Evaluation of Waste Reduction Sustainability

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Abstract

Waste reduction at the source is currently one of the major project in Indonesia. The main challenge of this project is to maintain its sustainability. The purpose of this study was to identify the level of sustainability of waste reduction system which was carried out in Cibangkongof Bandung City and Cilengkrang of Bandung Regency. These area are using Biodigester as the main technology to treat their organic waste. The level of sustainability was measured by using Weight Ranking Teqhnique (WRT) method based on three aspects, namely social, environmental and economic. The main indicators of the environmental aspects measured by the rate of waste reduction, economic indicators measured by Cost Benefit Analysis method while social indicators measured by the level of community participation. The efficiency of waste reduction in Cibangkong was smaller which only 49.5 L/day at 0.84% compared to Cilengkrang which has 80.53 L/day. The benefits of waste reduction to society was best perceived by Cibangkong (0.535 points) than Cilengkrang (0.465 points). The results of WRT method, the level three aspects of sustainability, Cilengkrang has a score of 0.546 meanwhile Cibangkong only at score of 0.454. The result showed that the level of of waste reduction sustainability in Cilengkrang which represent the sub urban areas was better than in the Cibangkong which representing urban areas.

Keywords: Waste Reduction, TheSustainabililty Level, Environment, Social, Economy

1. INTRODUCTION

Law No. 18 of 2008 declare that waste management is consists of waste reduction and waste handling. Waste handling is a series of activities that include sorting waste handling, collection, transportation to the processing of the final disposal. While waste reduction activities is addressing the emergence of waste from the source, reuse and recycling at the source and / or at on-site processing, these activities are known as the 3R (reduce, reuse, recycle) programs.

In Indonesia, various waste reduction activities made by local governments, in particular City Waste Management Institution of the City Government and the City District Government. Under Law no.18 / 2008, every local government is obliged to establish waste reduction targets and makes every effort to achieve it. The 3R target fulfillment, have been carried out using various types of both individual and communal technologies that are considered to have an appropriateness elements, such as composting. Honnwerg, et.all, 2000, informed over the past decades composting have failed due to technical, financial, and institutional reasons in the developing countries. Some of them are due to lack of attention to the biological process necessities, poor feed stock which yields poor quality finished compost, sensible preoccupation by municipal authorities to first concentrate on providing adequate waste collection, nuisance potential, poor marketing experiences, poor integration with the agricultural community, and sometimes constrains in land requirements.

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Especially in West Java for the last few years there has been a change towards the use of technology, by using anaerobic digester which often called as bio-digester. It is considered more practical in terms of operation and utilization of the bio-digester product, which can be directly used. Edelmann, et.al, 2005, stated that anaerobic digestion is shown to be advantageous compared to composting, incineration or a combination of digestion and composting mainly because the energy it generates is quite balanced. In addition, Igoni, et al., in 2007 said that the technology could be the solution as an alternative energy in the middle of low fossil energy production and noticed the opportunities of high municipal solid waste generation.

Learning from the ineffectiveness of the composter implementation, then the use of bio-digesters should perceive about the meaning of sustainability. Based on the definition from Brundlant, 1987, and Barbier, 1987, an activity can be stated to have a level of sustainability if it takes into consideration the three main pillars: environmental, social and economy. So to be considered sustainable, 3R program should pay attention to these three pillars. Integration of sustainability toward the use of the bio-digester, is urgently needed because the implementation of waste management by communal bio-digester has developed sporadically in both the urban and sub urban of Bandung City. Based on observations, the initiation of the implementation of the 3R program with bio-digester was initiated by various parties, ranging from the local government, the private sector through public initiatives, CSR even from the community itself. Therefore, 3R program with communal bio-digester is expected to reduce waste generation.

This study aims to compare the sustainability of the 3R program with biodigester through various differences in its initiation, from the local community and local government. The study also examines: (1) The level of environmental sustainability,observed through the impact of the existence of communal biodigester related to the level of waste reduction; (2) The level of economic sustainability, observed through self-reliance funding on the implementation of the 3R with manual biodigester and the level of its benefit for the society; (3) The level of social sustainability, observed through the level of community participation in the implementation of the program of communal biodigester; and (4) The level of waste redcution sustainability by using biodigester in both urban and sub urban area.

