Optimization biogas management as alternative energy from communal scale dairy farm

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Abstract. Cow Slurry can be the main pollution source in most villages in Indonesia. In this study, treatment of cow slurry intended to reduce pollution in Citarum river and greenhouse gases effect of CH4 and CO2. As a part of renewable energy, biogas can be one of solution to be implemented in small-scale and remote area. In Pejaten, Tarumajaya Village, the cost-effective reached when 7 cattleman united to treat cow slurry in one biodigester. The breed varies cow from calf, veal to adult cattle. The installation of anaerobic-bio digester that produce biogas 28 m³/day equivalent with Rp 168,000 to be consumed for 14 households. In addition, villager also benefitted manure as 42.5 ton monthly. As a whole, the highest profit comes from adult cattle that produce 900 kg/month slurry as Rp 59,919 monthly. Furthermore, this system gives job opportunity for villagers to be biodigester operator is the main beneficial with the higher income compare to mower that only Rp 600,000 monthly as Rp 1,065,000.

Keywords: anaerobic-biodigester, biogas, cow-slurry, cost-effective, job opportunity, manure

1. Introduction
Dairy Commodity is a means of empowering the community because the characteristics of its products can be harvested daily, thus allowing farmers to earn a sustainable income [1]. Although cattle farm provide economic benefits and community empowerment but it have a negative impact such as animal waste in the form of livestock manure, the remaining feed and others. Livestock manure chemically contains complex and high organic materials. Livestock manure discharged into waters can contaminate water quality due to high organic material, which can cause algae blooming, development of pathogenic bacteria and decrease oxygen content in waters due to increased microorganisms, thereby threatening fish life in these waters. Meanwhile, if stacked can pollute the land and seep into the groundwater or carried away "run off" into the surface water. The accumulation of livestock waste over a long period of time, will result in an anaerobic process in the decomposition of organic matter and will lead to the release of methane (CH4) and CO2 into the air, which can contribute to global warming. Good livestock waste management is essential to minimize negative environmental impacts, such as pollution to soil, water and air and infectious diseases [2]. The previous study showed that biogas also have possibility to be utilize as power generation source [3],[4] and as daily needs consumption energy [5]. In addition, the sludge output from Biogas reactor can be reused as raw material of organic fertilizer. Therefore, processing of cattle livestock wastes with biogas technology or anaerobic digesters can provide benefits in terms of economic and environmental aspects. This is one of the cause of the slacken gait of biogas development as [6]. Biogas development opportunity as an alternative energy source and energy decentralization is very big considering the decrease of fossil fuel and increasing of pollution caused by the use of petroleum fuels and the increasing of oil price. As alternative energy, compare to other energy
sources Indonesia government have just pay more attention lately. Even biogas technology itself has been introduced since 1962 in Indonesia. Research on the use of livestock waste, especially cow feces to become biogas has been widely done both inside and outside the country, some research suggests that biogas has the potential to be developed to become a renewable energy source both from technical aspect, environmental aspect and economic aspect. But until now the utilization of biogas technology in cow breeding, especially in Indonesia has not been running sustainably [7], [8], [9], [10], [2]. Study on existing condition of biogas technology utilization in study area is a first step to know coefficient of coefficient in arranging optimiation model of biogas technology utilization in dairy farm in sustainable study area. The optimization model approach will be done using Linear programming.

2. Research Method
The wide focus research of biogas usage has been done by in the previous study by qualitative method to get the affected and interrelation component for sustainable biogas production in cow farmer. Thus, this research conduct to examine area of study that related with farming activity and biogas production, existing condition of biogas utilization and to formulate optimiation model of biogas utilization community based by linear programming in resource allocation and pollution control. The research object, is Biogas Reactor, farmer and non breeder in the study area. Furthermore, this study will allocate maximum number of farmer and biogas consumption with natural and human resource, revenue of biogas farmer/worker as the constrain. Data were obtained by direct observation in the study area, distributing questionnaires and direct interviews, and laboratory analysis. The number of respondents for breeders is 120 kk. Optimum condition in reaching sustainable development require:

1) In order to avoid pollution in the river then, all cow manure produced in the study area is processed into biogas (not disposed of the river)
2) Biogas price should be ≤ LPG (Liquid Petroleum Gas) price
3) Land requirements for houses, cattle pens and biogas reactors ≤ 40% of total residential area
4) Total grass fields ≤ 60 Ha (available with permission from Perhutani)
5) River water usage for livestock and biogas ≤ 10% river water discharge
6) The income of dairy cattle worker, worker of biogas and worker of fodder and workers ≥ Rp 1,060,500 / month (Regional minimum wage of Kab. Bandung).

