



Estimation of the Global Warming Potential (GWP) in the Scenario of Domestic Waste Management in Sukabumi City

Perkiraan Potensi Pemanasan Global pada Skenario Pengelolaan Sampah Domestik di Kota Sukabumi

THAYYIBAH NAZLATUL AIN*, SHINFI WAZNA AUVARIA, DYAH RATRI NURMANINGSIH

UIN Sunan Ampel Surabaya, Surabaya, Indonesia

*thayyibahnazlatul@gmail.com

INFORMASI ARTIKEL

Histori artikel:

Diterima: 13 Juli 2021

Disetujui: 21 Juni 2022

Diterbitkan: 31 Juli 2022

Kata Kunci:

Potensi Pemanasan Global

Pengelolaan Sampah Domestik

Penilaian Daur Hidup

ABSTRAK

Potensi pemanasan global disebabkan oleh beberapa aktivitas manusia, salah satunya pengelolaan sampah. Pengelolaan sampah menghasilkan potensi pemanasan global dari proses pengangkutan dan pengolahan yang berhubungan dengan material, kebutuhan energi dan hasil sampling dari keseluruhan prosesnya. Dampak lingkungan dari pengelolaan sampah sering kali tidak dipertimbangkan. Hal tersebut akan berpengaruh pada penerapan regulasi untuk mengelola sampah secara holistik. Penelitian ini bertujuan untuk mengetahui skenario terbaik dengan potensi pemanasan global yang paling rendah dari pengelolaan sampah rumah tangga dengan mempertimbangkan dampak lingkungan dari proses pengelolanya terutama yang berhubungan dengan potensi pemanasan global. Penelitian ini menggunakan pendekatan penilaian daur hidup atau LCA menurut ISO 14040:2006 dengan unit fungsional 1 ton sampah rumah tangga. Kategori dampak dibatasi hanya untuk analisis potensi pemanasan global dari ketiga skenario yang ditentukan berdasarkan tujuan dan definisi. Metode analisis dampak (LCIA) menggunakan *Center of Environmental Science Leiden University Impact Assessment* (CML-IA) dengan software SimaPro program versi 9.1. Hasil penelitian menunjukkan bahwa skenario terbaik dengan potensi pemanasan paling rendah yang dianalisis dengan pendekatan LCA adalah skenario 2 dengan $5,0 \times 10^{-6}$ kg CO₂-eq, sedangkan skenario 0 adalah $1,21 \times 10^{-5}$ kg CO₂-eq dan skenario 1 adalah 6,0001 kg CO₂-eq. Maka, pengelolaan sampah rumah tangga terbaik dengan dampak paling kecil adalah pengelolaan dengan skenario 2, meliputi: pemilahan sampah, komposting rumah tangga, penyaluran ke bank sampah, dan pengangkutan residu ke TPA.

ARTICLE INFO

Article history:

Received: July 13th 2021

Accepted: June 21st 2022

Published: July 31st 2022

Keywords:

Global Warming _otential

Domestic Waste Management

Life Cycle Assessment (LCA)

ABSTRACT

Global warming potential is caused by several human activities, waste management is one of them. Municipal waste management releases the global warming potential from transportation and treatment processes related to the material, energy needs, and byproducts. Often, environmental impact from domestic waste management is not considered. Therefore, it will affect the implementation of regulation in handling solid waste holistically. This research aimed to produce the best scenario with the lowest global warming potential for domestic waste management. This research used Life Cycle Assessment (LCA) approach according to ISO 14040:2006 with the functional unit of 1 ton of domestic waste. The impact category was observed and limited on global warming potential (GWP) by analyzing three scenarios based on goals and scope definition. The LCIA method used was the Center of Environmental Science Leiden University Impact Assessment (CML-IA) using SimaPro program version 9.1. The results show, the best scenario with the lowest GWP based on the LCA approach is scenario 2 with 5.60×10^{-6} kg CO₂-eq. While, scenario 0 is 1.21×10^{-5} kg CO₂-eq and scenario 1 is 6.0001 kg CO₂-eq. Therefore, the best scenario with the lowest GWP of domestic waste management is scenario 2, which manages upstream domestic solid waste management: sorting of waste, household composting, distributing to waste bank, and transporting residue to landfill.

1. INTRODUCTION

1.1 Background

Global warming is unbalancing ecosystem that is caused by increasing atmosphere rate temperature especially due to by GHGs (CO₂, CH₄, fluorinated gases, etc). This significantly makes infrared radiation heat trapped in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) stated that if we do not prevent and treat GHG emissions with our effort, the earth's temperature will increase by 6.4 °C (Kristanto, *et al.*, 2019).

Indonesia's efforts to contribute to global warming mitigation are by ratifying several international agreements such as Kyoto Protocol in 2004 dan Paris Agreement in 2016, in which Indonesia seeks to maintain global temperature increase below 2 degrees. In the Paris Agreement, it was stated to limit the temperature rise to 1.5 °C (Romawati, 2018). Based on an update from Nationally Determined Contribution (NDC) for dealing with global warming, Indonesia's target for reducing GHG is 29% and 41% with international assistance by 2030 (Ministry of Environment and Forestry, 2021).

