Estimation Of Greenhouse Gas Emissions At Gunung Kupang Final Processing Site Landfill Using The IPCC Method

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Abstract.
Methane gas (CH_4) is one of the main Greenhouse Gases (GHG), which contributes 14.5% to global warming. The methane gas potential that can be created from final processing site landfills in 45 big cities in Indonesia in 2010 reached 11,390 tons of CH_4/year or the equivalent of 239,199 tons of CO_2/year. The decomposition process that occurs in the waste pile will produce methane emissions and be released into the atmosphere by 50-60%. Gunung Kupang final processing site is a final processing site that serves the Banjarbaru City area in addition to the Banjarbakula Regional final processing site, with waste coming in every day which continues to increase and has the potential to generate emissions. The purpose of this research is to analyze the characteristics in the form of waste generation and composition at the Gunung Kupang final processing site and to analyze the estimation of methane gas from the Gunung Kupang final processing site landfill activities using IPCC methods. The methods used in this study are the Intergovernmental Panel on Climate Change (IPCC). Total greenhouse gas emissions produced in the IPCC method from 2014-2020 were 1.49 Gg/year. In 2021-2024, it is estimated that methane produced using the IPCC method is 0.528 Gg/year.

Keywords: *Emissions, methane, landfill, waste and IPCC.*

I. INTRODUCTION

The impact of climate change causes negative things to happen, such as rising earth temperatures. The IPCC defines global warming as the process of increasing the average temperature of the atmosphere, sea and Earth's land. IPCC have been grouped various human activities into 4 sectors such as the energy sector, IPPU, waste and AFOLU contributed to greenhouse gas emissions including the deforestation sector [1]. Greenhouse gases are the cause of global warming and one of them is methane gas which causes global warming of 14.5% [2]. Methane gas has the potential to be 21 times more at risk as a greenhouse gas than carbon dioxide gas [3]. Apart from deforestation, the livestock industry is the largest contributor of methane gas in the atmosphere with levels of 89% [4]. Specifically, the GHG emission reduction target set by the Indonesian government in 2030 is 29% with its own capabilities and 41% with international assistance [5].
Reducing GHG emissions in Indonesia is targeting five sectors, one of which is from the waste sector with predictions that by 2030, sector emissions will reach 296 million t CO2e [6]. Therefore, Indonesia's target for reducing GHG emissions from the waste sector in 2030 is 0.38% [7]. Sector of waste comes from landfill is the third largest source of methane accounting for 11% of global methane emissions [8]. Methane gas production potential from final processing site controlled landfills in 45 big cities in Indonesia in 2010 reached 11,390 tons of CH_4/year or 239,199 tons of CO_2/year [9].

94.64% of GHG emission production caused by waste is methane gas. The decomposition process in the waste heap will result in methane emissions being released into the atmosphere by 50-60% [8].Analysis carried in this study using IPCC software. The results of the IPCC method are compared with the hope of providing information to parties who need this research. The background for taking the two methods is due to differences both in terms of the calculation approach and the input and output parameters Intergovernmental Panel on Climate Change (IPCC) is a method used to analyze Green House Gases (GHG) more specifically, namely CH_4, CO2, and N2O from 5 sectors [10]. One of the sectors calculated at the IPCC is the solid waste sector. In this study, Tier 2 is used as an option in the IPCC calculation. Tier 2/First Order Decay (FOD) uses a first order degradation pattern [11]. The input needed is the generation and composition of each type of waste such as food waste, gardens and yards, paper and cardboard, wood, textiles, and others, then entered separately in MSW (Municipal Solid Waste) [12]. Other inputs are the default data provided by the IPCC itself [11].