2. MATERIALS AND METHOD

This research will discuss each pillars of sustainability and its integration which consist of social, environment and economic pillars that can be seen in the scheme in Figure 1.

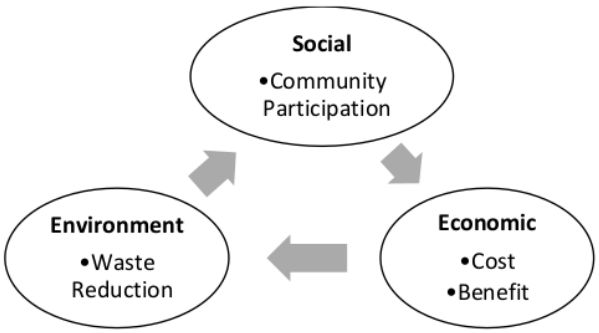

Figure 1. Research Scheme

The study were dominantly conducted as a field study which covered two study areas. The indicator in selecting the study area were (1) the use of bio-digester as the communal technology in 3R program, (2) different initiation, and (3) represents the differences between urban and sub urban area. The selected area was Cibangkong (RW 11) in Bandung City which represent the urban area and has initiative from stakeholders

such as government, academic institution (UNPAD) and private sector (Biomethagreen). Whereas Cilengkrang (RW 17) in Bandung sub-districts represents the sub-urban area with initiative solely comes from the community and it has other 3R activities which being in active implementation, such as composting actions and bio-pori actions.

The biodigester specification in both study area are made of fiber and resin, the process use water and waste with ration of 1:1, meanwhile the contrast are as follows (1) Cibangkong was using trapezoidal in shape with total volume is about 550 L, continues feeding, waste segregated, (2) Cilengkrang : trapezoidal in shape with total volume is about 150 L, semi continues feeding, waste segregated and chopped.

The measurement on environment sustainability will focus on the waste reduction. Waste reduction will calculated based on waste generation, waste input to bio-digester and the ration of bio-digester capacity with waste input. The waste input was directly measured and conducted using the Indonesian National Standard (SNI)19-3964-1994, while the waste generation of each area study were calculated based on the previous study which was conducted by Dwihapsari, 2013. The key parameter of waste characterization in bio-digester process was measured in accordance to the standard method for the examination of water and wastewater which can be seen at Table 1. The purpose of waste characteristic measurement was to determine the substrate feasibility of bio-digester in order to produce gas and fertilizer. Parameters that being measured for waste characterization are Moisture, Organic Carbon, Nitrogen Total Kjedahl (NTK), and Phosphate.

Table 1. Key Parameter Method Measurement

No.	Parameter	Method
1.	Moisture	Gravimetry
2.	Organic Carbon	*Wakley and Black*
3.	Nitrogen Total Kjedahl	Kjedahl analyzer
4.	*Phosphate*	Spektrofotometry

The social sustainability will focus on measurement of the level of community participation meanwhile the economic sustainability measurement will focus on determination of financial analysis to gain the cost data, the pay-back period data and the level of beneficiaries of bio-digester that the community experienced. Both pillars were measured by using questionnaires with research design questionnaire scheme that can be seen in Figure 2. The questionnaire which was designed using Likert Scale and also using related secondary data. Slovin formula was used to determine the number of sample in each study area. The secondary data were used for analyzing the cash flow in calculating the pay-back period. The data needed are the investment data for biodigester manufacturing, revenues and expenses which are incurred due to the 3R activities, such as income of gas and liquid fertilizer sales and bio-digesters operation and maintenance cost. The entire unit calculations on the financial aspects were using Rp.per year.

The analysis will be conducted on every aspect of sustainability separately in order to get the comprehensive review which used qualitative and quantitative analysis methods. Meanwhile the comparison of the degree of the sustainability of 3R program for both study area will used the Weighted Ranking Method.