The potential of global warming from GHG is caused by several activities, especially human activities, such as agriculture, industry, land use, energy, transportation, household, and waste. The energy and land-use sectors are the two most significant GHG contributors accounting for 50% of GHG emissions (Kristanto, *et al.*, 2019). Waste management is one of sectors that contributes to global warming. Waste management activities contribute to the emission of greenhouse gases into the atmosphere. Waste management accounts for 11% of the GHG emissions (Karosekali, 2018). Moreover, in developing countries such as Indonesia, urban waste is still carried out in the conventional way, namely collect-haul-dispose (Damanhuri & Padmi, 2018).

Waste management is a complex process involving many technologies and disciplines which are generally related to the control of waste generation, handling, storage, collection, transfer, transportation, processing, and landfill (Karosekali, 2018). In Indonesia, municipal solid waste management is regulated in Law Number 18 of 2008 concerning solid waste management. The final process of waste management ends with landfilling at the disposal location. 60–70% of waste generated in Indonesia is transported to landfill, while the remaining 30–40% is burned in households, lakes, rivers, seas, or managed by the community (Karosekali, 2018).

1.2 Objectives

This research aimed to produce the best scenario with the lowest global warming potential for domestic waste management. This research used Life Cycle Assessment (LCA) approach according to ISO 14040:2006. LCA is an objective process for evaluating the environmental impact of a product, process, or activity holistically. The impact is analyzed by identifying the energy and materials used and the waste that is released from the whole processes into the environment. LCA consists of four stages, including; (a) Goal and Scope, (b) Inventory Analysis, (c) Impact Assessment

and (d) Interpretation (Mcdougall, *et al.*, 2001). The analysis of LCA in this study used SimaPro software to assist with impact assessment. SimaPro is a tool to collect, analyze and monitor the sustainability performance data of products and services, including the whole process of the material and energy flow. SimaPro provides several data inventories and can be adapted to conditions in the field.

This research was conducted in Sukabumi city Figure (1), which is 96 km from Jakarta and 120 km from Bandung, and has a population of 346,325 people with a growth rate of 1.44% in 2020 (Dinas Lingkungan Hidup Kota Sukabumi, 2018). Sukabumi generates an estimated 171 tons of waste per day, and it was still treated around 10.06% in TPS 3R, waste bank, community composting, and TPA Cikundul. The existing waste management facilities in Sukabumi comprise one landfill known as the Cikundul Landfill, with controlled landfill system and 2 years remaining of the landfill age (Lubis, 2018). In addition, 12 waste management facilities (TPS 3R) are not optimized, which left only 3 facilities that are operating.

Plenty of studies have evaluated the GHG emissions reduction by managing solid waste in several cities (Romawati, 2018). This study aimed to analyze three scenarios planned for waste management in Sukabumi to grasp the best scenario with the lowest global warming potential. The life cycle assessment method in this study is based on ISO 14040:2006 with the basic functional unit being 1 ton of domestic waste.

2. METHOD

2.1 Location

The location of this research was conducted at Sukabumi City (Figure 1). Determination of sampling location based on level of community income (Aprilia, 2018). The location consists of Gedong Panjang Sub-municipality, Citamiang Sub-municipal representing lower-middle community; Baros Kencana Public Housing, Baros Sub-municipal representing middle-class community; and Griya Selabumi Indah Estate, Gunung Puyuh Municipality representing upper-middle community.

2.2 Data and Analysis

The data collected consists of primary and secondary data. Secondary data from this study include data on the weight of waste dumped in Cikundul landfill and TPS 3R, population data of Sukabumi City, resident income, the strategic plan of Environmental Office of Sukabumi city (DLH Kota Sukabumi), and other literatures.

