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MORALITY BEFORE KNOWLEDGE

Greenhouse gas emission calculation and energy impact of TPS3R flamboyan using waste reduction model (WARM) V.15: Implications for disaster risk reduction

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ABSTRACT

Background: Human activities contribute to increased greenhouse gas concentrations, such as CO_2 and CH_4, which intensify the greenhouse effect and elevate Earth's temperature. TPS3R Flamboyan aims to reduce plastic waste through recycling, composting, and landfilling at TPA Cipeucang. While these processes help reduce waste, they can also produce CO_2 emissions. This study evaluates the CO_2 emissions from the baseline waste management scenario and compares it with an alternative scenario using the Waste Reduction Model (WARM) to assess GHG emissions and energy use. **Methods:** Data was collected in June 2020 from TPS3R Flamboyan and TPA Cipeucang in South Tangerang, analyzing waste types and GHG emissions using the WARM software. The study utilized baseline and alternative waste management scenarios to assess CO_2 emissions and energy use, with input data on various waste types such as food waste and plastics. WARM compared the emissions and energy use for each scenario, providing insights on GHG reductions and energy efficiency in waste management practices. **Findings:** Total GHG emissions from baseline MSW generation and management ($MTCO_2E$) is -2.23 and total GHG emissions from alternative MSW Generation ad management ($MTCO_2E$) is -4,46. Total Energy use from baseline MSW Generation and Management (million BTU) is -33.98 and total Energy use from alternative MSW generation and Management (million BTU) is -92.22. **Conclusion:** Both scenarios indicate that the alternative scenario results in a higher reduction of emissions compared to the baseline management. This demonstrates the effectiveness of the alternative waste management practices in reducing greenhouse gas emissions. **Novelty/Originality of this article:** This research provides a novel approach by using the Waste Reduction Model (WARM) application, developed by the U.S. Environmental Protection Agency (EPA), to estimate greenhouse gas emissions and energy use in municipal solid waste management scenarios. This application offers high-level estimates for emissions reduction and energy efficiency, providing valuable insights for waste management practices.

KEYWORDS: WARM; CO_2; energy use; municipal solid waste; organic waste.

1. Introduction

Emissions have implications for human activities. One of these implications is the increase in the concentration of various greenhouse gases. These gases include carbon dioxide, methane, chlorofluorocarbons, and nitrogen oxides. This will result in an enhanced greenhouse effect, leading to a rise in Earth's surface temperature.

As a result of global warming, among others: The thinning and melting of ice at the north and south poles and other ice areas, causing the water level to rise. Increasingly hot weather on earth results in rapid evaporation of seawater so that rain occurs quickly. The

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ferocity of the weather causes very heavy rains, forest fires, sudden floods, and sudden hurricanes. The occurrence of immigration/migration on a large scale. A place inhabited by indigenous people traditionally migrated due to natural disasters as well as animal migration, for example, a group of butterflies in western North America has migrated as far as 95 km in the last 100 years. Outbreaks of both human and animal diseases (Ramlan, 2002). At present, many city dwellers are suffering from diseases due to deadly urban pollution which cannot be treated except by organ transplantation and of course requires high costs for treatment. Examples of diseases triggered by air pollution: Decreased lung function, asthma, lung cancer, respiratory tract infections (ARI), and pneumonia. Animal diseases are often found in areas where the forests have been deforested. Animals exposed to air pollution may exhibit symptoms of open mouth breathing, vomiting, or loss of appetite, with an animal's risk of having an acute cardiovascular episode and developing coronary artery disease rising. Decomposition of organic waste will produce carbon dioxide which decomposes in the air and forms methane gas. These two substances become emissions that contribute to the greenhouse effect in the world.

Meanwhile, waste from various sources comes from production that uses resources that produce GHG emission such as CO_2 and pollutants. This type of waste will be very important in the environment, especially if it is managed by burning The Ministry of Environment and Forestry (KLHK) reported that Indonesia produced 67.8 million tons of plastic waste in 2020, which means that there are more than 185,000 tons of waste every day, and 37.3 percent of it comes from household activities.

TPS3R Flamboyan, for example, functions as a plastic waste management site. This is carried out through recycling, composting, and the remaining waste is buried at the Cipeucang landfill. These actions are taken to reduce the amount of organic and inorganic waste, but various processes involved in waste treatment and distribution generate carbon dioxide. Therefore, it is necessary to calculate the amount of carbon dioxide produced based on waste management practices. The results are then compared with alternative urban waste management models to draw conclusions from the analysis. This is done using the Waste Reduction Model (WARM) application. The purpose of calculating greenhouse gas emissions is To find out how much CO_2 is formed from waste management activities at the flamboyant TPS3R TPS3R is a temporary waste disposal site that applies the 3R principles, namely reuse, reduce and recycle. TPS3R Flamboyan located in Perumahan Reni Jaya, blok AA No. 31, RW 020, Pamulang Barat, Kota Tangerang Selatan. It started operate since 01 April 2017. The capacity is 750 head of family. the current number of customers.e. in 2022 is 345 houses. The reason why the writer choose TPS3R Flamboyan for the source of data of solid waste management is because this tps3r Flamboyan one of the solid waste disposal sites that apply composting and recycling management in the city of south Tangerang while the other is only temporary landfill without any process that will only be disposed of to landfiles this is in line with the objective of calculating greenhouse gases. From waste management processes such as composting, combustion, landfilling, and recycling to produce CO_2, CO_2 is one of the greenhouse gas emissions that can cause a greenhouse effect, so it is necessary to calculate the amount of CO_2 and also alternative scenarios from waste management to find out what kind of waste management process can be a solution to reduce CO_2 in TPS3R flamboyant waste management. The CO_2 calculation is performed using the WARM application, which is developed by the EPA. This application provides upper-level estimates regarding the reduction of greenhouse gases, energy savings, and the economic implications of waste management actions. Using this application, the impacts of waste reduction, composting, recycling, incineration, and landfilling can be estimated.

The main sources of pollution in Jakarta, according to the Jakarta Environmental Agency, are land transportation, power generation and heating, industrial emissions, and household burning. The percentages for each source are 75%, 9%, 8%, and 8%, respectively. The high levels of CO_2 are inversely related to the scarcity of plants. For example, in 2019, Indonesia's forests covered 125 hectares, but by 2021, this had decreased to 95.6%, which is equivalent to 50-51% of the country's land area, according to the Ministry of Environment and Forestry. The Carbon DIoxide will build up in the atmosphere, preventing the earth from emitting heat, causing the heat to be reflected back into the ground. As a result, the earth gets very heated, and the greenhouse gas effect is once more present. Climate Change Potentials In terms of their ability to trap heat, Carbon dioxide, CH_4, N_2O, and perfluorocarbons (PFCs) are quite distinct gases. The measurement of heat-trapping potential is done using CO_2, which has been designated as the reference gas by the Intergovernmental Panel on Climate Change (IPCC) (also known as global warming potential or GWP). The GWP of one kilogram (kg) of CO_2 is one by definition. The following are the GWPs of additional typical GHGs produced by materials management activities. Since CH4 has a GWP of 25, one kilogram of it has the same capacity to trap heat as 25 kilograms of CO_2. The GWP of N_2O is 298. The most potent GHGs in this investigation are PFCs, with GWPs of 7,390 for CF4 and 12,200 for C2F6. WARM employs the instrument of GWP to compare all emissions on an equal footing by expressing comparative GHG emissions in metric tons of CO_2 equivalents (MTCO2E). WARM makes use of IPCC GWPs.

