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Greenhouse Gas Reduction Potential based on Waste Recovery Factor in Gading and Dukuh Setro Subdistrics, Surabaya

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ABSTRACT

People's growth and their activities increase waste generation. Therefore, efforts to reduce waste are needed, including community-based reduction efforts. This research is located in Gading and Dukuh Setro sub-districts in Surabaya City. The purpose of this study was to measure the potential for waste reduction and greenhouse gas reduction. Measurement of waste generation, waste composition, and waste density was based on SNI 19-3964-1994. The researcher conducted sampling in low, middle, and high-income areas, covering 83 families. Greenhouse gas emissions were estimated using the LandGEM (U.S. EPA) method based on the waste disposed at the landfill, considering the existing reduction conditions and optimal material recovery. Solid waste generation in 2022 per year was 4.695,58 tons. The largest composition of waste consisted of biodegradable waste (37.13%), plastic waste (25.73%), and diapers and sanitary napkins (18.25%). The average density of loose waste was 152.42 kg/m3. The existing reduction had 1.47% waste bank reduction activity and 0.72% composting reduction activity, for a total reduction of 2.19%. The average optimal reduction was 52.7%, whereas the optimal reduction in the waste bank was 17.5%. The optimal composting reduction was 35.2%. Thus, the existing scenario in 2032 obtained reductions from total landfill gas of 725,498 Gg/year, methane of 193,788 Gg/year, carbon dioxide of 531,710 Gg/year, and NMOC of 8,330 Gg/year. Meanwhile, the optimal scenario for 2032 obtained reductions from total landfill gas of 239.067 Gg/year, methane of 63.857 Gg/year, carbon dioxide of 175.209 Gg/year, and NMOC of 0.412 Gg/year

Keywords: *greenhouse gas (GHG), LandGEM, reduction potential, community-based reduction*

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ABSTRACT

Pertambahan jumlah penduduk dan peningkatan aktivitas meningkatkan jumlah timbulan sampah, sehingga diperlukan upaya reduksi termasuk upaya reduksi berbasis masyarakat. Penelitian ini berlokasi di Kecamatan Gading dan Dukuh Setro Kota Surabaya. Tujuan penelitian ini adalah mengukur potensi reduksi sampah dan reduksi gas rumah kaca. Pengukuran timbulan sampah, komposisi sampah dan densitas sampah sesuai dengan SNI-19-3964-1994. Sampling dilakukan pada area berpenghasilan rendah, menengah dan tinggi sebanyak 83 KK. Prakiraan emisi gas rumah kaca berdasarkan sampah yang masuk ke TPA dengan kondisi reduksi eksisting dan recovery material optimal dengan menggunakan metode LandGEM (U.S EPA). Timbulan sampah tahun 2022 sebesar 4.695,58 ton/tahun. Komposisi sampah terbesar yaitu sampah biodegradable 37,13%, sampah plastik 25,73%, dan sampah diapers & pembalut 18,25%. Densitas sampah lepas rata-rata sebesar 152,42 kg/m3. Reduksi Eksisting memiliki Kegiatan Reduksi Bank Sampah sebesar 1,47 % dan Reduksi Komposting sebesar 0,72% sehingga total reduksi sebesar 2,19%. Reduksi Optimal rata-rata sebesar 52,7% dimana reduksi Bank Sampah optimal rata-rata sebesar 17,5% dan Reduksi Komposting Optimal rata-rata sebesar 35,2%. Skenario Eksisting tahun 2032 diperoleh reduksi dari total landfill gas 725,498 Gg/year, methane 193,788 Gg/year, carbon dioxside 531,710 Gg/year dan NMOC

8,330 Gg/year. Sedangkan, Skenario Optimal tahun 2032 diperoleh reduksi dari total landfill gas 239,067 Gg/year, methane 63,857 Gg/year, carbon dioxside 175,209 Gg/year dan NMOC 0,412 Gg/years

Keywords: *gas rumah kaca (GRK), LandGEM, potensi reduksi, reduksi berbasis masyarakat*

INTRODUCTION

Solid waste is the solid residue of human activities [1]. Solid waste generation will increase with population growth in parallel with the increment of consumption habits. The solid waste management capacity of the city government with the distribution pattern of the community is still not optimal [2]. Based on solid waste sources, consist of residential and non-residential. Residential or municipal solid waste has a larger generation than non-residential. Solid waste can contribute to a stinging and widespread problem in both urban and rural areas in developing [3].