The advantage of the IPCC method is that there are complex calculations and input parameters to analyze Greenhouse Gases from five sectors so that the results are more specific [13].Gunung Kupang final processing site located in Banjarbaru City has been operating since 2006 and there is processing of methane gas in the form of biogas. Since the COVID-19 pandemic, the scale of biogas processing at the Gunung Kupang landfill has shrunk, so the methane gas that is managed in landfills is not as large as before. The landfill at Gunung Kupang final processing site is divided into two cells, where the first cell has been closed and the second cell covering an area of 4.5 hectares is still being used from 2021 until now. Direct measurement of the amount of methane gas produced in the Gunung Kupang final processing site landfill has never been carried out. The hope is that by estimating emissions in the form of methane gas potential in the Gunung Kupang landfill using the IPCC method, it can help estimate the amount of methane produced in the Gunung Kupang landfill, both the first cell and the second cell.

II. LITERATURE REVIEWS

Waste composition is a description of each component in waste and its distribution. The composition of waste is grouped into 11 criteria, namely food, paper/cardboard, nappies, garden waste, wood, cloth, rubber and leather, plastic, metal, glass and others [14]. The composition of the material is usually seen from the components of the materials that make up the solid waste material in percentage by weight [15]. The composition of the waste is one of the parameters indicating the wet weight of the waste and the dry weight of the waste components [14]. This factor will determine greenhouse gas emissions from waste management because the organic/carbon components contained in the waste will affect the amount of Greenhouse Gases (GHG) [16]. Factors that influence the composition of waste are solid waste sources, population activities, collection and disposal systems used, geography, socio-economic, climate, technology, and time. The composition of waste is divided into two, namely physical composition and chemical composition [17]. Waste composition and generation are required as one of the input parameters to the IPCC.Waste generation is the amount of waste arising from community activities in units of volume and capita weight per day, or road extensions and building expansions [18]. The amount of waste generated based on the source has a different volume/weight for each source component. This is caused by differences in people's consumption levels, population size and growth rates, seasons, lifestyles, population mobility, and ways of handling food [19].

The method for measuring waste generation is divided into 4 methods, namely the method of direct measurement of waste generation units, Load-Count Analysis, Weight-Volume Analysis, and Material-Balance Analysis.Methane is a greenhouse gas produced from the decomposition of organic matter by anaerobic bacteria. The increase of methane gas in the atmosphere was first investigated in the 1980s [20]. The increase in methane gas itself has reached 5-10 ppb/year [21]. The characteristics of methane are that it is flammable and produces carbon dioxide as a by-product. Sources of methane are usually produced in the soil as the end result of anaerobic decomposition of organic matter [22]. Wetlands, oceans, agriculture, use of fossil fuels, burning of biomass and especially waste in landfill are some of the sources of methane pollutants [23]. The use of fossil fuels which is one of the sources of methane production can have a major impact on climate change and air pollution [24]. Methane based on its source can be grouped into 3 categories namely biogenic, thermogenic and pyrogenic methane [25]. Biogenic methane is methane produced from biological processes (eg agriculture, wetlands and livestock). Thermogenic and pyrogenic methane is usually produced through physical and chemical processes. Methane gas emissions from landfills are estimated to reach 3-19 percent of anthropogenic sources in the world [26].Final Processing Site is a place with a large capacity and is used for the final disposal of very large amounts of waste from temporary landfills [27].

So far, waste management has only focused on government officials who process it in the order from the source of waste to the TPS and ends at final processing site [28]. Even if the final processing site still uses an open dumping system, it is certain that it will cause soil, water and air pollution [29]. final processing site has its own procedures where the location is an isolated place and meets standards in the form of providing facilities and applying appropriate procedures, so as not to cause an impact on the environment around the final processing site [17]. Sequential waste management process is container, collection, transfer, transportation, management and utilization,The potential for methane from waste disposed of in landfills depends on the MSW (Municipal Solid Waste) composition, the operation of the disposal site and environmental conditions. The potential of CH_4 can be determined through sampling both in the laboratory and in the field. The formation of methane in landfills requires consideration of several factors, including biogas potential, waste composition & variation over time, climate and operations, environmental management conditions, and finally the level of waste disposal in landfills. Therefore, the estimation of methane formation cannot be carried out haphazardly without careful planning [30]. There are two processes to convert methane gas into alternative energy from the landfill process, namely combustion and non-combustion technology [31].IPCC (Intergovernmental Panel on Climate Change) is a method widely used by the United Nations (UN) in the quantification of greenhouse gases.In addition, the IPCC can be used to estimate an inventory of anthropogenic greenhouse gas emissions from sources to absorption from a country/region in various sectors, especially the waste sector [32].