Some of the effects of CO_2 as greenhouse gas emission are as follow. Plant metabolism will be disrupted because plant cells experience rapid aging. As a result, farmers will lose because their plants die quickly. This is the impact of CO_2 on plants. The occurrence of global warming. Excessive CO_2 levels will cause more heat to be absorbed and reflected to the earth so that the earth's temperature increases. Greenhouse gases, one of which is excessive CO_2 in the atmosphere, will be able to withstand solar heat radiation from leaving the earth's atmosphere, resulting in global warming. The result Changes in temperature cause changes in rainfall. As a result, storms occur more frequently and more intensely, causing floods and landslides, destroying homes and communities, and causing material and non-material losses. The effect of global warming resulting from greenhouse gases, one of which is CO_2, is an increase in drought. More and more places are experiencing a water shortage. Devastating sand and dust storms that transport billions of tons of sand across continents can be sparked by droughts. The area suitable for growing food crops is being reduced as deserts grow. The fear of ongoing water shortages is currently being felt by a lot of people. Heat stress from global warming can reduce water resources and pastures for grazing, leading to reduced yields and affecting livestock.

The problem of this research is listed as follows. First, What is the result of Green House Gas Calculation in Metric Tons CO_2 Equivalent ($MTCO_2E$)? second, What is the result of the Waste Reduction Model of Green House Gas (GHG)? Third, What is the result of Energy Impact in million British Thermal units (BTUs)? Fourth, What is the result of the Waste Reduction Model of Energy Impact?

1.1 Carbon dioxide

Naturally, greenhouse gases in the atmosphere have a role in maintaining the earth's temperature so that it is suitable for habitation, because if there were no greenhouse gases, the Earth's temperature would be 33 OC cooler than current conditions (Kusumaputri, 2009). There are many types of gases that are considered greenhouse gases. CO_2 is the type of greenhouse gas that contributes the most to the increase in global warming (Buchdahl et al., 2002). Moreover, this gas has been increasing massively year by year (see Figure 1). In 1960, its concentration was only around 0.7 ppm/year, then it increased to 2.38 ppm/year by 2014. Meanwhile, Indonesia has become a significant source of global CO_2 increase. In 1990, it contributed 0.6%, then in 2005 it rose to 1.2%, and by 2015 it reached 1.4% (Susandi, 2006).

Sources of CO_2 gas come from both natural and human activities. Forest and land fires are one of the sources of CO_2 gas emissions in Indonesia which occur almost every year. Climate change is the greatest challenge facing the global community, caused by CO_2. The natural processes that reduce CO_2 in the atmosphere are much slower than human activities that produce this gas, which occur at a much faster rate (GAW, 2017). As a result, global temperatures have been rising for many years, at least since 1960. Since then, Earth's temperature has increased due to the greenhouse effect caused by carbon dioxide and various other pollutant particles.

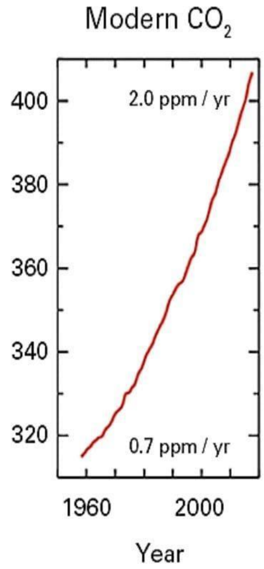

Fig. 1. The rate of increase in global CO_2 concentrations
(Teller et al., 1996)

As greenhouse gases increase, the Earth experiences a deficiency in infrared radiation, causing a reduction in the amount of infrared radiation escaping into space. However, at the same time, sunlight continues to be received by the Earth, creating an imbalance between the incoming and outgoing radiation energy at the tropopause layer of the atmosphere. This is expressed in terms of radiative forcing. Research group from various countries in the world present the results of research on climate change in the IPCC (Intergovernmental on Panel Climate Change) report. Based on the 1995 IPCC report on the greenhouse gas index, found a 64% increase in radiative forcing CO_2 from the pre-industrial period (1750) to 1995.

1.2 Solid waste

The definition of solid waste' would be anticipated to be 'a waste in a solid state'. However, solid waste may be solid, or liquid as a sludge or as a free chemical phase. This originates from defining solid waste as waste that is not water (wastewater) or air borne (flue gasses) (Christensen, 2011). The types of waste are categorized into inorganic and organic waste, the composition of the waste is reflected in the percentage of the types of waste, while the character of the waste is displayed through wet and dry waste. The waste management strategy chosen is determined based on the character of the waste (Olivier et al., 2017). Some of the waste management processes are as follow.

Municipal solid waste (MSW) reflects the culture that produces it and affects the health of the people and the environment surrounding it (Vergara & Tchobanoglous, 2012).The USA, China and India are the top three producers of municipal solid waste. The composition of solid wastes varies with income: low-to-middle-income population generates mainly organic wastes, whereas high-income population produces more waste paper, metals and glasses. Management of municipal solid waste includes recycling, incineration, waste-to-energy conversion, composting or landfilling. Landfilling for solid waste disposal is preferred in many municipalities globally (Nanda & Berutti, 2021). Solid waste management is one among the basic essential services provided by municipal authorities in the country to keep urban centres clean (Asnani, 2006). Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, MSW clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of MSW and improper incineration contributes significantly to urban air pollution (Alam & Ahmade, 2013).

1.2.1 Composting

Composting is an organic waste management technique that tries to minimize and transform trash into usable goods. Composting is an environmentally friendly technique for processing organic waste. Compost is usually made from leaves or animal manure. The goal is to balance the nitrogen and carbon content, which speeds up the decomposition process because their ratio is aligned. Various types of animal manure can be added. In this regard, the SNI 19-7030-2004 standard serves as a reference for assessing the quality of the produced compost. Numerous living creatures, including bacteria and fungus, actively participate in the composting process by dissolving complex organic materials into simpler forms. To accelerate microbial proliferation, certain microbial isolate products have been found which are marketed as bioactivators in composting, one of which is Effective Microorganisms 4 (EM4) which was first discovered by Prof. Teruo Higa from Ryukyus University, Japan. The EM4 solution contains fermenter microorganisms consisting of about 80 genera, and these microorganisms are selected which can work effectively in the fermentation of organic matter. Of the many microorganisms, there are three main groups, namely photosynthetic bacteria, Lactobacillus sp., and fermented fungi . In addition to the commercial product EM4, various kinds of decomposing microorganisms in nature can be used as bioactivators in the composting process. This type of microbe is often referred to as a local microorganism (MOL), which can be cultured using a variety of sources organic matter. Vegetable waste can be a good medium for breeding decomposing microorganisms, and can be used as bioactivators in composting. Almost all vegetables will undergo lactic acid fermentation, which is usually carried out by various types of bacteria Streptococcus, Leuconostoc, Lactobacillus, and Pediococcus. These microorganisms will convert the sugar in vegetables, especially into lactic acid which will limit the growth of the organism others (Pujiastuti, 2010).

