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Potential Methane Gas Emissions as Renewable Energy at the Suwung Waste Final Processing Area

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Abstrak

Masalah sampah dalam satu dekade terakhir merupakan masalah multidimensi mulai dari mencari lokasi penimbunan sampah yang selalu menjadi masalah sosial di masyarakat hingga menentukan teknologi yang digunakan untuk mengelola sampah. Tata cara pengolahan sampah di perkotaan di Indonesia, masih menerapkan teknik konvensional yaitu open dumping, dimana dalam pelaksanaannya penanganan sampah dengan cara ini masih menimbulkan permasalahan. Tumpukan sampah yang semakin banyak akan mengeluarkan emisi metana, tentunya akan meningkatkan efek gas rumah kaca. Dampak dari situasi ini akan menimbulkan masalah pemanasan global dan perubahan iklim. Tempat Pemrosesan Akhir Suwung terletak di Desa Suwung, Kota Denpasar, Provinsi Bali dimana sistem pengelolaan sampahnya masih menggunakan teknologi open dumping. Metode penelitian menggunakan penelitian deskriptif kuantitatif dan berpedoman pada Intergovernmental Panel on Climate Change (IPCC) 2006. Hasil penelitian ini menemukan bahwa sebagian besar sampah organik yaitu 78,35%, sedangkan sampah anorganik 21,66%. Komposisi sampah organik yang paling banyak masuk ke TPA Suwung adalah sampah kebun dan taman yaitu 44,97% dan yang paling sedikit adalah sampah karet dan kulit sebesar 1,17%. Mengacu pada ketentuan IPCC 2006 perhitungan potensi emisi gas metana yang dihasilkan oleh sampah organik di TPA Suwung adalah 2.957,10 ton. Penelitian ini menemukan potensi pengelolaan gas metana yang mampu menghasilkan energi listrik sebesar 5,75 MW.

Kata Kunci: *Energi Listrik, Emisi Metana, Limbah, Gas Rumah Kaca.*

Abstract

The waste problem in the last decade is a multidimensional problem starting from finding a location for landfilling waste, which has always been a social problem in the community to determining the technology used to manage the waste. The procedure for processing waste in urban areas in Indonesia, still applies conventional techniques, namely open dumping, where in practice handling waste with this method still causes problems. The pile of waste that is getting more and more will release methane emissions, of course it will increase the effect of greenhouse gases. The impact of this situation will cause global warming and climate change problems. The Suwung Final Processing Area is located at Suwung Village, Denpasar City, Bali Province where the waste management system is still using open dumping technology. The research method uses descriptive quantitative research and is guided by Intergovernmental Panel on Climate Change (IPCC) 2006. The results of this research found that mostly organic waste, which is 78.35%, while inorganic waste is 21.66%. The composition of organic waste that mostly enters the Suwung Final Processing Area is garden and park waste, which is 44.97% and the least is rubber and leather waste at 1.17%. Referring to the provisions of the IPCC 2006 the calculation of potential methane gas emissions produced by organic waste at the Suwung Final Processing Area is 2,957.10 tons. This research found potential management of methane gas are able to produce electrical energy of 5.75 MW.

Keywords: Electrical Energy, Methane Emissions, Waste, Greenhouse Gases.

INTRODUCTION

(Calibri 11, BOLD, SPASI 1, SPACING BEFORE 12 PT, AFTER 6 PT)

The waste problem in the last decade has become a concern for all stakeholders because the waste has not been optimally resolved. The next problem that must be resolved immediately is the energy crisis that has begun to hit several countries. Waste management today has focused on processing and final disposal of waste streams from the community to become a sector that makes a significant contribution to energy supply and secondary resource recovery. Renewable energy is more sustain to help energy recovery as one of a method to reduce dependence on imported fossil fuels.