There are 3 Tiers used in the IPCC 2006 method, namely Tier 1 with the First Order Decay (FOD) method for activity data and emission factors using default numbers. Then Tier 2 which uses the FOD method is calculated based on more accurate activity data FE still uses the default figure. Finally, Tier 3 is used based on the most accurate data between the two previous tiers and has used country specific.The main parameters in the IPCC including input parameters are detailed as follows: DOC (Degradable Organic Carbon) is a characteristic of the waste that determines how much methane gas can be produced from the waste degradation process [33]. Both the DOC data and the Southeast Asia region's default waste composition data are provided in IPCC [32]. The second main parameter is the dry matter content which is defined as the fraction (%) of the dry weight of a component or composition of wet waste. The next parameter is the Decomposed DOC Fraction (DOC_f) which has a meaning of the carbon fraction eventually degraded and released from landfill with a default value of 0.5. Then the Methane Correction Factor (MCF) or the CH_4 (Methane) Correction Factor is a value that functions to describe the level and characteristics of a final processing site [17]. Next is the methane gas fraction (F) which has a default value of 50% or 0.5. The sixth parameter is the CH_4 recovery factor (R) which states the amount of CH_4 recovered. The default value for CH_4 recovery is 0 [32]. Oxidation factor (OX) is the amount of CH_4 gas that oxidized on the surface of the landfill cover by methanotropic microorganisms. The last parameters are the half-life ($t_{1/2}$) and the reaction rate constant (k) for the formation of CH_4.

III. METHODS

This research is a qualitative-quantitative type of research and aims to calculate the production potential of greenhouse gas emissions in the form of methane gas produced at the Gunung Kupang landfill using the IPCC Tier 2 method. Methane gas calculations using the IPCC method can be estimated using the First Order Decay (FOD) method which gives the assumption that methane is formed from the slow decay of Degradable Organic Carbon (DOC) from solid waste. Calculations involving DOCi on a wet weight basis as one of the data will produce DOC values. The DOCi on a wet weight basis used is the existing DOCi of Gunung Kupang Landfill, obtained from calculations in research [34].

The required research equipment consists of:

(a). Stationery for note-taking, Microsoft applications, Personal Computer (PC) or laptop and printer

(b). Software in the form of the IPCC (Intergovernmental Panel on Climate Change) Model

(c). Equipment for sampling, including: 500 liter density box, rubber gloves, stationery, hanging scales, sickles, bamboo baskets, masks, safety shoes/boots, etc.

The data in the study were divided into primary data (data obtained from direct observation and measurement activities at the Gunung Kupang final processing site) and secondary data (data obtained from various sources related to this research):

(a). The primary data are the composition, generation and amount of waste entering the Gunung Kupang final processing site (b). Secondary data is in the form of waste DOC, final processing site profile, planned year of operation, design capacity of Gunung Kupang final processing site, determination of model parameters, and annual amount of waste that goes to final processing site.

The procedures carried out in this study were divided into several stages which can be explained as follows:

(a). Sample generation and waste composition:

The sampling technique used in this study is the SNI 19-3964-1994 method, namely sampling waste for 8 consecutive days with an estimated waste weight of 100 kg. Calculated the quantity of waste by recording the weight of incoming waste with a weighbridge and recorded the weight for 8 days in accordance with SNI 19-3964-1994 concerning Methods for Collection and Measurement of Sample Generation and Composition of Municipal Solid Waste [17].