The Scenario to be applied are:
1) The maximum income can be obtained by varying the number of livestock by age category (calf, veal and adult cattle), grass management and biogas business management as an interconnected and bonded sustainable supporting business. To run a dairy farm business, cultivation of grass and biogas effort required limited land resources and water resources.
2) The maximum revenue of biogas exploitation can be achieved by varying the number of livestock manure being treated and the pattern of livestock management

The revenue of dairy farms (Y) can be counted as:

\[ MaksY = aX_1 + bX_2 + cX_3 \] (1)

Whereas a is the average profit for 1 calf caring. \( X_1 \) is number of calf. b is the average profit for 1 veal caring. \( X_2 \) is number of veal. c is the average profit for 1 adult cattle caring. \( X_3 \) is number of adult cattle.

For obstacle of lawn formulated as:

\[ dX_1 + eX_2 + fX_3 \leq 600,000 \text{ m}^2 \] (2)

Whereas \( X_1 \) is the lawn need for \( X_1 \), \( X_2 \) is the lawn need for \( X_2 \) and \( X_3 \) the lawn need for \( X_3 \). While for land formulated as :

\[ (g+h)X_1 + (i+j)X_2 + (k+l)X_3 \leq 40 \% \text{ land-yard} \] (3)
Whereas \( g, i, k \) is land need for cow pen of \( X_1, X_2, \) and \( X_3 \) and \( h, j, l \) is land need for biogas reactor of \( X_1, X_2, \) and \( X_3 \). Water resources formulated as:

\[
mX_1 + nX_2 + qX_3 \leq 10\% \text{ water flow}
\]

Whereas \( m, n, q \) is water need for cattle and biogas reactor. Total biogas production formulated as:

\[
P_{bg} = (T \times M \times C_{bg})
\]

Whereas \( T \) is number of cattle in study area and \( P_{bg} \) is biogas production (m\(^3\)/yr). \( M \) is number of manure every cattle (kg/head/yr). \( C_{bg} \) is coefficient of biogas forming from cow manure (m\(^3\)/kg) = 0.03 m\(^3\)/kg Manure [2]. To obtain optimal results, it is necessary to analyze the sensitivity of the model to the variation of the number of cattle based on the age category. Based on the analysis of the long-term opportunity of raising livestock (calf 4 months, veal 8 months, and adult cattle 24 months), then made some alternative combination of livestock breeding between amount of calf, veal and adult to choose the most optimal combination.

This study located in Pejaten Village, Tarumajaya, Kertasari sub-district, Bandung, West Java (7°12'11.1"S 107°39'50.2"E). The domain system is village of cow-farming community based where residential area and cow farming along the river. Besides, it also nearby Cisanti wellspring and conservation area, which cow-farmer activities have direct impact to environment. Even several biogas reactor either individual or communal installed in this area but obstruction occurred like unoptimum function, unmanaged and abandon. Dairy farming in Pejaten comprises of 5 group with different number of cattlemen as seen in the Table 1.

**Table 1. Dairy Farming in Pejaten**

|          | Unit                          | Group          |
|----------|-------------------------------|----------------|
|          |                               | Pejaten 1      |
|          | Number of Cattleman           | Pop. 35        |
|          | Number of dairy cows         | Head 69        |
|          | Average ownership lactacy cattle per Cattleman | Head 2 |
|          | Total Revenue                 | Rp/month 35,561,200 |
|          | Average revenue per Cattleman | Rp/month 1,016,034 |
|          | Total MilkProduction         | liter/month 28,633 |
|          | Average MilkProductionper Cattleman | liter/month 895 |
|          |                               | Pejaten 2      |
|          |                               | Pejaten 3      |
|          |                               | Pejaten 4      |
|          |                               | Grand Total    |
|          |                               | 35             |
|          |                               | 35             |
|          |                               | 25             |
|          |                               | 44             |
|          |                               | 120            |
|          |                               | 35             |
|          |                               | 35             |
|          |                               | 25             |
|          |                               | 44             |
|          |                               | 477            |
|          |                               | 2              |
|          |                               | 2              |
|          |                               | 2              |
|          |                               | 2              |
|          |                               | 35,561,200     |
|          |                               | 46,155,300     |
|          |                               | 42,965,200     |
|          |                               | 61,485,000     |
|          |                               | 186,166,700    |
|          |                               | 1,016,034      |
|          |                               | 1,318,723      |
|          |                               | 1,718,608      |
|          |                               | 1,397,386      |
|          |                               | 1,339,329      |
|          |                               | 28,633         |
|          |                               | 32,887         |
|          |                               | 28,078         |
|          |                               | 38,062         |
|          |                               | 127,661        |
|          |                               | 895            |
|          |                               | 940            |
|          |                               | 1,276          |
|          |                               | 928            |
|          |                               | 982            |