Composting is predicted by the WARM model to have carbon storage benefits, nitrogen and phosphorus fertilizer offsets, and little CO_2 emissions from transportation and mechanical compost pile churning. The breakdown of source materials, such as newspaper, grass , leaves, brush, and food scraps, results in CO_2 emissions during composting. However, the biogenic CO_2 released during composting from these materials is not included in the calculation of GHG emissions, as stated in the text box on "CO_2 Emissions from Biogenic Sources." Additionally, composting creates trace quantities of CH_4 and N_2O. (due to anaerobic decomposition during composting), which change depending on how much nitrogen and how much carbon are in the garbage being composted. These fugitive emissions were included in WARM version 13 because research suggested they might occur even in properly maintained compost piles. Due to the impacts of compost application on soil carbon repair and humus formation, composting does improve soil carbon storage.

1.2.2 Landfilling

Landfill is a place for storing burned waste / garbage, located in a layer of soil shallow, can be exploited economically and politically. One thing to consider in a sanitary landfill is the geological and topographical structure of the soil. Another consideration is the depth of groundwater, soil layers to rock layers. Landfill locations will have an adverse effect on surface water and groundwater located below the landfill base. In such circumstances, the land can be given some renovation to deal with leachate. In this way, the quality can be improved before being separated from surface water or groundwater, the flow from this soil can form a cover material. So that it can create an optimal renovation facing leachate.

The landfill site must be chosen carefully from the available locations, namely wet and dry silt can be used as a good and spacious enough for a santary landfill. When a sanitary landfill is placed in a dispersed area close to a clean water supply, The rock and groundwater reservoir depths must be taken into consideration. There is uncertainty about the exact mechanism of leachate production. That leachate is mostly a result of sanitary landfill. The hydrological method shows that with a little rain water, leachate will form, so sanitary landfill is thought to be a source of pollution.

Culham et al. (1969) investigated a larger type of landfill an additional equipment is obtained to do certain things, a fast scraper to transport and remove the covering material, a sprinkler controllers/dust, types of direct-operated ground equipment, tractors, bulldozers. Sanitary landfills have the potential to be utilized by lands that previously could not be used. So large is reused, thus adding to the economic value. From the life side, a sanitary landfill will undergo a decomposition process, aerobically or anaerobic when the material is first placed in the filling, the process decomposition leads to aerobic events, when the oxygen component is consumed, then landfills are considered to be subjected to anaerobic conditions, the duration of which depends on temperature and available oxygen. The aerobic decomposition period is faster than the anaerobic period in this process. The products obtained from aerobic decomposition are acids and alcohols, which consumed by micro-organisms which will produce methane and carbon dioxide. Gas Methane causes gas conditions to enter the house. Another gas produced anaerobically is hydrogen sulfide foul-smelling and explosive (Yulipriyanto, 2006).

Some of the organic waste that is landfilled breaks down anaerobically and produces CH_4. Some organic material never even begins to break down, and the carbon ends up being deposited in landfills. Metal and plastic waste disposal does not produce CH_4 emissions or carbon sequestration. Almost all of the CH_4 generated at some landfills is discharged into the sky. In other instances, CH_4 is collected for burning while recovering energy (e.g., electricity production). Nearly all of the collected CH_4 is transformed to CO_2, but because it is biogenic, it is not included in this study's calculations of GHGs. The averted GHG emissions from the electric utility are reflected in the emission factors when CH_4 is burned for energy recovery. Regardless of what happens to the CH_4, the carbon dioxide accumulation in landfills caused by the disposal of certain organic waste is taken into account.

1.2.3 Combustion

With an environmentally sound development and to reduce the level of environmental pollution from solid waste , it is necessary to have a waste treatment process . To overcome these problems is the need for a Solid Waste Treatment Plant (IPLP). The process that can be used is the process of processing solid waste by combustion using a combustion chamber furnace unit in this way the volume of solids will be reduced so that it does not cause solids (waste other than that to ensure smoke / gas combustion products come out of the chimney clear without disturbing the surrounding environment Then the designed burning furnace is equipped with a smoke processing unit in the form of a scrubber. Scrubber is a means of binding air pollutant substances (dust particles, CO, NO, SO,) simple scrubber types, especially spray towers. Solid waste with a combustion system has been reported by various parties to have faced many problems, especially problems of technology, economy, and public health. Technological aspects that cause problems are location, physical form, working methods, spare parts and fuel. The problem with the community is the magnitude of the system's effectiveness, both in terms of quality and quantity.

The capacity of the incinerator to break down hazardous trash into a stable substance that poses no health risk is what is indicated by the quality element. While the capacity of the combustion chamber to reduce the amount and mass of trash is what is expressed in terms of quantity (Suwatanti & Widiyaningrum, 2017). The process of burning waste produces harmful gases. When burning a pile of garbage, the outside that gets enough oxygen will produce carbon dioxide (CO_2), while the inside of the garbage heap that lacks oxygen will produce carbon monoxide (CO).

1.2.4 Recycling

Recycling is the act of converting used resources into new ones in order to prevent waste that may instead be put to use, hence lowering the need for fresh raw materials.

Recycling can also be defined as the reuse of unused materials or goods in other forms. Recycling and reuse have the following objectives following: (1) Reducing the amount of waste to reduce pollution or environmental damage, (2) Reducing the use of materials or natural resources, (3) Get income because it can be sold to the public, (4) Preserving the life of creatures found in a certain environment, (5) Maintain the balance of the ecosystem of living things contained in the environment, (6) Reducing inorganic waste because inorganic waste can be survive for the next 300 years.

With an average rate of growth of 14.7% each year, plastic garbage now accounts for 15% of the nation's total waste output, making it the second largest donor (behind organic waste). Studies in various Indonesian cities show that the contribution of plastic waste to total municipal waste in Indonesia varies, including Jakarta (14%), Surabaya (10.8%), Palangkaraya (15%) (Garbage contribution percentage Plastics in Indonesia are not much different from Malaysia (14%) and Thailand (16%) but lower than Singapore (27.3%).