(b). Calculation of waste data going to final processing site:

Monthly and yearly data on waste going to final processing site is obtained at the Gunung Kupang Banjarbaru final processing site office

(c). Population projections and landfill waste generation:

The projection of waste generation is calculated based on weighbridge data over a 10-year period of Gunung Kupang final processing site, Banjarbaru City. The population projection in Banjarbaru City is calculated using arithmetic, geometric and Least-Square methods. The best method is chosen based on the smallest standard deviation (s) and the correlation factor (r) is close to 1 of the three methods

(d). Analysis of landfill methane gas production with IPCC

The first stage is input composition data and input default data on IPCC. The second stage is calculating the DOC value of garbage [34]. Next is the calculation of MSW data for Banjarbaru City. The last stage is the calculation of methane emissions in the Gunung Kupang final processing site

(e). Data analysis and discussion

Analysis of the data that has been obtained and discussed the results

(f). Preparation of reports

A report is written from the results of the research which will then produce a reference about the potential of methane (CH_4) gas.

IV. RESULTS AND DISCUSSION

a. Main Data

The first main data used in this study is population data for the City of Banjarbaru and its projections for 2014-2024. The population projection calculation uses the Least-Square method because it has the highest r value among the other 3 methods, which is 0.9322.

Table 1. Population Projection Calculation with the Least-Square Method

Year	***Least-Square***
2021	258,753
2022	266,041
2023	271,500
2024	276,960
2025	282,420
2026	287,879
2027	293,339
2028	298,798
2029	304,258
2030	309,717
2031	315,177
2032	320,636
2033	326,096

The second data used in this study is data on waste processing of Gunung Kupang landfill in the form of composting and recycling. Processing of kitchen waste by composting is 0.685 tonnes/day or 249.862 tonnes/year while processing plastic waste by recycling is as much as 0.181 tonnes/day or 65.932

tonnes/year. Waste processing is needed to protect or prevent too much land from being polluted by pollution [35]. The main effort that must be carried in environmental management is the prevention of environmental pollution or damage, while pollution control is the last step [36]. More detailed data is presented in the image below:

Fig 1. Waste Management at Gunung Kupang Landfill in 2022

In this study, sampling of waste generation was carried out using the Weight Volume Analysis method where weighbridge data was used for waste generation data at the Gunung Kupang Final Processing Site. The data obtained from the Gunung Kupang landfill is divided from 2019-2021.Sampling of waste composition was carried out using the SNI 19-3964-1994 method for 8 consecutive days from 10 November 2022 – 17 November 2022. The composition of waste from 2014-2019 was obtained from research [34] and the composition of waste for 2020-2021 was obtained from research [37]. The composition of waste in 2022 was obtained from field research (2022).

Table 2. Components of Waste Composition at Gunung Kupang final processing site 2022-2024

No	Garbage Components	Percentage (%)
1	Kitchen trash	16.27
2	Garden trash	14.13
3	Paper & Cardboard	5.10
4	Rubber & Leather	13.58
5	Wood	8.90
6	Metal	14.94
7	Glass	7.53
8	textiles	5.06
9	*nappies*	9.43
10	Plastic	4.21
11	Etc	0.83
Total		100

Source: Primary Data, 2022

Waste generation projections are carried out in 2014-2018 and 2022-2024 because waste generation data is available at Gunung Kupang final processing site only in 2019-2021. The formula used is as follows: Waste generation n year (kg/year)= (MSW x percentage service) – (composting + recycling) The percentage of service is obtained from the calculation of the average percentage increase in service. The increase in the percentage of self-service is obtained from the reduction in the percentage of service in year n+1 minus year n. In this study, only the percentage of services from 3 years is known, namely 2019, 2020 and 2021 because the amount of waste generation recorded at the Gunung Kupang final processing site weighbridge, only from 2019 - 2021, the rest has not yet been calculated in a structured manner. The projection of waste generation entering the Gunung Kupang final processing site in 2014-2024 can be seen in the following table:

Table 3. Projection of Waste Generation Entering the Gunung Kupang Landfill, Banjarbaru City, 2014 – 2024