While anaerobic degradation from organic waste is a common method for nowadays, renewable energy based on waste thermal conversion is a new approach with a better method to use.[1]. The main thermal technologies are: i) combustion of waste in special plants, ii) co-combustion with other fuels, iii) thermal gasification, and iv) thermal pyrolysis. While mass waste incineration is generally the most robust technology accepting a wide variety of waste materials (size, source), also other technologies such as fluidized bed incineration exist (a more homogeneous waste input is needed here). Co-combustion, gasification and pyrolysis are generally less widespread and are mainly applied to pre-treated sewage or municipal sewage sub-streams[2].

The complexity of the discussion on the waste problem starts from determining the location for the final disposal of waste, which always experiences polemics in the community, to determining the technology applied in the process of managing the waste. Today there are several alternative methods to process waste products into energy. The first method is a biological technique, which will produce gas-biogas. The second is a thermal technique which produces steam[3]. Waste processing techniques in urban areas in Indonesia mostly apply the open dumping method, where its application in the field causes problems[4]. The demand of Final Processing Area will always increasing because the impact of the waste reduction process does not run effectively, bad impact of health and environmental health, such as the stinky smell of garbage, the potential for disease spreading in the environment around the final processing site. For the example incident of the waste explosion case on February 21, 2021 at the Leuwigajah Final Processing Site, Bandung City which killed 157 people, indicates that the waste management system must be well planned.[5]. A similar incident also occurred at the Suwung Final Processing Site, Denpasar City in 2014, 2015, 2017 and 2018 where there was a garbage fire that caused air pollution in the Denpasar City area.[6].

Suwung Final Processing Area located in Bali Province is the largest final processing Area owned by the Bali Provincial Government. Waste processing at the Suwung Final Processing Area applies an open dumping system. The use of an open dumbing system use the slow processing of waste so that waste is often piled up where this can trigger an explosion caused by the high concentration of methane gas. One of the efforts that can be done in dealing with waste is the use of waste as fuel for power plant engines.

Based on the explanation above, it is necessary to conduct research on the potential for methane emissions as a fuel for electricity energy.

METHOD

Data Sources

Sources of data in this study consisted of the following data:

1. The primary data in this study were obtained from the Denpasar City Environment and Hygiene Service, Public Market Area, and Non-Public Company. Waste data in the form of the value of dry matter content on each component of waste, as well as the volume of waste.
2. Secondary data in the form of data from several literatures related to this research.

Measurement of Composition and Dry Weight of Waste

The research uses a method based on *Intergovernmental Panel on Climate Change* (IPCC) 2006“Waste”. The composition of the waste is determined by sampling the new waste to be disposed of at the Suwung Final Processing Site. Sampling of waste is 1 cubic meters

(no reduction in the volume of sample waste) where then this sampling is considered to represent the composition of waste in the Suwung Final Processing Site. Referring to IPCC 2006 "Waste" the distribution of municipal solid waste consists of 11 classifications, namely 1) food waste, 2) garden/garden waste, 3) paper and cardboard, 4) wood, 5) garments/textiles, 6) nappies. , 7) rubber and leather, 8) plastic, 9) metal, 10) glass/ceramic, 11) other (such as: ash, dirt, soil, electronic waste)[7]. The percentage of the weight of each component of waste is obtained by calculating the weight of each component divided by the total weight.

$$component\ weight = \frac{weight\ of\ waste\ each\ component}{total\ weight\ of\ the\ waste} \times 100\% \quad (1)$$