However, given that Indonesia generates 189 kilo tons of garbage each day on average, the generation of plastic waste there is extremely significant., which is much larger than countries in Southeast Asia. This is because the population of Indonesia is larger than the population of countries in Southeast Asia. Because plastic cannot disintegrate naturally, managing plastic garbage presents a challenge (non-biodegradable) so that the management of plastic waste by landfill or open dumping is not appropriate. Combustion-based plastic waste treatment can have a detrimental influence on the environment by releasing dioxin emissions, that are carcinogens. Another method of managing plastic trash is to recycle it into new forms, although this method simply modifies the amount of plastic waste; as a result, when the recycled plastic product is no longer useful, it decomposes back into plastic garbage. Other solutions are thus required to deal with this amount of plastic garbage.

Recycling is one option for dealing with plastic trash. Plastic waste is pyrolyzed to create fuel as a type of recycling technique. Plastic trash may be pyrolyzed to produce high-value fuel with a significant quantity of energy, in addition to being effective for lowering the volume of plastic waste. Typically, 1 kilogram of polyolefin plastic, such as polypropylene, polyethylene, and polystyrene, may be pyrolyzed to yield 950 cc of fuel oil. Research has been done on the production of gasoline from plastic garbage. By altering the content and kinds of plastic raw materials, Pratama & Saptoadi (2014) and Kadir (2012) studied the pyrolysis of plastic trash. While the studies thatconducted by Osueke & Ofondu (2011) focused on pyrolysis which took place at high temperatures and the effect of using a catalyst on product quality. However, in general the studies that have been carried out using complex pyrolysis installations are more directed for industrial scale. There have not been many studies examining simple (small-scale) installations. Simple pyrolysis installations with low production capacity and low investment costs are currently being developed (Khuzzaman et al., 2013).

Urban dwellers produce a significant amount of waste, which is regarded to be a possible source of methane gas. Methane is also a greenhouse gas that contributes to the enhancement of the greenhouse effect, resulting in global warming. In large cities, only 450 landfills are capable of using open dumping methods, which helps to manage waste disposal. In 45 major cities, the waste produced reaches 4 million tons. As a result, 11,390 tons of methane and 239,199 tons of carbon dioxide are emitted. This amount is equivalent to 64% of the waste from these major cities—those cities include Jakarta, Medan, Surabaya, Palembang, Bekasi, Depok, Makassar, Bandung, Depok, and Tangerang (Wahyudi et al., 2018). Food and yard debris that we dump in the trash will be transported to landfills and buried there. Methane gas is created during the breakdown of the garbage at the bottom. Because methane gas is a ghg that might contribute to climate change, it will harm the ozone layer of the planet.

Additionally, burning garbage can result in the production of greenhouse gases such Carbon Dioxide, Nitrogen Oxide, Ammonia, and Organic Carbon. The primary gas released when garbage is burned is CO_2, and it does so more quickly than for other gas emissions (Johnke, 2000). Waste management and the use of appropriate technologies are ways to reduce waste emissions. With technology, CO_2 can be reduced, and electricity can be generated for the benefit of society (Rajaeifar et al., 2017). Additionally, the public can also strive for sustainable carbon reduction through a zero waste strategy. Furthermore, the reduction of greenhouse gases can be carried out hierarchically, starting from energy recovery, composting, recycling, and waste minimization by utilizing reusable products (Trois & Jagath, 2011).

1.2.5 Anaerobic digester

Anaerobic digestion is a process of organic biomass degradation in the absence of oxygen. Organic waste from households has the potential to become biomass to be processed using a reactor (called a biodigester) because it contains substrates tha easily degraded by microorganisms. Processing of organic waste using anaerobic digestion is a sustainable and potentially profitable process because in addition to reducing organic waste, biogas is produced in this process. high energy and digestate which can be used as a soil additive (Prayitno, 2007).

2. Methods

2.1 Research location, time periode, and data collection

TPS3R Flamboyan located on Jl. Flamboyan No.31, Pamulang Bar., Kec. Pamulang, Kota Tangerang Selatan, Banten 15416. TPS3R Flamboyan is the waste collection place where the researcher take data from. TPA Cipeucang is the landfill area where the residue trash from TPS3R will be deliver. TPA Cipeucang addressed Jl. Kapling Nambo No.51, Serpong, Kec. Serpong, Kota Tangerang Selatan, Banten 15310. Service area TPS3R Flamboyan are 287 houses Reni Jaya, 35 houses Gardena and 15 public shophouses.

Fig. 2 (a) TPS3R flamboyan; (b) TPA cipeucang; (c) Service area TPS3R flamboyant

The independent variable in tons are Corrugated Container, Newspaper, Office Paper, Textbooks, Food waste, PET, PP, PVC, Mixed plastics, Aluminum Cans, Mixed Metals, Mixed Recyclables, and HDPE. The dependent variables are CO_2 carbon dioxide in metric ton of CO_2 equivalent in baseline and Scenario waste management as well as energy use in million BTU for baseline and Scenario waste management. The secondary data needed in this study are as follows: (1) The amount of inorganic and organic waste and residue in one year. This study took data in 2020; (2) The flow of waste processing at TPS3R Flamboyan; (3) Amount of inorganic waste in one month for recycling process; (4) Baseline data for generation and waste material; (5) Alternative Scenario Data for generation and waste material

2.2 WARM software

The Application that writer use is Waste Reduction Model (WARM) Version 15. It is available in Excel Formation. It was created by the U.S Environmental Protection Agency (EPA) to help Solid Waste Planner and Organization estimate Green House Gas (GHG) emission Reductions From Several Different Waste Management Practice. For given time period under each scenario by material type and by management practice, the mode allows to customize the result based on project specific landfill gas recovery practice, anaerobic digestion practice and transportation distance.

The most recent version, updated in May 2019 of the LCA model utilized in this study is WARM. emissions of greenhouse gases caused by various methods of waste management Using WARM, the GHG emissions based on an analysis of three key aspects: (1) GHG emissions during the life cycle of (2) The amount to which the production, recycling, and disposal of the item effect carbon sinks (3) The degree to which the management plan recovers energy from the material and the substance .These tools contrasts waste management scenarios to give decision-makers with comparative information emissions figures. In tons of CO_2 equivalents, WARM measure relative GHG emissions ($MTCO_2E$), which makes use of the GWP tool to compare all emissions equally.

The objective of the research is to calculate Green House Gas in metric tons CO_2 Equivalent ($MTCO_2E$) and to see energy analysis to estimate GHG emission reduction from several different waste management practice. The way how to interpret the result is If a GHG emission value is negative, it means that those emissions have been avoided during the management of that specific material type and/or scenarios. Likewise, if an energy consumption is negative, it means that the modelled scenario avoids the consumption of that amount of energy. If the total change between the alternative and baseline scenario is negative, then the alternative scenario will result in fewer GHG emissions, energy consumption, or economic impacts than the baseline, and vice versa. Only those materials for which data has been entered on the "Scenarios" step will be presented in the results.