Surabaya is the capital city of East Java that has 3 million residents. It makes Surabaya City also has problems with solid waste management. Benowo landfill is located in Surabaya City which receives 2222,62 tons [4]. Solid waste reduction before being transferred to Benowo Landfill makes the landfill's lifetime longer. The problem of waste reduction is a challenge in waste management including in Indonesia. Malaysia has problems with hundreds of tons of unmanaged solid waste [5].

Waste reduction is achieved through composting and 3R activities. 3R activities include solid waste separation that has value for sale and further processing. Compost can reduce solid waste to be disposed of, it will reduce about 12[6]. The potential amount of waste reduced depends on the composition and recovery factor of solid waste. The theoretical recovery factor is calculated based on the comparison between the total weight of waste that is potentially recycled and the total [7].

Global warming is an event that increases the temperature on Earth. The cause of global warming is gases that have a greenhouse effect. The greenhouse effect is a natural process where the atmosphere is unable to conduct heat radiation from the sun out of the earth because it is blocked by greenhouse gases. Solid waste is an important contributor to greenhouse gas emissions. Waste management activities that contribute to global warming consist of transportation and landfilling activities. In this study, greenhouse gas [8].

The LandGEM method is a useful tool for estimating landfill gas emissions, and it comes with a Microsoft Excel interface to make it easy to use. It can predict and estimate the rates of various emissions, including total landfill gas, methane, carbon dioxide, non-methane organic compounds, and other air pollutants that come from municipal solid waste landfills. LandGEM uses site-specific data to estimate greenhouse gas emissions and comes with default parameters based on federal regulations for landfills regulated by the Clean Air Act (CAA). These default parameters can be used to determine regulatory control requirements that are already in place. Additionally, the default inventory is used as the basis for emission factors in the EPA's compilation of air pollutant emission factors (AP-42), [9].

To estimate greenhouse gas (GHG) emissions from transfer stations and landfill, several significant parameters need to be inputted, such as the year of landfill opening and closing, landfill capacity, CH4 generation rate, potential CH_4 generation, and the level of waste acceptance from waste sources through sorting before entering the transfer station. By reducing the volume of waste entering the landfill, this can have a positive effect on GHG emissions. Estimating or predicting emission levels is based on site-specific data, as well as Clean Air Act (CAA) default parameters and Inventory defaults. The CAA default parameters, such as the L0 parameter of 170 m^3/Mg and k of 0.05 y^{-1}, can be used to estimate GHG emissions. Alternatively, the [10].

LITERATURE REVIEW

Increased municipal solid waste (MSW) generation, the exploration of alternative energy sources, and the pressing need to reduce greenhouse gas (GHG) emissions. According to the World Bank, the global annual generation of MSW currently stands at approximately 2.01 billion tons, and it is projected to experience a significant increase of 70% by 2050, reaching [11]. It is noteworthy that although cities occupy just 2% of the total land area, they contribute over 70% of the world's

GHG emissions due to the substantial levels of MSW generated within urban areas [12]. This highlights the critical role of cities in addressing the issue of GHG emissions by implementing effective waste management strategies.

LandGEM is a computerized tool designed to calculate emission rates pertaining to total landfill gas, methane, carbon dioxide, nonmethane organic compounds (NMOCs), and specific air pollutants originating from municipal solid waste (MSW) landfills. By utilizing LandGEM, landfill proprietors and operators can ascertain whether a landfill falls under the regulatory control requirements stipulated by the federal New Source Performance Standards (NSPS) for new MSW landfills (40 CFR 60 Subpart WWW), the federal Emission Guidelines (EG) for existing MSW landfills (40 CFR Subpart Cc), or the National Emission Standards for Hazardous Air Pollutants (NESHAP) for MSW landfills (40 CFR Subpart AAAA) [13].

The primary driver of climate change is the escalation of greenhouse gas (GHG) emissions, including gases such as argon, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulfur hexafluoride (SF6). To combat climate change effectively, it is crucial to prioritize the reduction of GHG emissions, with particular emphasis on decreasing CO_2 levels. Urgent actions are required to mitigate the impact of these emissions and work towards a more sustainable and environmentally friendly future [14].