Food waste, gardens, parks, wood, paper, diapers, cloth, rubber and leather are components of the waste that will be analyzed for dry matter content. The measurement of the dry matter content is calculated by the following equation:

$$Dry\ matter\ weight = 100\% - water\ content\% \quad (2)$$

Methane Emission Calculation Method

Methane gas is formed due to the reduction of organic matter contained in the waste due to the impact of anaerobic conditions. The characteristics of the amount of methane gas (CH_4) are determined based on the formation of the reduction of organic components or carbon in the waste, this is called Degradable Organic Carbon (DOC). DOC calculation is based on the percentage of waste weight and the amount of dry matter content of each waste composition[8]. The calculation of the DOC value uses the following equation:

$$DOC = \sum_i DOC_i \times W_i \quad (3)$$

The potential for the formation of methane gas comes from the decomposition of degradable organic waste materials that are buried in the Final Processing Site and then decomposed. Calculation of the formation of methane gas using equation 2.4. where the equation is also used to calculate the emission of methane gas (CH_4). Methane gas is estimated to have the potential to form throughout the year due to the amount and composition of waste that is buried in the Final Processing Site.

$$CH_4 generated_T = DDOC_{mdecompT} \times F \times \frac{16}{12} \quad (4)$$

$$DDOC_m = W \times DOC \times DOC_f \times MCF \quad (5)$$

$$L_0 = DDOCm \times F \times \frac{16}{12} \quad (6)$$

Methane Emission Conversion Method

The potential of methane gas as a source of fuel for electricity generation is estimated to have heat energy per 1 kg of methane gas in the range of 6.13 × 107 Joules, where it is known that 1 kilo Watt Hours is equivalent to 3.6 × 106 Joules, it is assumed that 1 kilogram of methane gas can produce electrical energy of 17 ,0278 kilo Watt Hours[9], then the magnitude of the value of electrical energy in kilo Watt hours, followed by converting that value into Watt units.

$$electric\ power\ potential = \frac{electric\ power}{24\ hours} \quad (7)$$

RESULTS AND DISCUSSION

Garbage Weight Measurement

Denpasar City is estimated to produce at least 850 tons per days. Source-based waste management in Denpasar City has not been able to run optimally where source-based waste management is only able to process waste as much as 22 percent of the waste source while the rest is transported to the final processing site [10]. The volume of waste brought to the Suwung Denpasar Final Processing Site, referring to the data obtained from the Denpasar City Government Work Plan reporting, was 1,195,939 cubic meters. The following is monthly data on the volume of waste transported to the final processing site in the period January 2020 to December 2020.

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Table 1.
Monthly Data Amount of Garbage

Bulan	DLHK Kota Denpasar (m^3)	PD Pasar (m^3)	Swakelola (m^3)	Swasta (m^3)	DPU dan PR Kota Denpasar (m^3)	Jumlah (m^3)
Januari	64.736	4.960	6.958	28.838	3.312	108.804
Februari	62.832	4.680	6.720	30.466	2.256	106.954
Maret	47.224	4.704	7.956	40.901	2.928	103.713
April	48.800	5.152	7.616	36.586	2.520	100.674
Mei	50.096	5.232	7.154	38.096	2.736	103.314
Juni	45.608	4.712	6.956	33.220	2.008	92.504
Juli	48.784	4.896	6.976	36.086	2.560	99.302
Agustus	46.440	4.848	6.826	35.760	3.440	97.314
September	45.400	4.672	6.750	33.708	2.168	92.698
Oktober	47.408	5.208	7.322	35.072	2.536	97.546
Nopember	47.448	4.976	6.622	32.566	2.256	93.868
Desember	48.944	5.392	7.302	35.074	2.536	99.248
Per Tahun	603.720	59.432	85.158	41.6373	31.256	1.195.939
Rata-Rata	50.310	4.953	7.097	34.698	2.605	99.662

Table 1 shows monthly data on the amount of Denpasar City waste that goes to the Suwung Final Processing Site. The parties that participate in the transportation and management of waste in the Denpasar City area consist of the Environment and Hygiene Service, Regional Market Companies, Public Works and Public Housing Service, and private and self-managed parties. Referring to table 1, it is estimated that the average waste transported to the Suwung Final Processing Site in Denpasar City is 99,662 cubic meters per years or around 3.322 cubic meters per day.