Source: Report of unit economic KPBS, 2009

* The Revenue excluded with cost of fodder

As KPBS (Koperasi Peternakan Sapi Perah Bandung Selatan) become the second biggest unit economic in Indonesia whereas Kertasari Sub-district is one of member. Hence, the number of Dairy cows greater than beef cattle. Every cattlemen has 1 to 6 head of cows.

3. Results and Discussion

3.1 Survey Result

Based on the survey results, it can be drawn up several point. Manure livestock aslivestock byproduct need systemic management to reduce its effect to greenhouse effect and other seriousenvironmental pollution [11]. The population of livestock in the study area reached 477 animals, if the average produce 20 kg of dirt per day, it will produce 9.40 kg/day manure.
Most of cattlement directly discharged livestock manure into the river (Figure 2). As many as 86.3% dispose directly into the river stream, 5% of farmers accumulate to be used as fertilizer and only 3.8% breeders cultivate into biogas. Several causes of cattlement did not treat the manure is limited land provide for reactor (57.5%) and funding issues (21.3%). Thus, the development of biogas reactor should be done through group system and the existence of stimulus fund for farmers as. In fact, only 22.8% of farmers understood that livestock manure could be processed into biogas and fertilizer and 25% of farmers understood to be fertilizers. As many as 12.7% knew that livestock manure could be made as biogas and slurry discharged into the river and 39.2% of farmers state that livestock manure can be discharged into the river. While the reactor owner's understanding of livestock manure management answered 88.9% biogas owners understand that cattle manure can be made biogas and its effluent is used as fertilizer, and only 11.1% of respondents stated that livestock manure can be discharge into the river. Main reason of undevelop biogas utilization are inhabitants did not know the usefulness of biogas (67%). Unsuccessful biogas reactor development due to the operator absence’s, therefore it is necessary to do further study the possibility of communal biogas reactor management and fully managed by operator who benefit financially from management of biogas reactors. Regarding with the readiness of the community in utilized biogas communal showed from 148 respondents, 56.3% of farmers agreed while 43.8% disagreed (Figure 3).

If biogas reactors are communally administered, a management officer must be required to obtain service fees, so that biogas reactor can operate sustainably. In Figure 4 it can be seen the percentage of respondents willingness to pay.

As 82.4% of the inhabitants is willing to use and manage biogas with mutual cooperation even in fact, there are no biogas reactors that function individually or communally, this is probably due to the lack of understanding of biogas reactor management, Organization of biogas managers. In addition, this biogas reactor given to farmers who have busy activity, so it is not possible to do sidejob. Of the 135 respondents, only 57 respondents were willing to pay contributions to use biogas. The ability to pay the...
biogas usage fee monthly are varied from Rp 100,000 (1.8%), Rp 50,000 (7%), Rp 25,000 (73.3%). Inhabitant are common to use LPG and firewood, as shown in Figure 5 whereas half inhabitant (53%) useLPG, quarter of still using firewood (25%) and 12.5% use combination for firewood and LPG. The monthly expenditure on fuel per head of family was Rp 78,000, equivalent to 6 kg of LPG and equivalent to 12 m³ biogas, so the biogas price equal to Rp 6,500/m³.

3.2 Model Result
By optimization model, it found that variation 5 reach monthly optimum profit by Rp 1,432,291,54.
The result of constrain shows that lawn is the component which always run out for every variation as seen in the Table 2.