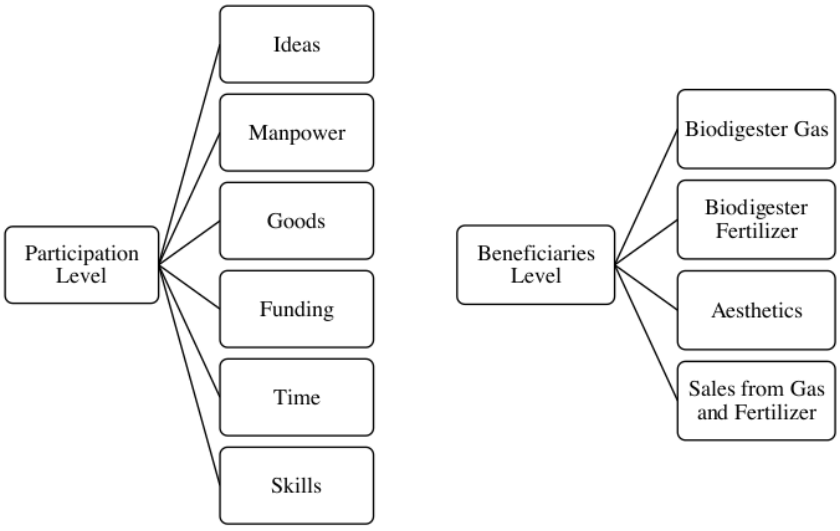

Figure 2. Research Questionnaire Design Scheme

3. RESULTS AND DISSCUSSION

3.1. The Level Of Environment Sustainability

Ratio of waste characterization on key parameter can be seen in Table 2. However, moisture content of the waste in Cibangkong are 90.9% and Cilengkrang was only 78.8%.The waste moisture in Cibangkong were larger than in Cilengkrang, the condition was caused by the differences of waste composition. Cibangkong waste composition was dominantly consists of food scraps or processed foods that are mixed with water, while Cilengkrang was dominated by agricultural products. Moisture content play a role to serves as a medium to transport critical nutrients (Honnwerg, et.all, 2000). Furthermore, both of the study area has waste moisture content above 60% which will restrict air movement and can resulted in anaerobic conditions (Lardinois and van der Klundert, 1994).

Table 2. Waste Characterization Comparison

Study Area	C:N	C:P	N:P
Cibangkong	31.84	1592.11	50
Cilengkrang	30.53	8141.67	266.67
Standard Theory	50	250	5

Table 2 also informs ratio C:N between two study area were not much different. However, low content of phosphate in both of study area (Cibangkong 0.076% and Cilengkrang 0.0012%) create the ratio of C: P and N: P were significantly different than the standard. Higher phosphate content (6 times) than in Cibangkong also due to the waste composistion differences. The content of phosphate in food scraps or processed foods is higher than in agriculture product for which phosphate is part of a nucleic acid that is present in all organisms and is an essential component of RNA, DNA, ATP, and phospholipids but in nature it is not available in large quantities (Waluyo, 2007). Compared with the ideal conditions in the biodigester process, the C: N ratio was below standard which mean that the waste has low nitrogen content and the low content of

phosphate causing the ratio C: P and N: P above standard. Based on the waste characteristic the biodigester in both study area needs a phosphate supplied as a starter in order to enhance the process of their bio-digester.

The most important part from environmental aspect is waste reduction. The waste generation from RW 11 Cibangkong and Cilengkrang up to 2.9 m^3/day and 0,565 m^3/day in sequence. The percentage of reduction due to Biodigester facility in Cibangkong was only 1.69%/day (0,49 m3/day), meanwhile the percantage in Cilengkrang reach 14.25% (0,8 m3/day). Actually, those percentage can be upgraded by maximizing the capacity of biodigesters. According to our calculation, biodigester in Cilengkrang was only used only 9% of their capacity and in Cilengkrang was up to 53%. This condition described that we need increasing public participation to increasing waste reduction by bio-digester.

3.2. The Level Of Social Sustainability

The level of Social Sustainability can be seen by the community participation. Sudradjat, 2000, stated that community participation consists of participation in forms of of ideas, man power, goods, funding, time and skills. The comparison of participation level in both of study area that divided into three categories (high level, medium level and low level) can be seen at Figure 3.