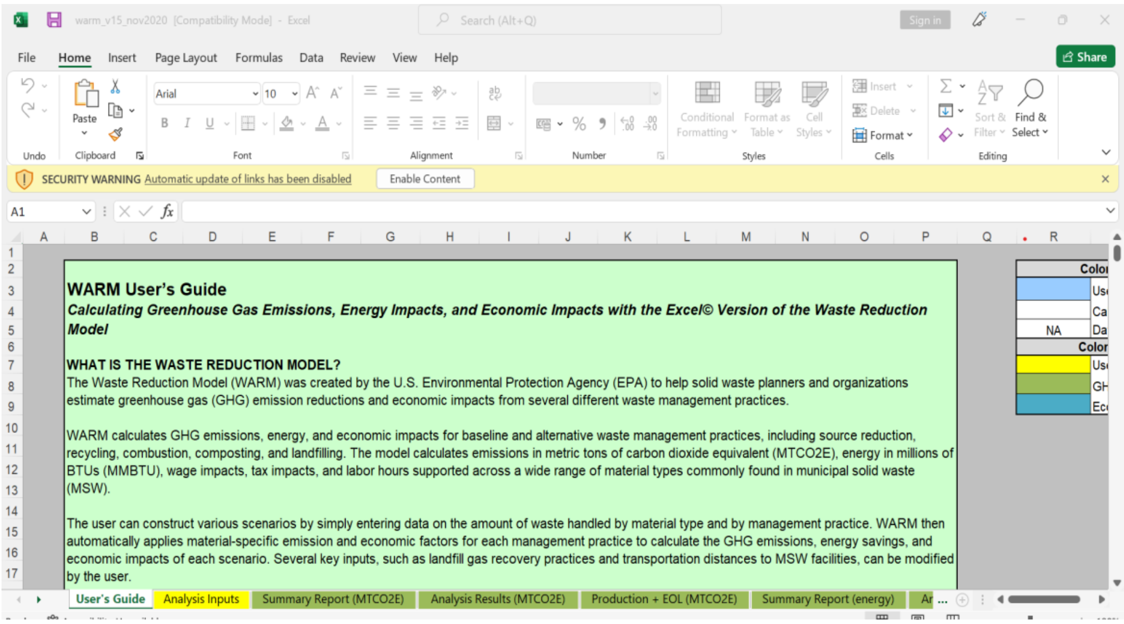

Fig. 3. The software usage for research

2.4 Data input and ccenario in WARM

Step by step input data. First, The amount of independent variable multiply by 2 to have one month data. Second, Take the data of food waste from data waste comes in 2020. Third, Insert all the data into waste reduction model. Fourth, Select "National Average"for option number. Fifth, Select "current mix" for option number 4. Sixth, Select " no LFG recovery"for option number 5. Seventh, Select "flare" for option number 6a. eight, Select "typical Operation-DEFAULT" for option number 6b. Ninth, select "National average – DEFAULT" for option number 7. Tenth, select "Wet Digestion"for option number 8a. Eleventh, Select "not cured"for option number 8b. Twelfth, Select üse default distances for option number 9a. After inputing the data the analysis result will appear from WARM application.

Table 1. Baseline and scenario data in warm

Number	Type of waste	Weight	Description
		Baseline data	
1	Corrugated Container	0.15	Recycled
2	Newspaper	0.014	Recycled
3	Office Paper	0.25	Recycled
4	Text Books	0.04	Recycled
5	Food Waste	1.565	Composted
6	PET	1.0	Recycled
7	PP	0.114	Recycled
8	PVC	0.607	Landfilled
9	Mixed Plastic	0.04	Recycled
10	Aluminum Cans	0.050	Recycled
11	Mixed Metal	0.030	Recycled
12	Mixed Recyclables	0.693	Recycled
13	HDPE	0.1	Landfilled
		Scenario data	
1	Corrugated Container	0.15	Recycled
2	Newspaper	0.014	Recycled
3	Office Paper	0.25	Recycled
4	Text Books	0.04	Recycled
5	Food Waste	1.565	Composted
6	PET	1.0	Recycled
7	PP	0.114	Recycled
8	PVC	0	Reduction in the first place
9	Mixed Plastic	0.04	Recycled
10	Aluminum Cans	0.050	Recycled
11	Mixed Metal	0.030	Recycled
12	Mixed Recyclable	0.693	Recycled
13	HDPE	0.1	Landfilled to recycled

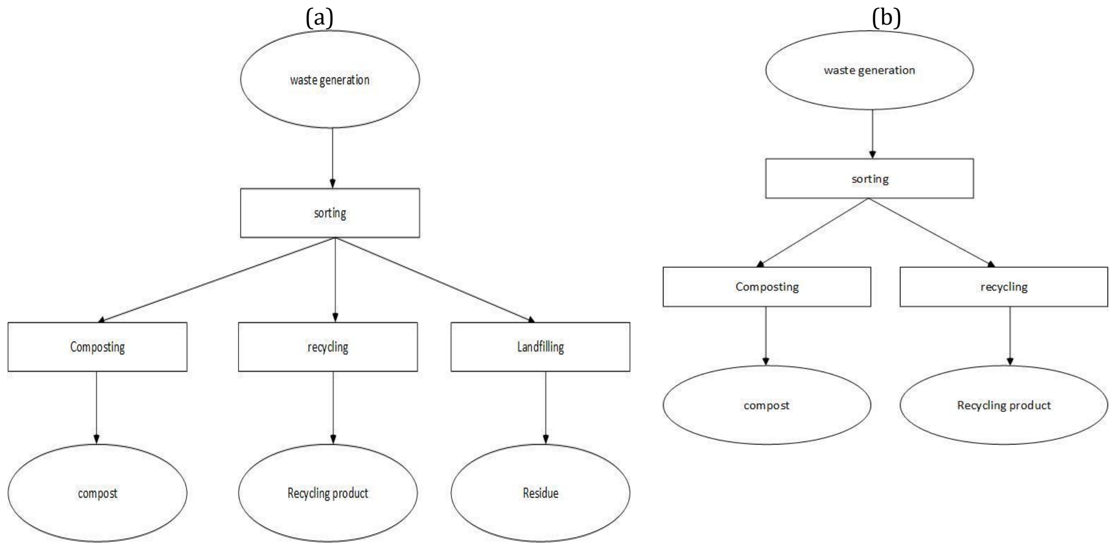

Fig. 4. (a) Baseline and (b) alternative flow chart data input

2.5 Data processing and output in WARM

In order to give decision-makers comparable emission data, WARM examines the emissions and offsets coming from a material in a baseline and an alternate management pathway. WARM might be used, for instance, to compare the effects on greenhouse gas emissions of recycling and landfilling 10 tons of office paper. The following is the guiding framework for net GHG emissions for any WARM scenario:

$$Net\ GHG\ emissions = Gross\ manufacturing\ GHG\ emissions - (Increase\ in\ carbon\ stocks + Avoided\ utility\ GHG\ emissions) \quad \text{(Eq. 1)}$$

This equation only needs to be taken into account when contrasting two different materials management plans in order to determine which one produces the fewest net GHG emissions. The following factors affect a material's net GHG emissions. Through source reduction (for example, “lightweighting” a beverage can—using less aluminum for the same function), GHG emissions throughout the life cycle are avoided. In addition, when paper products are source reduced, additional carbon is sequestered in forests, through reduced tree harvesting. Through recycling, the GHG emissions from making an equivalent amount of material from virgin inputs are avoided. In most cases, recycling reduces GHG emissions because manufacturing a product from recycled inputs requires less energy than making the product from virgin inputs. Composting with application of compost to soils results in carbon storage and small amounts of CH_4 and N_2O emissions from decomposition.