METHOD

Research ideas based on problems that occur in society are important to solve. The topic raised in this research to solve the problem is Greenhouse Gas Reduction Potential based on Waste Recovery Factor in Gading and Dukuh Setro Subdistrics, Surabaya. Sampling time in this research from September – October. The research flowchart in this study can be seen in Figure 1.

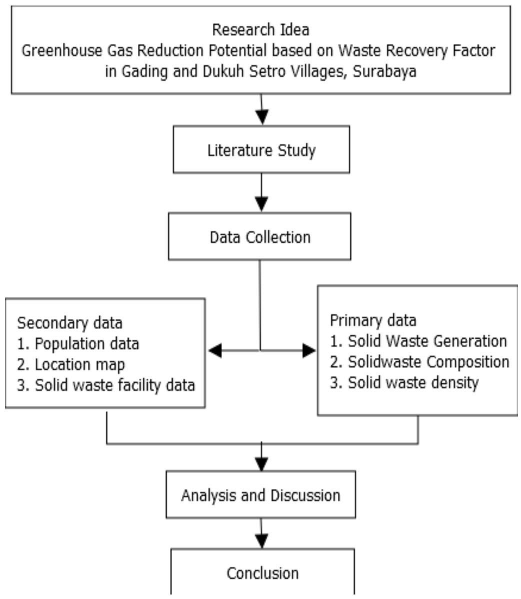
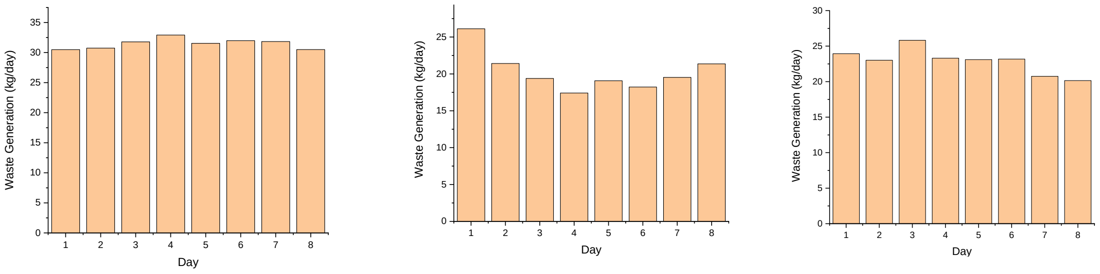


Figure 1. Research flowchart

The literature review conducted in this research aimed to gather various existing sources, including journals, articles, books, regulations, theses, and SNI 19-3964-1994, which covers sampling methods and measurement of waste generation and urban waste composition. The technique of collecting primary data can be done by conducting interviews with stakeholders such as government officials and the community. There are advantages to this primary data collection technique, which systematically formulates and answers research expectations based on the number of respondents adjusted according to research needs, and can be done within a certain period of time.

RESULTS AND DISCUSSION

Solid waste generation is measured based on the weight of waste that has not been collected by janitors and waste collectors in the residential area. The results of the sampling analysis of household waste generation from low-income areas, middle-income areas and high-income areas by conducting field measurements of solid waste generation analysis, waste density and waste composition for 8 consecutive days.

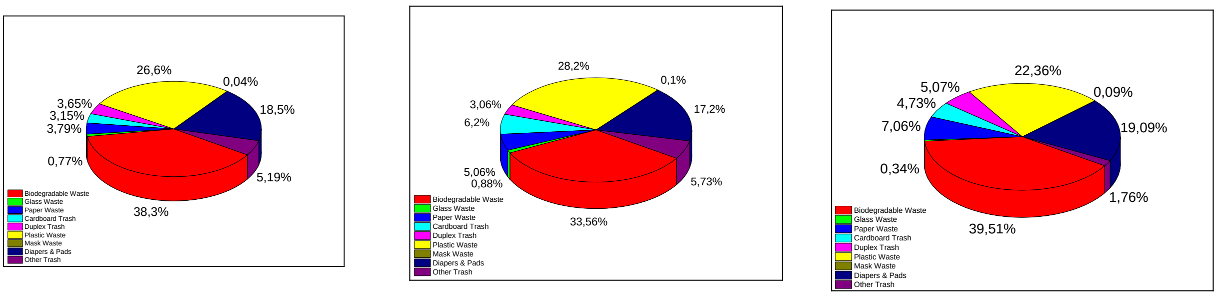


(a) (b) (c)

Figure 2. Solid Waste generation in : a) low-income area, b) middle-income area, c) high-income area.