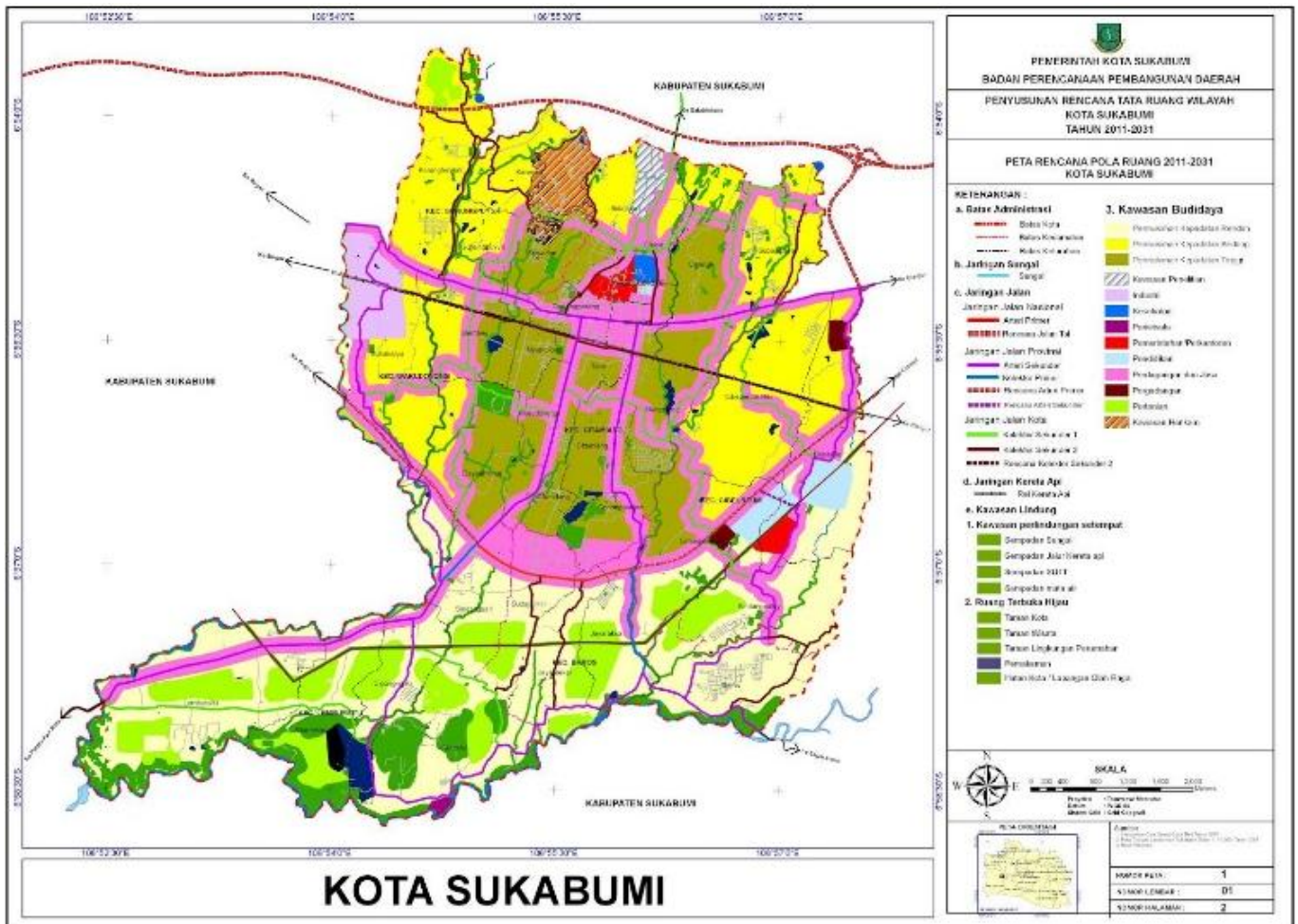


Figure 1. Sukabumi City Map. Source: Regional Development Planning Agency Sukabumi City, 2018

Primary data consists of the generation, density, and composition of the domestic waste, material and energy requirements in the waste management system, and domestic waste management regulations. The sampling of waste composition was based on SNI 19-3964-1995 concerning "Method of Collection and Measurement of Samples of Urban Waste Generation". Waste was sorted based on the composition of waste according to the input requirements for SimaPro analysis. Generation, density and composition analysis was done by collecting waste of 36 lower-middle samples, 24 middle-class samples, and 20 upper-middle samples. Data on material and energy requirements were obtained by interviewing employees of each waste management sector, while domestic waste management arrangements were obtained by interviewing officials from the Sukabumi City Environmental Office (DLH) and the Sukabumi City Regional Development Planning Agency (BAPPEDA).

The data was processed for population projections, waste generation rate in Sukabumi City, and calculation of material and energy requirements in waste management. Population and waste generation projections in Sukabumi City were estimated up to 2030, according to the TPS 3R operation period based on the strategic plan.

The results of the calculations of material and energy requirements in waste management were used as inventory for life cycle assessment analysis on SimaPro software based

on ISO 14040:2006. Measurement of potential environmental impacts was carried out using the CML IA Baseline method by calculating the potential for global warming. In the LCA analysis, it is necessary to determine the functional unit. The functional units are the basic reference units used in all scenarios. Therefore, it will be compared representatively. In this LCA analysis, the functional unit used at this stage was 1 (one) ton of waste.

In this research, three scenarios of waste management were planned. The first scenario was the existing waste management implemented in Sukabumi City, while the other two scenarios were designed. These scenarios were developed based on the waste composition and available affordable technologies. Figure 2, 3, and 4 summarizes the detailed processes in each scenario, amounts of waste handled, and boundaries system of analyzing. The first scenario (scenario 0) assumed that 100% waste was transported to the landfill. Scenario 0 analyzed the material and energy flow of collecting waste from household, the transferring process to Temporary Waste Dump Site (TPS) and the transporting process to the landfill. While in the second scenario (scenario 1), waste treated in TPS 3R is about 10.6% of total domestic waste based on the field condition. In scenario 1, waste planned by collecting from household then transferred to Waste Dump Site by Reduce, Reuse, Recycle methods (TPS 3R). The waste is treated in TPS 3R by composting, sorting and distribution to recycling center and

residue transport to the landfill. In the third scenario (scenario 2) waste is treated in the upstream sector (households) including composting and distributing to waste bank. Therefore, waste that is transported to the landfill is only residual waste after being managed in households.