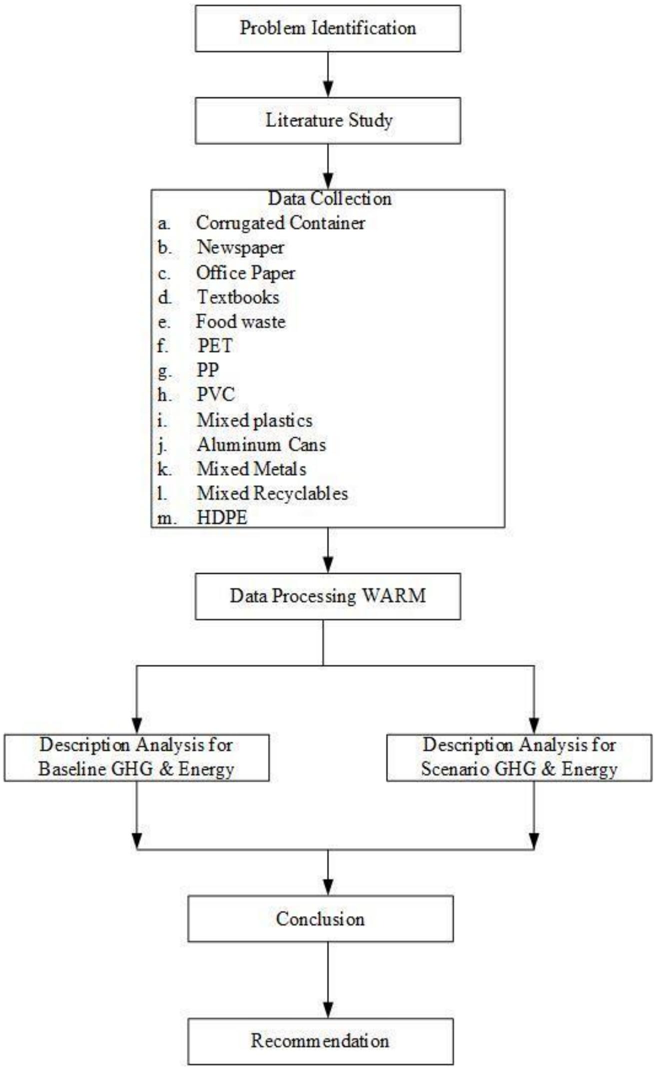

Fig. 4. Research framework

The anaerobic digestion captures biogas from the digestion of organic materials. The biogas is assumed to be combusted to produce energy, offsetting emissions from fossil fuel consumption. Additionally, the digestate resulting from the digestion process is applied to agricultural lands, resulting in soil carbon storage, avoided use of synthetic fertilizers, and trace CH_4 and N_2O emissions during digestate curing and after land application. Landfilling results in both CH_4 emissions from biodegradation and biogenic carbon storage. If captured, the CH_4 may be flared, which simply reduces CH_4 emissions (since the CO_2 produced by flaring is biogenic in origin, it is not accounted for in this assessment of anthropogenic emissions). If captured CH_4 is burned to produce energy, it offsets emissions from fossil fuel consumption. Combustion of waste may result in an electricity utility emissions offset if the waste is burned in a waste-to-energy facility, which displaces fossil-fuel-derived electricity. The output will be GHG Emissions from baseline waste management ($MTCO_2E$), GHG Emission from alternative waste management scenario ($MTCO_2E$), Energy use from baseline waste management (million BTU), and Energy use from alternative waste management scenario (million BTU).

3. Results and Discussion

3.1 Secondary data

The flow of the TPS3R Flamboyan waste processing process, namely waste is divided into 2 parts, namely degradable waste (food waste) and non degradable waste. Degradable waste (Food waste) will be sorted which can be used as compost and which are not so that it becomes a residue that will be taken to the TPA Cipeucang final waste disposal site. For non degradable waste, it will be separated into junk which will be sold to third parties and the rest such as coffee wrappers and pampers including residue to be taken to third parties TPA Cipeucang final disposal site. Amount of waste that enter in 2020 is 217.816 kg and the residue that went to TPA Cipeucang is 75.234.

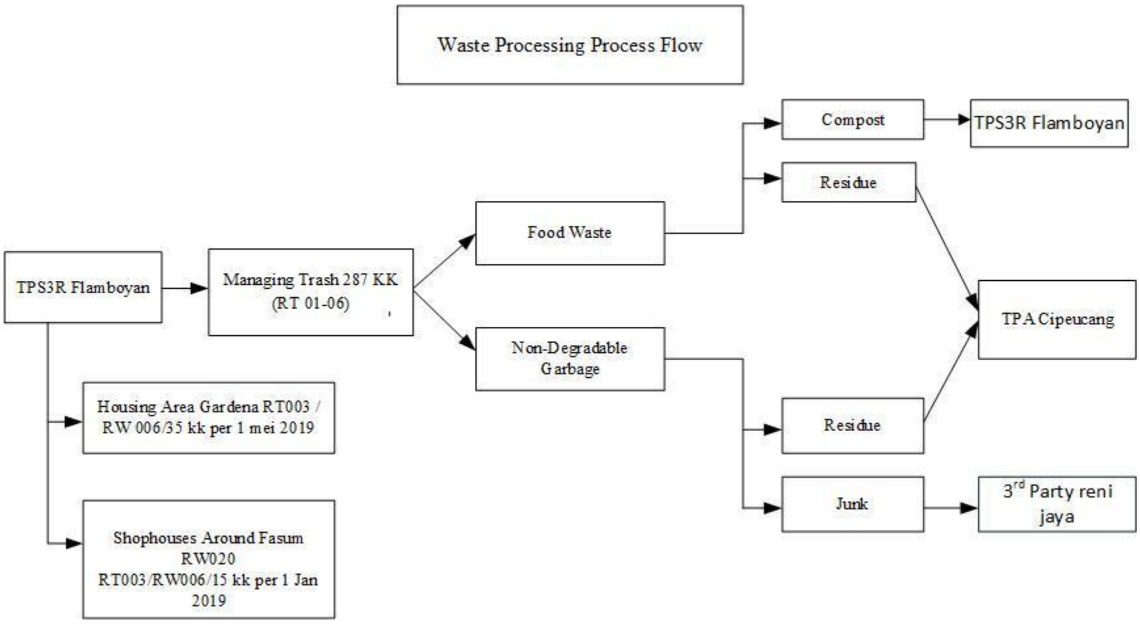

Fig. 5. Waste processing flow

3.2 Type of source reduction alternative data

The amount of substance that would otherwise be created but is not produced as a result of a program encouraging waste minimizing or source reduction is how source reduction is calculated in this research. Any modification to the design, production, acquisition, or usage of products or materials (including packaging), which lowers the quantity of items accessing the waste collection and disposal system, is referred to as source reduction. Source reduction lowers GHG emissions while conserving resources. The production and raw material acquisition methods for the typical industry mix of virgin and recycled inputs for products on the market are used to calculate the averted GHG emissions. Because it is believed that a specific amount of substance or product was never generated in the first place, end-of-life management doesn't emit any emissions.