Solid waste generated in settlements obtained from field research in low-income areas obtained an average of 0,21 kg/person.day, the average waste generated in middle-income areas is 0,25 kg/person.day and the average waste generated in high-income areas is 0,23 kg/person.day, so average of solid waste generation from Gading and Dukuh Setro Subdistrict is 0,23 kg/person.day. Another study of municipal solid waste generation in Pamekasan is 0,46 kg/person.day [15]. If it compares to other study, municipal solid waste generation in Gading and Dukuh Setro Subdistrict has lower amount.

Solid waste composition is obtained by sorting, waste can generally be divided into wet waste, plastic waste, paper waste, glass waste, cloth waste, diapers & pads waste and other waste. The waste is then divided into waste processing such as residual or recycled waste. After the weight of each waste component is measured, it can be calculated using the applicable percentage formula in SNI 19-3964-1994 on how to take samples and measure urban waste generation. Percentage of solid waste composition ineach area can be seen in Figure 3. Based on solid waste composition data covering the three areas the average generated can be seen in Figure 4.



(a) (b) (c)

Figure 3. Solid Waste composition in : a) low-income area, b) middle-income area, c) high-income area.

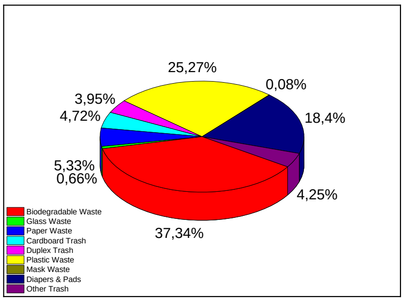


Figure 4. Solid waste composition

Based on figure 4, it shows that the biggest composition of municipal solid waste from two subdisctrics is biodegradble waste (37,34%). Municipal solid waste in Singapore majorly consist of food waste, paper, plastics and glass then along with hazardous household waste. Composition of municipal solid waste is not the same in all regions, it varies from country to country [16]. During the field survey, the density of loose waste was analysed. Based on the three research locations, the results of the density of loose waste in the research area obtained an average result of 152.42 kg/m^3.

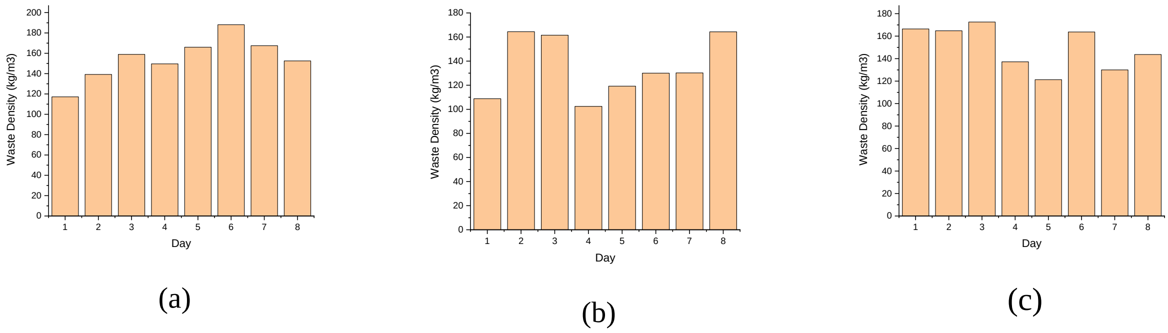


Figure 5. Solid Waste density in : a) low-income area, b) middle-income area, c) high-income area.

Estimation of solid waste generation

Data on the amount of waste generation carried out for 8 days, which obtained household waste, was calculated through population data obtained by the Central Bureau of Statistics in 2022 with estimated waste generation projections from 2022 to 2032. Estimation solid waste generation from two subdistricts in 2032 is more than 5500 tons/year.

