J | 2.70E+04 | Wei XM,et all 2009 | 2.05E+14 |
| 16 | *N Fertilizer* | 2.06E+12 | kg | 4.62E+09 | Odum HT, 1996 | 9.52E+21 |
| 17 | *P Fertilizer* | 3.54E+11 | kg | 1.78E+10 | Odum HT, 1996 | 6.30E+21 |
| 18 | *K Fertilizer* | 1.02E+12 | kg | 1.74E+09 | Odum HT, 1996 | 1.78E+21 |
| | Total (Y) | 1.55E+13 | | | | 1.76E+22 |

## 4. Discussion

### 4.1 Emergy-Base Indices Result

Emergy-base indices calculation of biogas system are presented in Table 6. There are EYR, EIR, ELR and ESI.

**Table 6: Energy-Base Indices Result**

| Item | Scenario 1 | Scenario 2 | *Criteria* |
|---|---|---|---|
| Emergy Yield Ratio | 7.14E+03 | 2.86E+05 | Higher was better |
| Emergy Investment Ratio | 2.04E+15 | 2.18E+15 | Lower was better |
| Environmental Loading Ratio | 2.13E+01 | 2.04E+01 | Lower was better |
| Emergy Sustainable Index | 3.32E+02 | 1.28E+04 | Higher was better |

Table 6 showed that scenario 2 has the highest EYR value compared to scenario 1. This indicates that the second scenario is an efficient alternative in recovering emergy because of the higher utilization of livestock manure into biogas and organic fertilizer. In emergy investment ratio, scenario 1 has the lowest value, caused by a lower input compared to scenario 2 where the manure which used in scenario 1 fewer than the scenarios 2 that will affect other inputs such as the number of labor, water, construction investment and maintenance costs. ELR is an indicator to show the environmental burden of each scenario. Scenario 2 has lower value than the ELR on scenario 1 which reflects the lower pressure on the environment. The value of ESI showed that scenario 2 has the highest sustainability compared to scenario 1 because scenario 2 has higher EYR and lower ELR.

## 5. Conclusion

The utilization of cattle manure for biogas was evaluated in this study. The evaluation using emergy analysis was applied on two difference scenarios which are the BAU scenario and optimum scenario. The calculation included the Emergy Investment Ratio, Emergy Yield Ratio, Environmental Loading Ratio and Environmental Sustainability Index.

The result of the calculation showed that the scenario 2 which is the optimal scenario is better than scenario 1 in terms of Emergy Yield Ratio, Environmental Loading Ratio and Environmental Sustainability with a value of 2.86E+05 seJ, 2.04E+01 seJ and 1.28E+04 seJ, respectively. Scenario 2 (Optimum scenario) utilizes the output from biogas production not only for household, but also for the agriculture sector. The household can use the biogas for cooking, while the agricultural sector can use the organic fertilizer from the biogas residue. This can support the welfare of the community and the sustainability of the agriculture sector.

It is recommended for the next studies that the value of transformity should be calculated prior to the emergy analysis since the use of transformity from other references can lead to the bias of results since it may not represent the local conditions. Furthermore, the more scenarios can be proposed to enhance the possibilities of rural energy development with slightly different parameters.

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