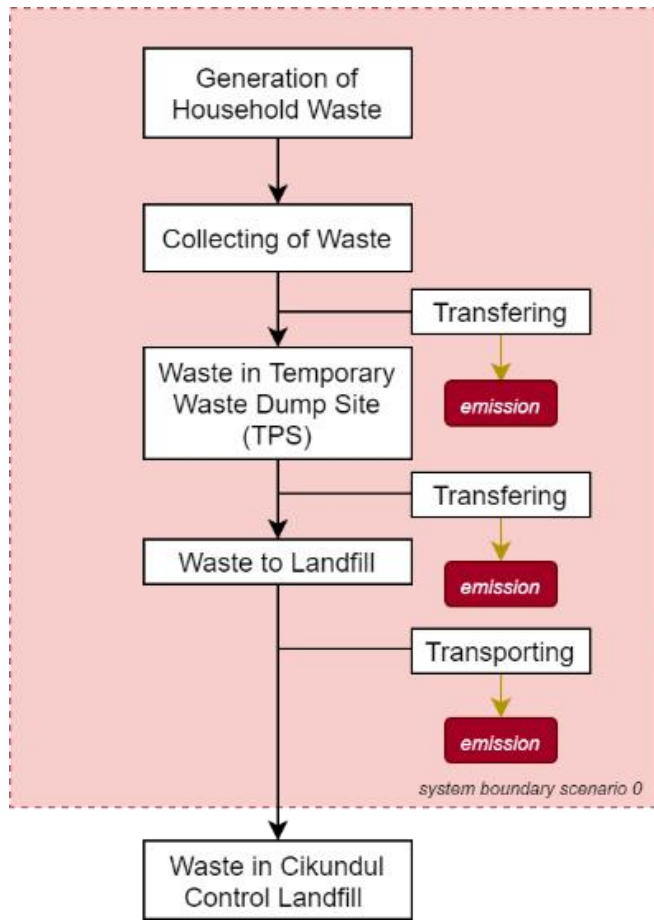


Figure 2. Scheme and boundary scenario 0

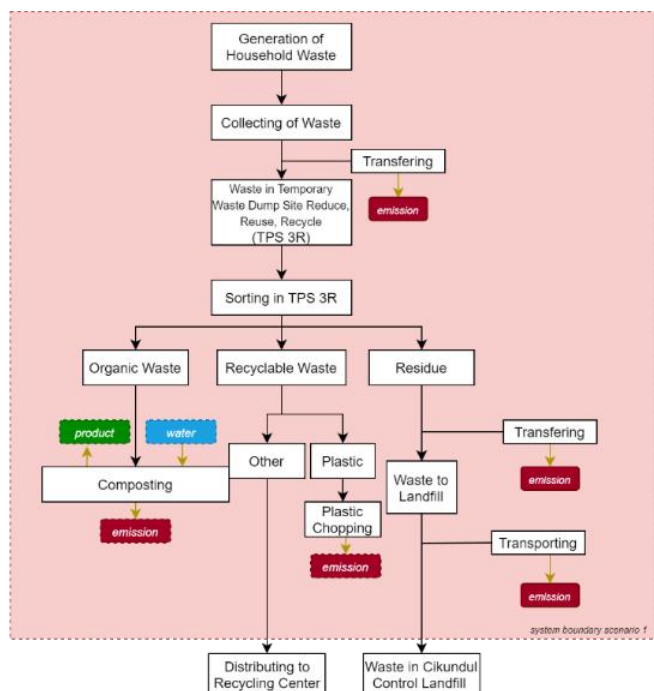


Figure 3. Scheme and boundary scenario 1

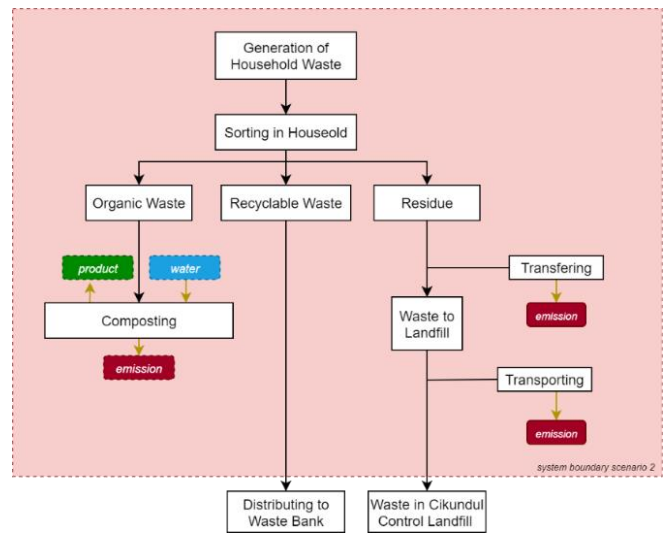


Figure 4. Scheme and boundary scenario 2

3. RESULT AND DISCUSSION

3.1 Waste Generation, Density and Composition of Sukabumi City

The results of sampling and calculations of waste generation and density are presented in Table (1). The sampling results present that the average waste generation is 0.47 kg/person-day. Based on the population, according to SNI 19-3983-1995, Sukabumi City is classified as a medium city with a waste generation range of around 0.7–0.8 kg/person-day. This means that the waste generation in Sukabumi City is still below the medium city range. Waste generation is influenced by various aspects, one of which is the level of income (Damanhuri et.al., 2018). As seen from the sampling results data, the highest waste generated from the upper-middle class is 0.55 kg/person-day. This shows that the higher the standard of living of the community, the higher the consumption pattern that affects the generation of waste produced (Damanhuri, et.al., 2018). Waste density is the weight of the material per unit volume. The density of this waste is influenced by geographical location, duration of storage and seasons in an area. This density will affect the design of storage areas, and overall waste management (Kiswandayani, et.al., 2015).

Table 1. Sampling results and calculation of waste generation and density in Sukabumi City

Sample	Waste Generation (kg/person.day)	Waste Density (kg/m ³)
Lower-Middle	0.36	143.3
Middle	0.51	135.9
Upper- Middle	0.55	102.2

Based on the sampling results, it was found that the average domestic waste density in sources is 127 kg/m³. The highest density of waste comes from the lower-middle class. This is because, even though this community produces household food waste which is relatively minor, plastic waste originating from the lower-middle class has been mixed with wet waste. This is also related to the

consumption pattern of the lower-middle communities, which, based on observations, are accustomed to consuming wet snacks wrapped in plastic. In addition, the Sukabumi City government is currently increasing the capacity of Micro, Small, Medium Enterprises (MSMEs) and encouraging local product branding by optimizing various types of packaging (Krishna, 2019). Thus, the potential for plastic packaging among the lower middle community is increasing.