Year	**Total population**	**MSW**	**Number of days**	**Service Percentage (%)**	**Waste Generation Weight**	
					Total Generation (Kg/Year)	**Total Generation (Mg/Year)**
2014	227,500	58,126,250	365	51	29,838,338	29,838
2015	234,371	59,881,791	365	56	33,733,610	33,734
2016	241,369	61,669,780	365	61	37,824,339	37,824
2017	248,423	63,472,077	365	66	42,103,358	42.103
2018	255,597	65,305,034	365	71	46,584,477	46,584
2019	262,719	67,124,705	365	76	51,238,751	51,239
2020	253,442	64,754,431	365	76	49,398,519	49,399
2021	258,753	66,111,392	365	86	56,838,776	56,839
2022	266,041	67,973,476	365	91	61,522,468	61,523
2023	271,500	69,368,250	365	96	66,575,661	66,576
2024	276,960	70,763,280	365	99	70,055,647	70,056

Calculation of the remaining service life of the second landfill cell of Gunung Kupang final processing site is used to estimate how many years the Gunung Kupang final processing site landfill will close. The calculation formula is:

Landfill area $= \frac{V+SC}{T}$

Buffer Area $= 25\% \text{ x } L_{landfill}$

Information:

$L_{final\ processing\ site}$ = Landfill area (m^2)

L_{buffer} = Landfill area zone and supporting facilities (m^2)

V = Waste volume (m^3)

SC = Soil cover or overburden layer (m^3)

= 15%of the waste volume

Q = Talllandfill and cover layer (m)

= In Indonesia between 10 – 15 m

Assuming that the final processing site landfill (cell 2) starts operating in 2021, the total waste in Banjarbaru City from 2021 to 2023 by multiplying the total volume of waste (kg) with the density of waste (250 kg/m^3) is obtained V = 739,748 m^3 [28].

Calculations can be calculated to be like this:

$$L_{final\ processing\ site} = \frac{554.811\ m^3 + 83.222\ m^3}{15+(0{,}002\ x\ 365\ x\ 4)}$$

$$= \frac{879.724\ m^3}{17{,}92\ m}$$

$$= 47170\ m^2 = 4.72 \text{ hectares}$$

The figure of 4.72 hectares is the total land required for the second landfill in 2024. Because 4.72 hectares is close to 4.5 hectares which is the original capacity of landfill cell 2 of Gunung Kupang final processing site, it can be concluded that the Gunung Kupang landfill can accommodate waste up to year 2024.

b. Supporting Data

Supporting data can be detailed as follows:

Table 4. Components of Waste Composition at Gunung Kupang final processing site 2014-2019

No	**Garbage Components**	**Percentage (%)**
1	Kitchen trash	49.42
2	Garden trash	11.65
3	Paper & Cardboard	10.45
4	Rubber & Leather	1.98
5	Wood	2.62
6	Metal	0.66
7	Glass	1.72
8	textiles	2.35

No	Garbage Components	Percentage (%)
9	*nappies*	2.39
10	Plastic	15.84
11	Etc	0.93
Total		100

Source: Secondary Data, 2018

Table 5. Components of Waste Composition at Gunung Kupang final processing site 2020-2021

No	Garbage Components	Percentage (%)
1	Kitchen trash	39.58
2	Garden trash	9.96
3	Paper & Cardboard	14.55
4	Rubber & Leather	0.64
5	Wood	1.28
6	Metal	0.45
7	Glass	1.15
8	textiles	2.22
9	*nappies*	6.84
10	Plastic	21.36
11	Etc	1.97
Total		100

Source: Secondary Data, 2020

Table 6. Waste's DOC at Gunung Kupang final processing site based on Rahmah's research (2021)

No	Garbage Components	DOC
1	Kitchen trash	0.073
2	Garden trash	0.026
3	Paper & Cardboard	0.042
4	Rubber & Leather	0.003
5	Wood	0.006
6	Metal	0.022
7	Glass	0.002
8	textiles	0.000
9	*nappies*	0.000
10	Plastic	0.000
11	Etc	0.000