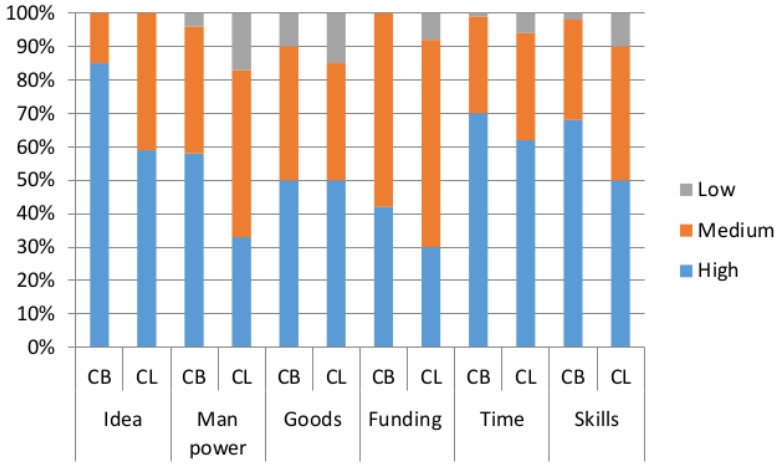

Figure 3. Proportion of Community Participation

The high level in all forms of participation can be seen more dominant in Cibangkong meanwhile the medium level were dominantly shown in Cilengkrang except participation in forms of goods. The community of Cibangkong prefer to participate more in forms of idea, time and skills meanwhile community of Cilengkrang prefer more in giving of their time and idea. Those phenomena were influenced by the difference of social economic level. The social economic characteristic in urban area shows that the education level were relatively higher, the types of profession force them mostly occupied more in the work places and the community contribution were relatively diverse.

The score of participation level in Cibangkong reach up to 3.6 points meanwhile Cilengkrang reach up to 3.3 points, even though their level was average (the highest participation reach up to 6 points) but Cibangkong community participation level were higher than Cilengkrang. This data shows that the community acceptance of Bio-digester in their area were quite high.

3.3. The Level Of Economic Sustainability

The level of Economic Sustainability can be seen by two aspects, which are the pay-back periods and the level of beneficiaries.

A. The Pay Back Periode

The pay back periods were calculated by make use of the investment costs and the cash flow analysis. Although the bio-digester in Cibangkong were granted from Unpad (Padjadjaran University), in this study the investment cost were taken into account so that the comparison will be equal. Based on direct interview and secondary data the investment cost for developing the bio-digester in Cibangkong and Cilengkrang in sequences were up to Rp. 28.000.000,- and Rp. 18.000.000,- where the contrast due to the capacity differences and in the process of developing the bio-digester. The cash flow analysis was calculated by taking into account the revenue and the expenses in the operation of 3R program implementation in each study area. The analysis were included not only the operation and maintenance of bio-digester but also other 3R activities that reduce waste (such as waste bank, communal composting and bio-pore action) along with other supported activities (such as the transportation of waste to landfill).

The revenue were mainly come from the retribution of waste management from the community (dues in Cibangkong Rp.5000,- per house/month meanwhile Cilengkrang Rp. 10.000,- per house/month). The other revenue comes from both sales of the bio-digester products which were gas and fertilizers and other 3R activities products. The sales gained in both study area for Cibangkong were respectively reached up to Rp.960.000/year and Rp. 12.000.000/year meanwhile Cilengkrang reached up to Rp. 120.000/year and Rp. 20.400.000/year. Based on this data, it shows that in the point of economic view the bio-digester alone would not support the cash flow of the area, meanwhile other 3R activities were more economic reliable for the community. In general, the revenue in Cibangkong (Rp. 42.960.000,-/year) were considerably higher than in Cilengkrang (Rp. 40.320.000,-/year) due to several differences such as number of households, the dues per households and especially the active level of 3R programs in the area.

The expenses were calculated by taken into account the cost for operating and maintaining the 3R program in the area which can be divided into fixed costs and variable costs. The differences in element of the fixed costs other than waste employee wages in the study area were the waste transportation costs in Cibangkong as it was included in City waste management agency service area, meanwhile Cilengkrang were not. These facts causing the cost of fixed costs in Cibangkong were relatively higher than in Cilengkrang. The operation and maintenance cost with similar elements for 3R activities in Cibangkong (Rp. 5.321.000,- per year) were considerably lower than Cilengkrang that reached up to Rp. 9.057.000,- per year due to the differences in variability in 3R activities. The pay back estimation for each study area can be seen at Table 3.

Table 3. Estimation of The Payback Period

No	Items	Units	Cibangkong	Cilengkrang
1	Investment Cost	per year	Rp 28,000,000	Rp 18,000,000
2	Cash Flow	per year	Rp 2,359,000	Rp 18,663,000
3	Payback Periods	year	11.87	0.96

Table 3 informed that the payback period of Cilengkrang were shorter than Cibangkong. These phenomena showed that the variability of 3R activities and the active part of the community will give positive contribution in economic reliability and sustainability.