The composition of waste in lower-middle, middle, and upper-middle community relatively are presented in Figure (5). Based on the analysis results in Figure (5), it is known that the highest composition of waste is food waste at 48.42%, while the second is plastic waste at 15.15%. There are differences in the composition of each economic strata of society, the highest percentage of food waste is in the middle class while the highest amount of plastic waste is in the lower middle class. The sampling results show that the lower-middle class tends to produce higher levels of plastic waste. This is from observations in the field of plastic waste produced from various food packaging, such as plastic packaging for children's snacks. This is also related to the increasing consumption pattern of the people. The consumption of the people of Sukabumi City in the last five years has increased from 43.74% in 2016 to 48.62% in 2020 (BPS, 2021).

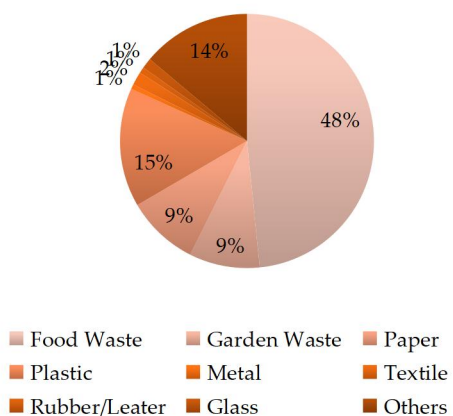


Figure 5. Waste composition

In addition, the Sukabumi City government program that accelerates the capacity of MSMEs causes high consumption of plastic used for packaging. Meanwhile, the middle class generates higher food waste because they tend to throw away a lot of leftovers that are still intact but in poor condition. Meanwhile, the composition of waste in an area is influenced by several factors, including income per capita of the community and socio-economic conditions. The upper-middle class will produce various types of waste (Kiswandayani, et.al., 2015).

3.2 Projections of Population and Waste Generation

Population projection is an estimate of population in the coming years. Population projection is needed to estimate the amount of waste generated by residents of Sukabumi. Population projection was carried out using the population projection method based on Sukabumi population data from

previous years. Sukabumi City population data from 2011 to 2020 were obtained from Sukabumi City Statistics as the basis for calculating.

Determination of the estimated population in this study is based on the value of the correlation coefficient of significance (r) (the value of r, which is closest to the value of 1). Based on the calculation of the correlation coefficient, the value of r for the arithmetic method, the geometric method, and the least square method is -0.009, 0.874, and 0.864. The closest result to one was obtained by geometric method, so that based on population estimate, it is estimated using the geometric method. The next population projection was calculated by geometric calculation for the next ten years from 2021 to 2030. This is based on the ten-year life planning of the TPS 3R Sukabumi. Projected waste generation is calculated by population estimates. The calculation of waste generation used the formula in Equation (1).

$$Total\ Waste\ Generation = m \times p \dots\dots\dots(1)$$

Where m is mass of solid waste per person (kg/person-day), and p is total population projection (person).