Table 2. Waste Composition and Weight of Waste Components at Suwung Final Processing Place

No	Komponen Sampah	DLHK Kota Denpasar (Kg)	PD Pasar (Kg)	Swasta/ Swakelola (Kg)	DPU dan PR Kota Denpasar (Kg)	Rata – Rata Keseluruhan (Kg)	Komposisi Sampah (%)
1.	Makanan	21,68	33,62	18,57	15,23	22,28	16,97
2.	Kebun&Taman	71,58	57,20	61,52	45,83	59,03	44,97
3.	Kayu	1,53	1,55	1,70	0,88	1,42	1,08
4.	Kertas & Karton	10,25	8,32	13,93	7.31	10,83	8,25
5.	Kain &Tekstil	6,88	7,68	3,22	1,28	4,77	3,63
6.	Nappies	5,13	1,12	4,62	1,09	2,99	2,28
7.	Karet & Kulit	1,89	1,25	1,85	1,13	1,53	1,17
8.	Plastik	24,63	23,15	33,25	18,38	24,85	18,93
9.	Logam	0,93	0,84	0,72	0,65	0,79	0,60
10.	Gelas	1,70	1,25	1,92	1,08	1,49	1,13
11.	Lain-Lain (Abu,Debu)	1,50	1,29	1,32	1,13	1,31	1,00
	Total Keseluruhan					131,29	100

Based on table 2, the most dominant composition of waste is garden and park waste with a percentage of 44.97 percent. The dominance of garden and garden waste is due to the background of ceremonial activities in Bali which use a lot of fruits and plants as a means of ritual. On the other hand, because most Balinese people are Hindus, almost every day there are religious activities. The type of plastic waste is in second place where the percentage of plastic waste is 18.93 percent.

Referring to table 2 which is classified as organic waste, namely food waste, parks/gardens, wood, nappies, rubber, leather, and textiles are the most waste transported to the Suwung final processing site where the percentage is 78.35 percent when compared to inorganic waste, namely 21.66 percent. The organic waste component is currently the largest waste in Indonesia, this problem is in contrast to other developed countries such as Norway which only has a 30 percent percentage of organic waste, Denmark 45 percent and Singapore 33 percent.[11].

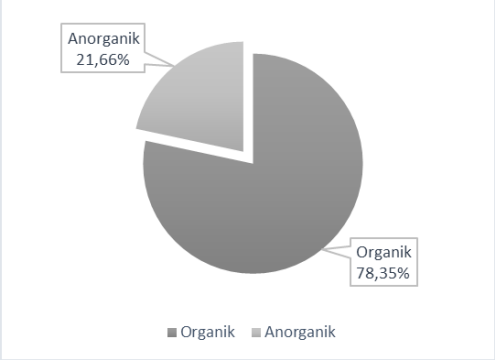

Fig 1. Comparison Diagram of Inorganic Waste with Organic Waste at Suwung Final Processing Site

Figure 1 displays data on the comparison of inorganic waste with organic waste based on the graphic results of organic waste dominating the waste in the Suwung Final Processing Site, which is 78.35 percent. The dominance of organic waste at the Suwung Final Processing Site has the potential to form methane emissions. Greenhouse Gas Emissions are the impact of unmanaged methane gas then released into the air, where this will have an impact on increasing global warming.

Garbage Dry Weight Composition

Measurement of Dry Matter waste in the Suwung Denpasar Final Processing Site is guided by the IPCC 2006 "Waste" method reference. Table 3 shows the results of measuring the average value of dry matter content of waste in the Suwung Denpasar Final Processing Site.

Table 3 Dry Matter Content Waste Suwung Final Processing Site

Komponen Sampah	Dry Matter Content ….%...
Makanan	18,12
Kebun & Taman	29,19
Kayu	71,75
Kertas & Karton	66,64
Kain & Tekstil	65,08
Nappies	30,76
Karet & Kulit	77,51

Referring to table 3, the results of each waste component are shown. The value of dry matter content for food waste is 18.12 percent, gardens and parks are 29.19 percent, wood is 71.75 percent, paper and cardboard 66.64 percent, cloth and textiles are 65.08 percent, nappies 30.76 percent, as well as rubber and leather by 77.51 percent.