**Table 2. Constrain in Optimization Model**

| Variation | Constraint 1 (lawn) | Constraint 2 (land) | Constraint 3 (water resource) |
|-----------|---------------------|---------------------|--------------------------------|
| 1         | 0                   | 30,801              | 571,200                        |
| 2         | 0                   | 31,287              | 577,400                        |
| 3         | 0                   | 31,598              | 581,374                        |
| 4         | 0                   | 31,815              | 584,139                        |
| 5         | 0                   | 31,898              | 582,870                        |
| 6         | 0                   | 29,192              | 550,675                        |

Farm size that include in availability land is the constrain of manure processing into biogas [12] and it’s stated as constrain 2, land remind between 30.801 – 29.192 m² exclude population growth. While constrain 3, Pejaten village is water surplus area. Profitability index (PI) of variation 6 are shown in Table 3.

**Table 3. Profitability Index (PI) for Dairy Cow with Variation 1:1:6**

| Year | CF      | IR (12%) | Present Value | IR (15%) | Present Value |
|------|---------|----------|---------------|----------|---------------|
| 1    | 10,241,622 | 0.892857 | 9,144,304.06  | 0.869565 | 8,905,756.20  |
| 2    | 4,055,733  | 0.797194 | 3,233,206.24  | 0.756144 | 3,066,718.39  |
| 3    | 2,296,093  | 0.71178  | 1,634,312.72  | 0.657516 | 1,509,717.56  |
| 4    | 723,606    | 0.6355581| 459,864.90    | 0.571753 | 413,724.14    |
| 5    | 7,336,117  | 0.567427 | 4,162,710.62  | 0.497177 | 3,647,348.43  |
| 6    | 14,154,594 | 0.508831 | 7,171,156.31  | 0.432326 | 6,119,399.17  |
| 7    | 26,470,998 | 0.452349 | 11,974,129.53 | 0.375937 | 9,951,427.62  |
|      | Asset in 80% month | 113,000,000 | 39,815,211.00 | 0.27859 | 31,480,670.00 |
|      | Sum PV     | 65,278,763  | 77,594,895.38 | 65,094,761.51 |
|      | OI         | 54,000,000.00 | 54,000,000.00 |
|      | NPV        | 23,594,895.38 | 11,094,761.51 |
|      | PI         | 1.44       | 1.21          |           |

**Table 4. Optimum Condition of Cow Cattle (variation 1:1:6)**

| Description      | Unit | Calf | Veal | Adult Cattle | Total |
|------------------|------|------|------|--------------|-------|
| Number of Cow    | Head | 269  | 269  | 1,617        | 2,155 |
| Fodder need      | kg/month | 40,350 | 121,050 | 1,697,850 | 1,859,250 |
| Pen cow width    | m²   | 12,878 | 38,633 | 541,873 | 593,384 |
| Pen cow width and | m²   | 678  | 1,423 | 9,427 | 11,528 |
| Biogas Reactor   |      |      |      | 88,935 | 118,525 |
| Water need       | liter/day | 14,795 | 14,795 | 1,309,064,988 | 1,418,903,337 |
| Profit           | Rp/month | 43,068,245 | 66,770,104 | 1,309,064,988 | 1,418,903,337 |
| Biogas Production| m³/month | 1,816 | 3,632 | 43,659 | 49,106 |

And the optimum one is for variation 4 with profit 1,418,903,337 and PI more than 1 for IR 12% and 15%. By this variation, need 270 cattleman with the monthly revenue Rp 4,853,424. It means 2.25 times than those number of cattleman (the average regional wage Rp 1,0605,000) with monthly revenue
Rp 1,339,329 (excluded cost of lawn worker). Biogas production from 2,155 cow is 49,106 m$^3$/month equal with 19,553 kg LPG as Rp 254,189,000 /month (see Table 4). At the moment, the number of cow is reach 477 head, with 120 cattleman. Means the utilize of natural resources is sufficient for farming needs. Even cattleman often facing less fodder since cattleman do not vary on the fodder intensively.

4. Conclusion

To reach sustainable biogas management, it need to consider the interrelation component compose of farmers, cattle, land farming, food, water resource, biogas, non-biogas fuel in Pejaten Village, Tarumajaya Bandung West Java connected with profit, farmer welfare and pollution control. The farmers get used to throw cow waste into Citarum river and make the decrease of DO from 5.8 into 4.9 mg/L and BOD increase from 15 into 101 mg/L. Biogas potential of 477 cattle is 285 m$^3$/day equal with 142 kg LPG for 711 household consumption. By linear programing, it shows the maximum profit able to reach if the combination of calf: veal : adult cattle is 1 : 1: 6 with the total number 2.155 cows. The constrain as maximum revenue is availability of land farming for 60 ha. The other constraint is water resource and homeland.

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