The results of the calculation of waste generation by population of Sukabumi city in 2021–2030 are presented in Table (2).

Table 2. Waste generation projection in 2021-2030

Year	Waste Generation (ton/day)
2021	166.09
2022	169.47
2023	172.92
2024	176.44
2025	180.03
2026	183.69
2027	187.43
2028	191.25
2029	195.14
2030	199.12

3.3 Total of Global Warming Potential in Domestic Waste Management

The GWP value is represented in Table (3) and Figure (6). The highest GWP value in scenario 1 resulted from the recycling process, namely the plastic crushing process. This is because destroying plastic requires energy from diesel which is large and higher than composting. The comparison of impacts in the Global Warming Potential (GWP) category shows that scenario 1 has the highest impact value of 6.0001 kg CO₂-eq. This value is higher than scenario 0 (existing) and scenario 2, which are 1.2190×10⁻⁵ kg CO₂-eq and 5.6044×10⁻⁶ kg CO₂-eq, respectively. Scenario 1 has the most significant GWP impact because several management processes contribute significantly, such as the waste counting process for composting, compost sifting, and plastic enumeration. These activities produce high GWP emissions from diesel engines that use diesel fuel. In addition, the inventory data

used in this analysis uses diesel engine inventory data with a capacity of 18.5 kW, while in field conditions, the required diesel engine capacity is around 5.8 kW. This probably impact the contribution result calculation to be three times greater than the conditions in the field. Therefore, it can be estimated that the GWP impact from the contribution of organic waste counting and sifting is around 0.91 CO₂-eq and plastic counting is approximately 1.08 kg CO₂-eq. Even so, this value is still much higher than the impact generated in scenario 0 (existing) and scenario 2.

Table 3. Global warming potential of waste management scenarios

Proses	GWP Value (kg CO ₂ -eq)		
	Scenario 0	Scenario 1	Scenario 2
Collection	1.12 × 10 ⁻⁶	4.99 × 10 ⁻⁷	7.22 × 10 ⁻⁹
Composting	0	2.75	2.49 × 10 ⁻⁷
Recycling	0	3.25	0
Transporting	1.11 × 10 ⁻⁵	1.13 × 10 ⁻⁵	5.35 × 10 ⁻⁶
Total	1.21 × 10 ⁻⁵	6.0001436	5.60 × 10 ⁻⁶

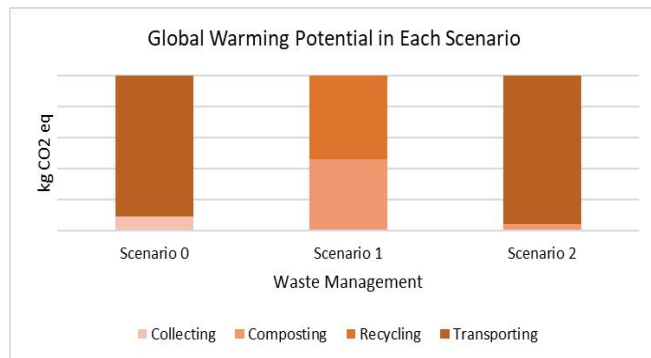


Figure 6. Global warming potential of waste management scenarios

3.4 The Analysis of Global Warming Potential caused by Collection and Transportation

Collecting and transporting is an important process in domestic waste management. The GHG emissions produced by transporting solid waste were calculated using Equation (2) while Table 4 summarizes the emission factors (EFs) used.

$$Emission = \Sigma(EF_{trans} \times d \times m) \dots \dots (2)$$

Where EF_{trans} is the fuel emission factor (kg of gas/ton/km), d is the distance (km), and m is the mass of solid waste (tons).

In Scenarios 0–2, the collection of domestic wastes generated 1.12 × 10⁻⁶, 4.99 × 10⁻⁷, and 7.22 × 10⁻⁹ kg CO₂-eq of GWPs, respectively. Meanwhile the transportation contributed 1.11 × 10⁻⁵, 1.13 × 10⁻⁵, and 5.35 × 10⁻⁶ kg CO₂-eq of GWPs, respectively. This contribution of GWPs from Scenario 0 to 2 is related to the amount of waste transferred to landfills. In collecting and transporting waste, tricycle motor, pick up car, arm roll truck, and dump truck were used. Analysis of transport fleet type is adapted to inventory data available in SimaPro databases as shown in Table (4).

In scenario 0, the amounts of solid waste transported to landfill were 167.65 tons/day. In scenario 1, the amount of waste processed in TPS 3R were 14.26 tons/day for composting and 23.96 tons/day for recycling, while 129.61 tons/day were dumped in landfill. In scenario 2, the amount of waste that was processed in the household were 2.73 tons/day for composting, 109.99 tons/day for distribution to waste bank and 55.8 tons/day dumped at landfill. In distributing waste to waste banks, it was assumed that 33 villages of Sukabumi city have waste banks. So, every household can distribute their waste to the nearest waste bank. For this reason, GWP of collecting and distributing of waste in scenario 0 was higher than the other scenarios because of the amount of waste that is transported. The comparison of GWP value of three scenarios is presented in Table (3) and Figure (6).