Electrical Energy Potential at Suwung Denpasar Final Processing Site

The initial step in calculating the potential for electrical energy to be generated is by analyzing the weight of each component of the waste, followed by calculating the *Degradable Organic Carbon* (DOC) of each component of the waste and then accumulating it in all components of the waste. The calculation of the potential for methane gas emissions as a fuel for electricity generation is as follows:

1. Calculate the total weight of waste that enters the Suwung Final Processing Site.

   Based on data from the Denpasar City Environment and Hygiene Service, the total volume of waste that enters the Suwung Final Processing Site is 1,195,939 m3 using the density equation, the weight of the waste can be calculated as follows:

$$\rho = \frac{m}{v} = \frac{131{,}29}{1} = 131{,}29\ kg/m^3$$

Weight of waste = 131.29 kg/m^3 × 1,195.939 m^3

= 157.014.831.31 kg

= 157,014.8 tons

2. Calculation of weight and percentage of each waste component

The following is a sampling of calculations from park and garden waste which is known to be 44.97 percent. Then the weight of garden and garden waste that enters the Suwung Final Processing Site is as follows:

$$\text{Garden trash weight} = 157.014{,}8 \text{ ton} \times 44{,}97\% = 70.609{,}56 \text{ ton}$$

The results of the calculation of the weight of garden and garden waste are 70,609.56 tons using the same equation, the results of each component of waste can be calculated as follows, which is shown in table 4.

Table 4 Garbage Weight Percentage

No	Garbage Components	Garbage Composition (%)	Garbage Weight (Tons)
1.	Food	16.97	26,645.41
2.	Gardens&Parks	44.97	70,609.56
3.	Wood	1.08	1,695.76
4.	Paperboard	8.25	12,953.72
5.	Fabrics &Textiles	3.63	5,699.64
6.	nappies	2.28	3,579.94
7.	Rubber & Leather	1.17	1,837.07
8.	Plastic	18.93	29,722.90
9.	Metal	0.60	942.09
10.	Glass	1.13	1,774.27
11.	Miscellaneous (Ashes,Dust)	1.00	1,570.15
Total Waste that goes to the Suwung Final Processing Site			157.030.50

Value of Degradable Organic Carbon (DOC)

Calculation of Degradable Organic Carbon (DOC) using the following equation:

$$DOC = W_i \times \%\, Dry\ Matter\ Content \times DOC_i$$

The DOC value for garden and park waste can be determined as follows:

$$W_i = 100\,\% - 29{,}19\% = 70{,}81\%$$
$$DOC = 70{,}81\,\% \times 29{,}19\% \times 49\% = 0{,}10$$
$$\%\, DOC = 0{,}10 \times 100 = 10\,\%$$

The results of the calculation of Degradable Organic Carbon for garden and garden waste are 0.10 Ggram C/Gram of waste or 10 percent, using the same equation, the value of Degradable Organic Carbon for each component is obtained as follows, which is shown in table 5.

Table 5. Value of Degradable Organic Carbon

Jenis Sampah	*Dry Matter Content*	DOCi (dalam Bahan Kering)	Wi (Fraksi Komponen)	Nilai DOC
		…%...		
Makanan	18,12	38	81,88	6
Kebun & Taman	29,19	49	70,81	10
Kayu	71,75	50	28,25	10
Kertas & Karton	66,64	44	33,36	10
Kain & Tekstil	65,08	30	34,92	7
Nappies	30,76	60	69,24	13
Karet & Kulit	77,51	47	22,49	8