Source: Secondary Data, 2020

c. Result analysis

In inputting data in the IPCC spreadsheets, it is necessary to generate total MSW data in Banjarbaru City. In this case, waste generation for medium cities weighs 0.70 – 0.80 kg/person/day. After the MSW value is obtained, the calculation of the value of waste per capita can be done by dividing the MSW per year divided by the number of residents in that year.On the 'Activity' sheet in the IPCC spreadsheet, input data in the form of the population of Banjarbaru City and waste generation going into the Gunung Kupang FINAL PROCESSING SITE are carried out. The calculation of methane gas emissions in this study uses scenario 3 by considering that waste entering the Gunung Kupang landfill has experienced reduction in the form of organic waste which is processed into compost and plastic, glass and paper waste which is recycled before being dumped in landfills.

After the waste generation data is inputted, the next step is to input the MSW data that was previously calculated and the total MSW value will be obtained automatically in the spreadsheet. Then the next calculation is % to SWDS.Calculation of % to SWDS uses the method of total waste generation at the Gunung Kupang final processing site divided by the total MSW in Banjarbaru City and multiplied by 100%. After the results are obtained, input the value into the % to SWDS value on the spreadsheet, where the % to SWDS value describes the percentage of service coverage by the Gunung Kupang final processing site for waste in Banjarbaru City. Next, input data on the composition of waste at the Gunung Kupang final processing site. The following is the data needed to input values on the 'Activity' sheet in the IPCC software [32].

Table 7. Estimated GHG Emissions for the 2021-2024 period
at the Gunung Kupang final processing site.

Year	**Garbage Generation Goes to Gunung Kupang Landfill**	**Population (Soul)**	**MSW Banjarbaru City (kg)**	***Waste per capita*(kg/person/year)**	***% to SWDS***
2014	29,838,338	227,500	58,126,250.00	255.5	51
2015	33,733,610	234,371	59,881,790.50	255.5	56
2016	37,824,339	241,369	61,669,779.50	255.5	61
2017	42,103,358	248,423	63,472,076.50	255.5	66
2018	46,584,477	255,597	65,305,033.50	255.5	71
2019	51,238,751	262,719	67,124,704.50	255.5	76
2020	49,398,519	253,442	64,754,431.00	255.5	76
2021	56,838,776	258,753	66,111,391.50	255.5	86
2022	61,522,462	266,041	67,973,475.50	255.5	91
2023	66,575,661	271,500	69,368,250.00	255.5	96
2024	70,055,647	276,960	70,763,280.00	255.5	99

The 'Amount Deposited' sheet will automatically calculate data on the weight of waste stockpiled in landfills for each waste component [32]. On the 'Methane Calculation' sheet, to obtain the CH_4 value formed from each waste component, calculations are automatically carried out by the IPCC. The final result of the calculation in the form of the amount of methane gas emissions at the final processing site will be presented on the 'Result' sheet [32]. Estimated methane gas emissions produced in 2021 – 2024 using waste generation projection are listed in the table below:

Table 8. Estimated GHG Emissions for the 2021-2024 period
at the Gunung Kupang final processing site

Year	**Garbage Generation**	**Total CH_4 Emissions**
2021	56,839	0.00
2022	61,522	0.14228
2023	66,576	0.16888
2024	70,056	0.21698
TOTAL		0.52814