Table 4. Inventory data for analyzing

Process	LCI Coefficient	Emission Factor	SimaPro Database	Sources
Waste Collection				
Waste Motorcycle and Pick Up (Peralite)	CO	0.0023766	Transport, passanger car, large size, diesel, EURO 3 {RoW} - Cut Off, U	EPA, 2014
	CH4	0.00004		
	N2O	0.00000845		
Pool to Source (Solar)	<i>generated</i>		Transport, freight, lorry, 16-32 metric ton, EURO 3 {RoW} - Cut Off, U	Ecoinvent 3 Simapro 9.1
Dump Truck	<i>generated</i>		Transport, freight, lorry, 3.5-7.5 metric ton, EURO 3 {RoW} - Cut Off,U	
Engkel Truck	<i>generated</i>		Transport, freight, lorry, 7.5-16 metric ton, EURO 3 {RoW} - Cut Off,U	
Arm Roll	<i>generated</i>			
Composting				
Process	CH4	0.3	Diesel, electric generating set, 18.5 kW (GLO)-production - Cut Off, U	Colon et.al, 2011
	N2O	0.2		
	NH3	0.025		
	VOCs	0.32		
Compos Chopping	<i>generated</i>		Diesel, electric generating set, 18.5 kW (GLO)-production - Cut Off, U	Ecoinvent 3 Simapro 9.1
Compost Shifting	<i>generated</i>		Diesel, electric generating set, 18.5 kW (GLO)-production - Cut Off, U	
Plastic Chopping	<i>generated</i>		Diesel, electric generating set, 18.5 kW (GLO)-production - Cut Off, U	

3.5 Analysis of Global Warming Potential caused by Solid Waste Treatment

Waste treatment in scenarios 1 and 2 were planned, while in scenario 0 it was assumed that the waste just transporting for dumping in a landfill. In scenario 1, the waste was also treated by composting, recycling, and distributing to recycling center also. The emissions produced by waste treatment (i.e., composting, compost sifting and plastic enumeration) were calculated using Equation (3) with Table (4) summarizes the emission factors (EFs) used.

$$Emission = \sum(EF \times m) \dots\dots\dots(3)$$

Where EF is the emission factor (kg of gas/ton, and m is the mass of solid waste (tons).

The estimated contribution value of 0.91 kg CO₂-eq was generated from the composting process in scenario 1 carried out on 11 TPS 3R units. For each TPS 3R unit, it is estimated that the GWP contribution from composting is around 0.083 kg CO₂-eq /TPS 3R unit. Compared with the GWP value the impact of the composting process in the compost processing unit is 5.58 ×10⁻²² kg CO₂-eq. The comparison of GWP values from the three scenarios is shown in Table (3) and Figure (6). Based on these data, the figures are much different. This is caused by the generation of waste generated and the type of fuel used. In this study, the composting machine used electricity, so the resulting impact was much smaller than a diesel engine that uses diesel fuel.

In addition, in the composting process, there is a natural decomposition of waste. Composting with the primary raw material of food waste and garden waste is an organic material with the chemical compound C₂₂₂H₄₇₇O₂₂₁N₇S (Christina, et.al., 2012). From the chemical formula, it can be seen that there is a potential for decomposition of chemical compounds in the breakdown of the structure in the waste degradation process. This results in greenhouse gas emissions, including CO₂, N₂O, and CH₄. Waste management activities can produce different GHG emissions. Composting activity can produce CH₄ and N₂O (Kiswandayani, et.al., 2015), CO₂ and CH₄ are anthropogenic compounds that cause greenhouse gases (Derwent, 2020). Therefore, in the process of composting food waste and garden waste naturally, it can impact global warming potential (GWP).

Waste management carried out in scenario 2 is handled directly from the source by sorting it first. This significantly contributes to reducing greenhouse gases because in mixed waste the potential for degradation of organic materials is even greater. Solid waste in the disposal site produces heat, water, and carbon dioxide in the aerobic process, while carbon dioxide and methane are made in an anaerobic process (Daura, 2016). Moreover, in mixed waste, the decomposition process for composting will not run optimally. In addition, inorganic waste management is carried out by distributing it to waste banks in each village. This is so that the waste transportation process does not require long distances to reduce the energy needs of the transportation process.