B. The Level of Beneficiaries

The level of beneficiaries of bio-digester can be measured by the perception of the community. Direct benefits of the existence of the bio-digester were gas and fertilizer that can be used, meanwhile indirect benefit were in the form of aesthetics and the sales of

bio-digester products. The comparison of beneficiaries' level in both of study area can be seen at Figure 4.

The communities in both of study area were classified to have a high level perception of the beneficiary to the bio-digester existence in their area. The Cibangkong give a better perception than Cilengkrang. This phenomenon happened because in Cilengkrang, based on direct observation, there were more other 3R activities with better implementation such as bio-pore actions, waste bank and composter actions, meanwhile in Cibangkong the main activities were the bio-digester.

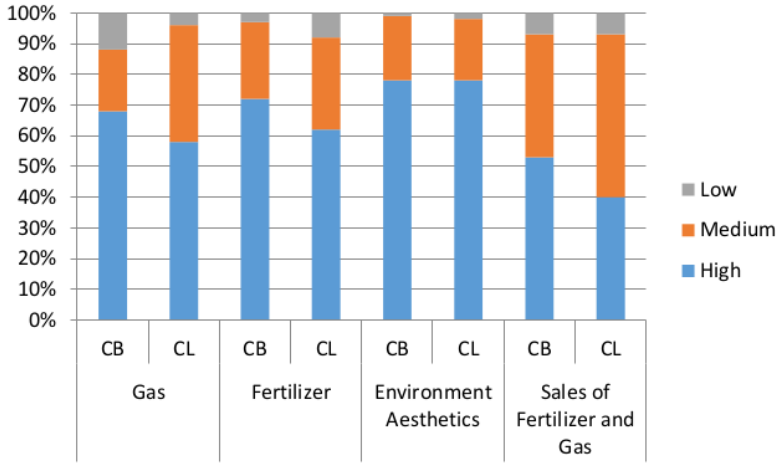

Figure 4. Proportion of Beneficiaries Level

The perception of beneficiaries' level in Cibangkong reach up to 3.7 point, meanwhile Cilengkrang reach up to 3.5 point which means that the community in both study area have a good perception to the bio-digester, they see the bio-digester gave many benefit to their environment, especially to the aesthetic and their product which can be directly used, such as gas and fertilizer.

3.4. The Comparison Of Sustainability Level

The level of waste reduction sustainability in both of study area will comprise of every aspect taken into consideration in environment, social and economic sustainability as an indicator. The method used was the Weighted Ranking Method. The first steps were indicator scoring process (IS) and determine the importance factor coefficient (IFC). The list of indicators and its value based on the previous explanation can be seen at Table 4. The estimation of indicators score for each aspect can be seen at Table 5. The calculation of IFC can be seen at Table 6. The final calculation of the weighted ranking technique of the waste reduction sustainability can be seen at Table 7.

Table 4 shows the list of indicators that were going to be used in measuring the degree of importance from each sustainability aspects (environment, social and economic). All indicators at Table 4 with each values that has been stated previously were used to determine each score of sustainability aspect.

Table 4. Lists Indicators of Each Aspect of Sustainability

Aspect Of Sustainability / Indicator	Value		Units
	CB	CL	
Environment			
Waste input to Biodigester	49.5	80.53	L/day
Ratio of waste input to biodigester capacity	0.9	5.4	%

Aspect Of Sustainability / Indicator	Value		Units
	CB	CL	
Social			
High perception of contribution on Idea	85.57	59.04	%
High perception of contribution on Man Power	42.27	20.48	%
High perception of contribution on Goods	49.48	50.6	%
High perception of contribution on Funding	44.33	31.33	%
High perception of contribution on Time	69.07	61.45	%
High perception of contribution on Skills	65.98	49.4	%
Economic			
The Investment Cost	Rp 28,000,000	Rp 18,000,000	Rp/Year
The Cash Flow	Rp 2,359,000	Rp 18,663,000	Rp/Year
The Pay Back Periods	11.87	0.96	year
High perception of Gas benefit	67.01	56.63	%
High perception of Fertilizer benefit	73.2	62.65	%
High perception of Aesthetics benefit	76.29	75.9	%
High perception of Sales benefit	53.61	38.55	%

Table 5 shows the results of the weighting process to determine the score for every aspect of sustainability. In this study, the economic aspect was divided into two sub aspects (cost sub aspects and benefit sub aspect) because each sub aspect had significant part to determine the sustainability. It shows that in Environment and Economic Aspect (especially in Cost sub-aspect), Cilengkrang had significant higher value than Cibangkong. Meanwhile in term of Social and Benefit sub aspect, Cibangkong were relatively higher thatn Cilengkrang. However the differences between both place on these two particular aspect is not too significant.