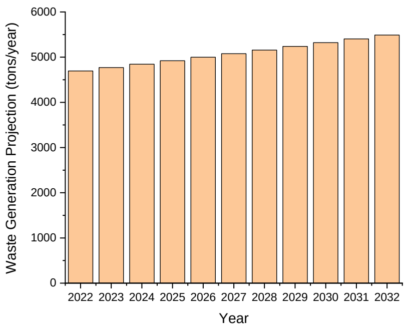


Figure 4. Estimation of solid waste generation 2022-2032

Recovery Optimal

Waste reduction in the study area is carried out by various waste management activities with Waste Banks and Composters which can be considered to reduce the amount of waste that will be taken to transfer station or landfill. The weight of waste reduction from various household activities will be considered with the recovery factor for each type of waste composition.

Tabel 1. Optimal condition scenario of waste generation

Year	Waste Generation (tons/year)	Recovery Factor (%)	Reducing Waste Weight	Residu
2022	4.695,58		2.474,97	2.220,61
2023	4.769,54		2.513,95	2.255,59
2024	4.844,67		2.553,55	2.291,12
2025	4.920,98		2.593,77	2.327,21
2026	4.998,55		2.634,66	2.363,89
2027	5.077,30	52,7%	2.676,17	2.401,13
2028	5.157,30		2.718,33	2.438,97
2029	5.238,56		2.761,17	2.477,40
2030	5.321,09		2.804,66	2.516,42
2031	5.404,87		2.848,82	2.556,05
2032	5.490,08		2.893,74	2.596,34

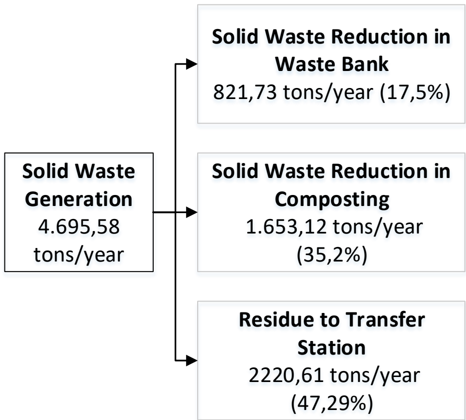


Figure 5. Mass balance of solid waste generation with Optimal Reduction Scenario in 2022

Reduction Potential of Methane Gas

Methane Gas Emission Analysis which covers the whole of the various landfill zones based on data obtained in the form of opening years, closing years, projected annual waste generation along with the parameter model used to estimate methane gas generation at the scale of residential areas. The parameter model used is the methane gas generation rate constant (k), potential methane gas generation capacity (LO) and non-methane organic carbon (NMOC).

$$QCH_4 = \sum_i^n \sum_{j=0,1}^{i} K\ lo\ \left(\frac{mi}{10}\right) e^{-kt_{ij}} \quad \text{.... (1)}$$

Description:
QCH_4 = amount of methane generated annually in the year of calculation (m^3/year)
i = increase for 1 year
n = (calculation year) - (initial year of landfill opening)
j = 0.1 year increase
k = methane generation constant (1/year)
L_0 = potential methane capacity (m^3/Mg)
m_i = mass of waste received in year i (mg)
t_{ij} = age of waste in j by mass received in year-i (decimal year, e.g. 3.2 years)

LandGEM may use specific data as emission estimates or default parameters that contain specific data from the field. CAA default values may be based on landfill regulations established by the Clean Air Act (CAA) and may determine the landfill meets requirements, controls, or regulations.

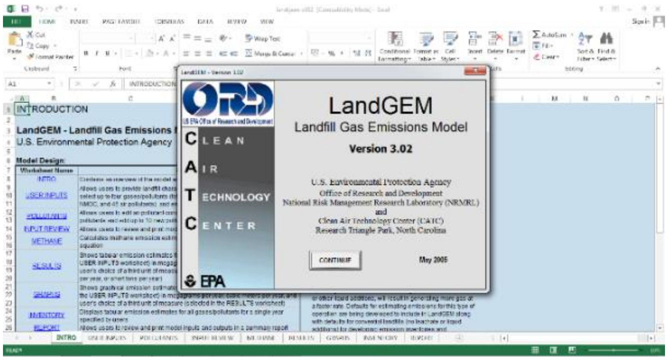


Figure 6. Software LandGEM v.3.02

Data entry into LandGEM software with several calculations and data collection steps including: Data from the year the landfill was operated, the year the landfill was closed, waste generation prediction data, parameter selection, default values, calculation steps, then get the results through graphs.