4. CONCLUSION

Waste management is one of the contributors to global warming which is represented by the value of Global Warming Potential. Several scenarios were analyzed to find the best scenario with the lowest global warming potential from domestic waste management by considering the impact on the environment, especially related to global warming potential. Based on this research, the best scenario with the lowest GWP based on the LCA approach is scenario 2 with 5.60×10⁻⁶ kg CO₂-eq. While, scenario 0 is 1.21×10⁻⁵ kg CO₂-eq and scenario 1 is 6.0001 kg CO₂-eq. Domestic waste management in scenario 2 is upstream waste management: sorting of waste, household composting, distributing to waste bank, and transporting residue to landfill. However, in determining the best scenario in domestic waste management holistically, it is not only based on the lowest impact of global warming potential (GWP) but also needs to be considered by several other technical and non-technical aspects, one of them is referring to the achievement of waste management targets in accordance with the Regional Strategy and Policy (Jaktrada) and adjusted to the available budgeting.

ACKNOWLEDGMENT

Authors thank to Dinas Lingkungan Hidup Kota Sukabumi who provided data and support the process, also facilitate this research.

REFERENCES

- Aprilia, N. L. (2018). Perencanaan Teknis Tempat Pengolahan Sampah (TPS) 3R Kecamatan Jekan Raya Kota Palangka Raya. Skripsi. UIN Sunan Ampel Surabaya.
- Badan Pusat Statistik (2021). Produk Domestik Regional Bruto Kota Sukabumi Menurut Pengeluaran 2016-2020. Sukabumi: Badan Pusat Statistik Kota Sukabumi.
- Christina R.M, E., Samudro, G., Handayani, D. S. & Cyntia. (2016). Kajian Penentuan Metode Pengolahan Sampah Berdasarkan Timbulan, Komposisi, dan Karakteristik Sampah di Universitas Diponegoro (Studi Kasus: FSM, FIB, dan D3 Teknik). Prosiding Seminar Nasional Sains dan Teknologi. ISBN 978-602-99334-5-1.
- Damanhuri, E & Padi, T. (2018). Pengelolaan Sampah Terpadu. Bandung: ITB Press.
- Derwent, G. (2020). Global Warming Potential (GWP) For Methane: Monte Carlo Analysis of The Uncertainties in Global Tropospheric Model Predictions. Atmosphere, 11, 486. Doi:10.3390.
- Dinas Lingkungan Hidup. (2018). Rencana Strategis Kota Sukabumi Tahun 2018-2023. Sukabumi: Dinas Lingkungan Hidup Kota Sukabumi.
- Fikri, E., Purwanto, P., & Sunoko, H. R. (2015). Modelling of Household Hazardous Waste (HHW) Management in Semarang City (Indonesia) by Using Life Cycle Assessment (LCA) Approach to Reduce Greenhouse Gas (GHG) Emissions. Procedia Environmental Sciences.

- 23, 123–129. Doi: 10.1016/j.proenv.2015.01.019.
- Karosekali, K. (2018). Greenhouse Gas Emissions from Municipal Solid Waste Management in Bandung, Indonesia. Master Thesis. Wageningen University and Research.
- Kiswandayani, A. V., Susanawati, L. D. & Wirosuedarmo, R. (2015). Komposisi Sampah dan Potensi Emisi Gas Rumah Kaca pada Pengelolaan Sampah Domestik: Studi Kasus TPA Winongo Kota Madiun. *Jurnal Sumberdaya Alam dan Lingkungan*, 1, 9–17.
- Kreith, F. G. T. (2020). *Handbook Of Solid Waste Management*. New York: Mcgraw-Hill.
- Krishna, Dwipayana. (2019). Kembangkan Pemasaran Umkm, Pemkot Sukabumi Jalin Kerja Sama Dengan Perusahaan Layanan Pesan Antar Makanan Online. Post DPMPSTSP Kota Sukabumi. Retrieved from <https://gdpmpstsp.sukabumikota.o.id/Seputar-Penanaman-Modal/Kembangan-Pemasaran-Umkm-Pemkot-Sukabumi-Jalin-Kerja-Sama-Dengan-Perusahaan-Layanan-Pesan-Antar-Makanan-Online/>
- Kristanto, G. A. & Koven, W. (2019). Estimating greenhouse gas emissions from municipal solid waste management in Depok, Indonesia. *City and Environment Interactions*. 4, 100027. Doi: 10.1016.
- Lubis, E.W.N. (2018). Analisis Timbulan, Komposisi dan Karakteristik Sampah Rumah Tangga Di Kota Medan Wilayah I (Studi Kasus : Kecamatan Medan Johor dan Kecamatan Medan Tembung). Skripsi. Universitas Sumatera Utara.
- Ministry of Environment and Forestry. (2021). *Greenhouse Gasses Inventory Report*. Jakarta: Ministry of Environmental and Forestry .
- McDougall, F.R., White, P.R., Franke, M. (2001). *Integrated solid waste management: A Life Cycle Inventory (2nd Ed)*. *International Journal Life Cycle Assessment*. 6, 320. Doi: 10.1007/BF02978794
- Rohmawati. (2018). Emisi Gas Rumah Kaca dari Sampah Rumah Tangga di Kecamatan Bulak, Kota Surabaya dengan Metode IPCC. Skripsi. Institut Teknologi Sepuluh Nopember.