Table 6 shows the continuation process of the weighted ranking process in determining the degree of importance between each aspect of sustainability which using the Delphi method. The result shows that environment and benefit had the same degree of importance in 3R program sustainability followed by respectively social aspect and cost aspect.

The comparison of sustainability level for both study area were calculated based on the IS and IFC that has determined before. The result on Table 7 shows that Cilengkrang had better sustainability level than Cibangkong. Sustainability level in Cilengkrang had reach to 0.575 point, meanwhile Cibangkong had reach 0.425 point. The gap of the waste reduction sustainability level was not significantly high.

From the estimation for every sustainability aspects in Table 6, it showed that environmental and benefit aspect have the same degree of importance. Eventhough Cibangkong had slightly higher support from its social and benefit aspect than Cilengkrang, but there were significant gap on the environment and cost aspect.

Table 5. The Estimation of IS for each Aspects of Sustainability

Aspect Of Sustainability / Indicator	Score of IS	
	CB	CL
Environmental		
Waste input to Biodigester	0.190	0.310
Ratio of waste input to biodigester capacity	0.072	0.428

Aspect Of Sustainability / Indicator	Score of IS	
	CB	CL
Total Score of Environmental Aspect	**0.262**	**0.738**
Social		
High perception of contribution on Idea	0.094	0.065
High perception of contribution on Man Power	0.107	0.052
High perception of contribution on Goods	0.103	0.106
High perception of contribution on Funding	0.093	0.065
High perception of contribution on Time	0.084	0.074
High perception of contribution on Skills	0.090	0.068
Total Score of Social Aspect	**0.570**	**0.430**
Economic		
The Investment Cost	0.130	0.203
The Cash Flow	0.037	0.296
The Pay Back Periods	0.025	0.308
Total Score of Cost Aspect	**0.193**	**0.807**
High perception of Gas benefit	0.117	0.098
High perception of Fertilizer benefit	0.116	0.099
High perception of Aesthetics benefit	0.178	0.177
High perception of Sales benefit	0.125	0.090
Total Score of Benefit Aspect	**0.535**	**0.465**

Table 6. The Estimation of IFC

No.	Aspects	1	2.1	2.2	3	Sum	IFC
1	Environment Aspect		0.5	0.5	1	2	0.333
2	Economic Aspect						
2.1	Cost Aspect	0.5		0	0	0.5	0.083
2.2	Benefit Aspect	0.5	1		0.5	2	0.333
3	Social Aspect	0	1	0.5		1.5	0.250
							1.000

In this study the point of sustainability level differences emerge due to the environment aspect especially the waste reduction. Cilengkrang had been more able to reduce their waste up to 80.53 L /day compare to Cibangkong which only almost half of it, which was 49.5 L/day. The other aspect that influence the gap between Cibangkong and Cilengkrang was the cost sub aspect.

Table 7. The Estimation of Sustainability Level

No.	Aspects	IFC	IAC		IFC x IAC	
			CB	CL	CB	CL
1	Environment Aspect	0.333	0.262	0.738	0.087	0.246
2.1	Cost Aspect	0.083	0.193	0.807	0.016	0.067
2.2	Benefit Aspect	0.333	0.535	0.465	0.178	0.155
3	Social Aspect	0.250	0.570	0.430	0.143	0.107
					0.425	**0.575**

4. CONCLUSIONS

Waste reduction sustainability level in sub urban area was better than urban area. The sustainability level in sub urban area emerge due to the environmental and economic aspect. The dominant factor in environmental aspect was the waste reduction level and the beneficiaries level for the economic aspect. This study finds that the bio-digester have a good acceptance from the community but it has to be integrated with other 3R activities to enhance its economic sustainability.