Methane Emission Potential

Calculation of the electrical energy generated, can be done after calculating the potential for methane emissions. Calculating methane emissions can use equations 2.4 and 2.5 as follows:

$$DDOCm = W \times DOC \times DOCf \times MCF$$
$$Lo = DDOCm \times F \times 16/12$$

The DDOC value is the decomposition of the DOC mass value while the MCF value = 0.8 and the DOCf value = 0.5 where the value is determined data based on the 2006 IPCC[12]. The following are the results of the calculation of potential methane emissions from garden and park waste types:

$$DDOCM = 70.609{,}56 \times 0{,}10 \times 0{,}5 \times 0{,}8$$
$$= 2.860{,}54\ ton$$
$$Lo = 2860{,}54 \times 0{,}5 \times (16/12) = 1907{,}03\ ton$$

Table 6. The results of the calculation of the potential methane emissions of each waste component

Garbage Type	)OCf	MCf	)DOCm (Tons)	F	Lo (Tons)
Food	0.5	0.8	500.90	0.5	400,60
Gardens & Gardens	0.5	0.8	860.54	0.5	907.03
Wood	0.5	0.8	68.74	0.5	45.83
aperboard	0.5	0.8	506.84	0.5	337.89
Fabrics & Textiles	0.5	0.8	155.44	0.5	103.62
nappies	0.5	0.8	182.99	0.5	121.99
Rubber & Leather	0.5	0.8	60,20	0.5	40,14
Total					,957.10

Table 6 above is the result of the calculation of potential methane emissions where the total formation of methane gas is 2,957.10 tons. The value of the electric power potential that can be generated from methane emissions can be calculated as follows:

Methane Emission Potential = 2,957.10 tons = 2,957,100 kg
1 kg of methane = 6.13×107 Joule
2,957,100 kg of methane gas = 18,127,023×107J/kg
1 kWh = 3.6×106 J

$$Potensi\ energi\ listrik\ (kWh) = \frac{18.127.023 \times 10^7}{3{,}6 \times 10^6}$$

$= 50.352.841{,}6\ kWh/tahun$

$$Daya\ Pembangkitan\ per\ jam = \frac{50.352.841{,}6}{8760}$$

$= 5748{,}04\ kW = 5{,}75\ MW$

The calculation results show the potential for generating electrical power by using methane gas as fuel with the amount of processed waste amounting to 157,014.8 tons, which can generate electricity of 5.75 MW. This indicates that the use of waste as fuel in generating electrical energy has a very large potential in the province of Bali, especially Denpasar City. In other areas as a comparison, the results of the study on the construction of PLTSa in Banda Aceh City were declared feasible to be developed with an estimated volume of waste per day of 150.02 tons that could generate electricity potential of 1.7 MW with a generator efficiency of 25%.[13]. Other countries such as Israel have been using waste as fuel for electric power since 2002 with the amount of waste management amounting to 88,000 tons/year producing electrical energy in the range of 2-3 MW. Another example in Lucknow City, India, since 2005 has been using waste as fuel for electrical energy, where waste management of 165 tons/year produces 5 MW of electrical energy.

SIMPULAN

Based on the results and discussion of the research, the following conclusions can be drawn:

1. In 2020 Denpasar City produces 150.02 tons of waste per year. The waste that enters the Suwung FINAL PROCESSING PLACE is dominated by organic waste of 78.35% while inorganic waste is 21.66%. The composition of organic waste that mostly enters the Suwung FINAL PROCESSING PLACE is garden and park waste, which is 44.97% and the least is rubber and leather waste at 1.17%.
2. Waste from food waste components is waste with the lowest dry matter content value of 18.12% and the highest dry matter content is the waste component of rubber and leather, which is 77.51%
3. the potential for methane emissions produced by organic waste at the Suwung FINAL PROCESSING PLACE is 2,957.10 tons. Based on the results of the calculation of the potential management of methane gas capable of producing electrical energy of 5.75 MW.

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