Any action that lowers the quantity of a material or agriculture input required and subsequently used to produce goods or food is referred to as source reduction. There are only a few situations when the emission factors may be utilized to calculate the advantages of reducing GHG emissions by switching from one product or material to another, in addition to the aforementioned activities. In this study, waste that can be recycled will be recycled, such as 0,1 tonne of recycled HDPE from sources usually landfilled, and Waste reduced from the beginning cut without using PVC by 0.61 tons.

3.3 WARM analysis result for GHG

GHG emissions from waste management at baseline are -5.24 $MTCO_2E$. The TPS3R Flamboyan waste management system's GHG emissions under the present and alternative scenarios were estimated using the WARM model. Tables 2 show the model's input data and output data. As the data demonstrate, the TPS3R waste management system's extravagant offering with model consumes energy and emits greenhouse emissions. The data did not include the waste materials' composition since it was not accessible. Alternative scenarios have been drawn up regarding the make-up and capabilities of the TPS3R Flamboyan solid waste systems. Note: A negative value denotes a decrease in emissions, whereas a positive value denotes an increase in emissions. Green house gas emission from baseline waste management ($MTCO_2E$) can be seen in Table 3.

Table 2. Green house gas emission from baseline waste management ($MTCO_2E$)

Material	Tons recycled	Tons landfilled	Tons combusted	Tons composted	Tons anaerobically digested	Total $MTCO_2E$
Corrugated Containers	0.15	-	-	NA	NA	(0.47)
Newspaper	0.01	-	-	NA	NA	(0.04)
Office paper	0.25	-	-	NA	NA	(0.72)
Textbooks	0.04	-	-	NA	NA	(0.12)
Food Waste	NA	-	-	1.57	-	(0.18)
HDPE	-	0.1	-	NA	NA	0.00
PET	1	-	-	NA	NA	(1.04)
PP	0.11	-	-	NA	NA	(0.09)
PVC	NA	0.61	-	NA	NA	0.01
Mixed Plastics	0.04	-	-	NA	NA	(0.04)
Aluminium Cans	0.05	-	-	NA	NA	(0.46)
Mixed Metals	0.03	-	-	NA	NA	(0.13)
Mixed Recyclables	0.69	-	-	NA	NA	(1.98)

The alternative waste management scenario has a -6.50 $MTCO_2E$ GHG emission. It is greater than the baseline waste management GHG emission, which is -5.24 $MTCO_2E$. It indicates that compared to baseline management, the alternative scenario would produce larger emission reductions. Table 3 shows that the TPS3R Flamboyan's present waste management system has an emission of greenhouse gases rate of -5.24 $MTCO_2E$. The effect of source reduction, increased recycling, and composting on emissions of greenhouse gases was examined in the alternative scenario. The model's output shows that this state's greenhouse gas emissions were 6.50 - ($MTCO_2E$). Source reduction and recycling can significantly lower greenhouse gas emissions, according to model results. Green house gas emission from alternative waste management scenario ($MTCO_2E$) can be seen in Table 3.

The results of the Waste Reduction Model (WARM) analysis show the greenhouse gas (GHG) emissions associated with municipal solid waste (MSW) management. Based on the baseline scenario, total GHG emissions were recorded at 5.24 metric tons of carbon dioxide equivalent (MTCO2E). In comparison, the alternative scenario resulted in total emissions of

6.50 MTCO2E. This indicates an increase in emissions, with incremental GHG emissions amounting to 1.26 MTCO2E. These findings suggest that the alternative waste management approach produced more emissions than the baseline, highlighting the importance of evaluating the environmental impact of proposed changes in waste handling practices.

Table 3. Green house gas emission from alternative waste management scenario ($MTCO_2E$)

Material	Ton's source reduced	Tons recycled	Tons landfilled	Tons combusted	Tons composted	Tons anaerobically digested	Total $MTCO_2E$
Corrugated Containers	-	0.15	-	-	NA	NA	(0.47)
Newspaper	-	0.01	-	-	NA	NA	(0.04)
Office paper	-	0.25	-	-	NA	NA	(0.72)
Textbooks	-	0.04	-	-	NA	NA	(0.12)
Food Waste	-	NA	-	-	1.57	-	(0.18)
HDPE	-	0.1	-	-	NA	NA	(0.08)
PET	-	1	-	-	NA	NA	(1.04)
PP	-	0.11	-	-	NA	NA	(0.09)
PVC	0.61	NA	-	-	NA	NA	(1.17)
Mixed Plastics	-	0.04	-	-	NA	NA	(0.04)
Aluminium Cans	-	0.05	-	-	NA	NA	(0.46)
Mixed Metals	-	0.03	-	-	NA	NA	(0.13)
Mixed Recyclables	NA	0.69	-	-	NA	NA	(1.98)

3.4 Estimates of baseline and alternative management scenarios' GHG emissions per ton

Figure 6 displays the monthly emissions of greenhouse gases from various waste management processes. Projected Alternate Management of MSW Incremental GHG Emissions were -5.24 $MTCO_2E$. The total additional GHG emissions in carbon dioxide equivalents ($MTCO_2E$) for the baseline and alternative are shown in Figure 7.