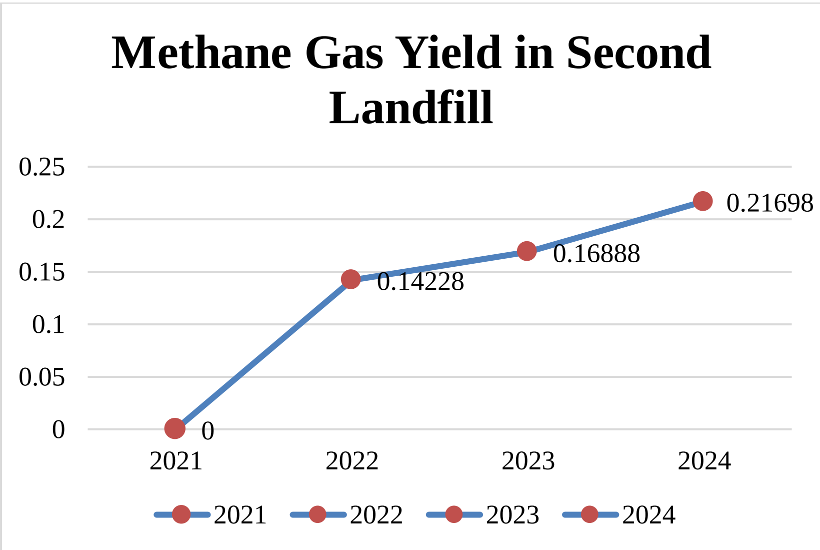

Fig 2. Graph of Second Cell Landfill Methane Yield (2021-2024) using the IPCC Method

Calculation of estimated GHG emissions in the first (old) landfill of final processing site Gunung Kupang (2014-2020) uses waste generation data from the 2014-2020 waste landfill period. Based on the results of the calculations carried out, an estimate of GHG emissions was obtained in the first landfill of Gunung Kupang final processing site during the 2014-2020 period.

Table 9. Estimated GHG Emissions for the 2021-2024 period at the Gunung Kupang final processing site

Year	Garbage Generation	Total CH_4 Emissions
2014	29,838	0.00
2015	33,734	0.09037
2016	37,824	0.16401
2017	42.103	0.22707
2018	46,584	0.28364
2019	51,239	0.33651
2020	49,399	0.38748
TOTAL		1.48908

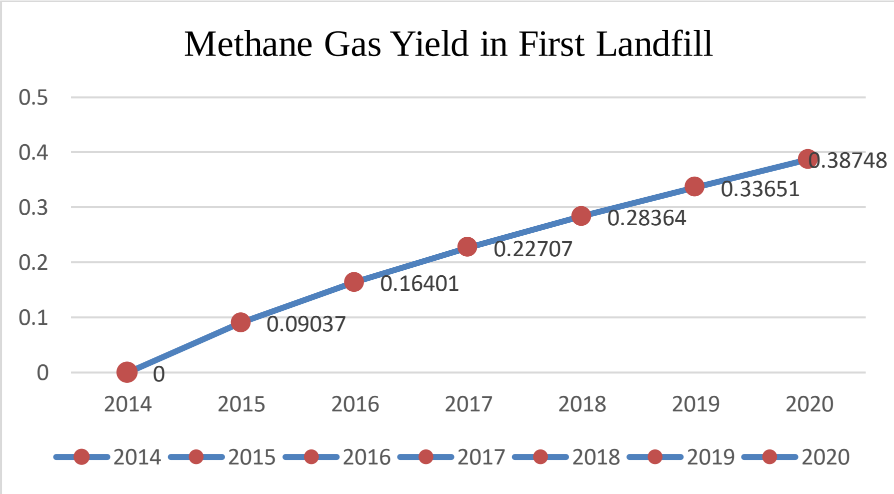

Fig 3. Graph of First Cell Landfill Methane Gas Yield (2014-2020) using the IPCC Method

V. CONCLUSION

The results of the study carried out resulted in several conclusions, including the following:

a) Based on the IPCC method, in 2022 the landfill at Gunung Kupang final processing site will produce greenhouse gas emissions of 0.14428 Gg/year. The results of the calculation of total greenhouse gas emissions in the existing conditions from the latest landfill activities, namely in 2021 – 2024 final processing site Gunung Kupang is 0.528 Gg/year.

b) Based on the IPCC method, the total greenhouse gas emissions in the existing conditions from the first landfill of Gunung Kupang landfill from 2014 – 2020 is 1.49 Gg/year

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