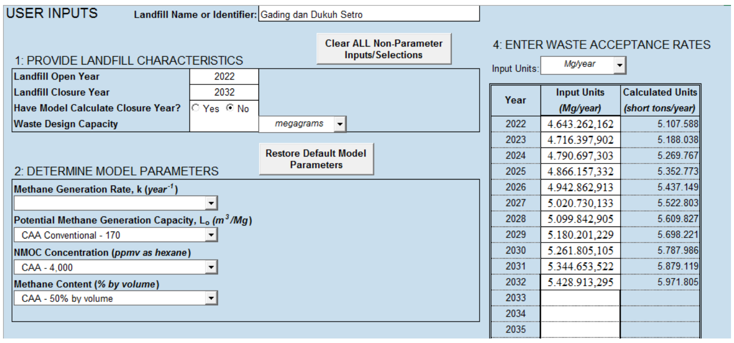


Figure 7. User Inputs LandGEM v.3.02

The data used is the residual data of waste generation projections by inputting using the Landfill Gas Emissions (LandGEM) method, the parameters used to determine the correct results can choose the CAA default value (cannot be considered as excessive leachate). Constant Value (k) which means the faster the rate of formation with the value of k used based on the CAA standard of 0.05 per year, and Default Inventory of 0.04 per year which is assessed as Methane Forming Capacity (Lo) based on Conventional CAA standard of 170 m^3/mg and Default Inventory Standard of 100 m^3/mg.

The Landfill Gas Emission Model (LandGEM) is an automated assessment tool provided by the US Environmental Protection Agency (EPA) based on a Microsoft Excel model to estimate the emission rate of any gases generated in landfills containing CH_4, CO_2 and Non-methane. Organic compounds and air pollutants from solid waste landfills.

Tabel 2. Optimal condition of methane production

Year	Residu	(Mg/years)	(Gg/years)
2022	2.220,609	2.245.035,000	2245,035
2023	2.255,586	2.280.397,000	2280,397
2024	2.291,119	2.316.321,000	2316,321
2025	2.327,207	2.352.806,000	2352,806
2026	2.363,891	2.389.893,000	2389,893
2027	2.401,131	2.427.543,000	2427,543
2028	2.438,966	2.465.794,000	2465,794
2029	2.477,397	2.504.648,000	2504,648
2030	2.516,423	2.544.103,000	2544,103
2031	2.556,045	2.584.161,000	2584,161
2032	2.596,342	2.624.901,000	2624,901

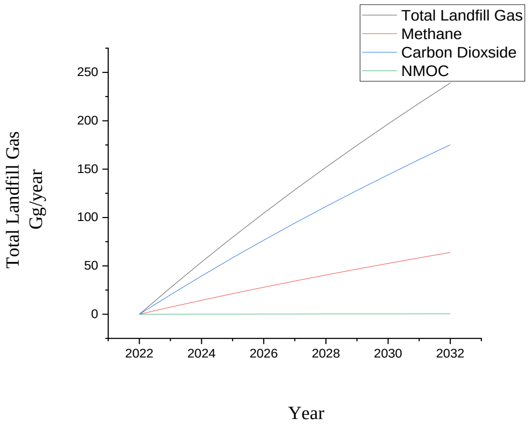


Figure 8. Chart of estimated methane gas production under optimal conditions

CONCLUSION

1. Waste generation from the 2 urban subdistrics resulted in a weight of 218.113 tonnes/year. The average waste composition consists of biodegradable waste of 37.13%, plastic waste of 25.73%, paper waste of 5.30%, cardboard waste of 4.69%, duplex waste of 3.93% and other waste of 23.22% and the density of loose waste has an average of 152.42 kg/m^3.
2. Optimal Reduction has an average Optimal RF of 52.7%, an average Optimal Waste Bank Reduction of 17.5% and an average Optimal Composting Reduction of 35.2%.
3. The Optimal Scenario in 2032 obtained reductions of total landfill gas 239.067 Gg/year, methane 63.857 Gg/year, carbon dioxide 175.209 Gg/year and NMOC 0.412 Gg/year.

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