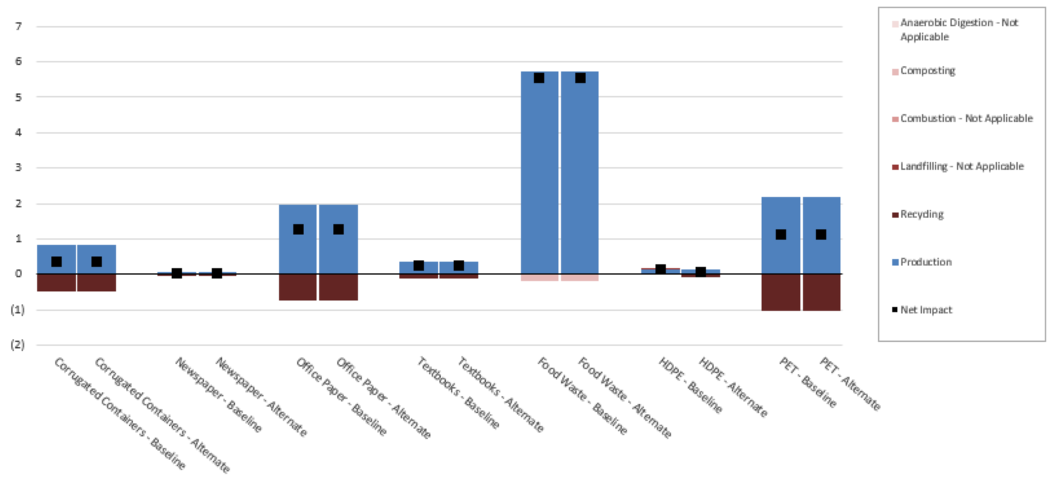

Fig. 6. Emissions at baseline, alternative production, and end of life

This research study's source-segregated materials recycling was demonstrated. It can be seen from Fig. 7 that a net value with a positive value reflects $MTCO_2E$ emissions that are saved. The examination of recycled materials revealed seven materials as the source of net $MTCO_2E$ reductions. Food waste was the only non-recyclable material used in the composting process, and its incremental GHG emission values were negative. When comparing various materials for alternate scenario management, the size of these savings differed significantly. Emissions at baseline, alternative production, and end of life can be seen in Figure 6.

3.5 WARM analysis result for energy use

Model was calculated Energy Use from Baseline and Alternative Waste Management system. Based on Table 4 energy Use from Baseline was "58.79 -"million BTU and from alternative scenario was "-92.68-" million BTU. Results show energy usage reduce when use alternative scenario. Energy use for transportation based on distance, HDPE Baseline from TPS3R to TPA Cipeucang is 12 km, HDPE Alternative from TPS3R to 3rd Party Reni jaya is 150 m. Use of energy in basic garbage management (million BTU) can be seen in Table 4.

Table 4. Use of energy in basic garbage management (million BTU)

Material	Tons recycled	Tons landfilled	Tons combusted	Tons composted	Tons anaerobically digested	Total million BTU
Corrugated Containers	0.15	-	-	NA	NA	(2.27)
Newspaper	0.01	-	-	NA	NA	(0.23)
Office paper	0.25	-	-	NA	NA	(2.52)
Textbooks	0.04	-	-	NA	NA	(0.04)
Food waste	NA	-	-	1.57	-	1.14
HDPE	-	0.1	-	NA	NA	0.03
PET	1	-	-	NA	NA	(28.59)
PP	0.11	-	-	NA	NA	(5.07)
PVC	NA	0.61	-	NA	NA	0.16
Mixed Plastics	0.04	-	-	NA	NA	(1.40)
Aluminium Cans	0.05	-	-	NA	NA	(7.64)
Mixed metals	0.03	-	-	NA	NA	(2.00)
Mixed Recyclables	0.69	-	-	NA	NA	(10.36)

Figure 7 depicts the monthly energy consumption from various waste management processes. According to this calculation, total incremental GHG energy use was 33,83 million BTU. According to the model's conclusions, minimizing waste at the source and implementing policies that promote the reuse of resources like materials and energy may both considerably cut environmental emissions.

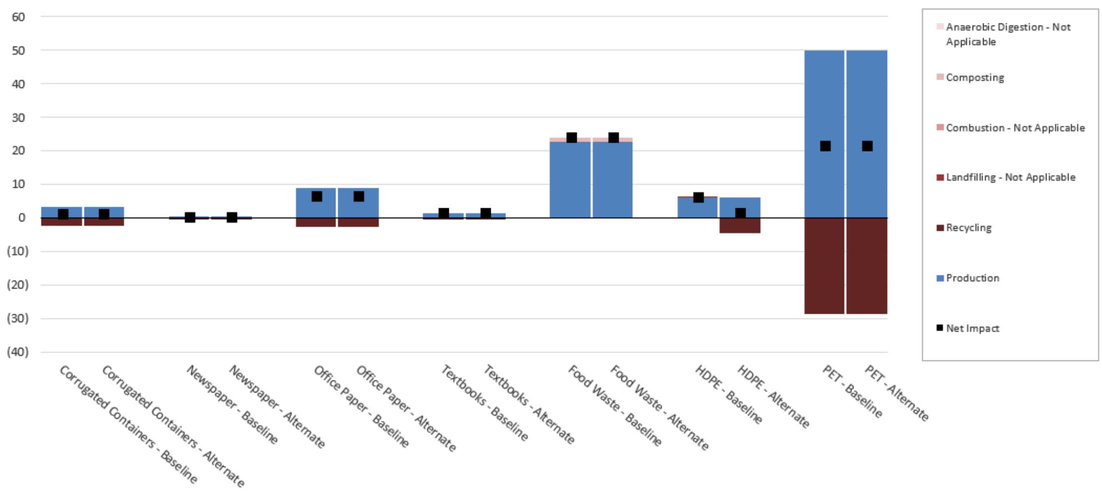

Fig. 7. Baseline and alternative energy usage during production and after disposal (million BTU)

Redesigning products to use less material, utilizing recycled goods and supplies, increasing product life, and most importantly, avoiding the use of materials are key strategies. Given the importance of GHG emissions and the correlation between Reni Jaya's population growth and increased waste production, selecting the best waste management alternative can help reduce GHG emissions significantly. Selecting the right waste management system can also provide economic benefits to the government. To be ecologically and economically feasible, the most practical solution for waste management must be selected based on the nature of the waste and the facilities available in Pamulang.

Table 5. Baseline waste management scenario

Material	Energy Use from production (Million BTU)	Energy Use from Recycling	Energy Use from Landfilling	Energy Used from Combustion	Energy Use from Composting	Energy Use from Anaerobic Digestion	Production+ End-of-life Impact (Million BTU)
Corrugated Containers	3.35	(2.27)	-	-	NA	NA	1.08
Newspaper	0.51	(0.23)	-	-	NA	NA	0.28
Office paper	9.15	(2.52)	-	-	NA	NA	6.63
Textbooks	1.42	(0.04)	-	-	NA	NA	1.38
Food Waste	22.78	NA	-	-	1.14	-	23.92
HDPE	6.11	-	0.03	-	NA	NA	6.14
PET	50.02	28.59	-	-	NA	NA	21.43
PP	7.51	(0.09)	-	-	NA	NA	7.42
PVC	29.22	NA	0.01	-	NA	NA	29.23
Mixed Plastics	2.18	(0.04)	-	-	NA	NA	2.14
Aluminium Cans	4.48	(0.46)	-	-	NA	NA	4.03
Mixed Metals	1.53	(0.13)	-	-	NA	NA	1.39
Mixed Recyclables	NA	(1.98)	-	-	NA	NA	(1.98)

The highest production of million British thermal unit energy use is from PVC and the second is food waste.

Table 6. Alternate waste management scenario

Material	Energy Use from production (Million BTU)	Energy Use from Recycling	Energy Use from Landfilling	Energy Used from Combustion	Energy Use from Composting	Energy Use from Anaerobic Digestion	Production+End-of-life Impact (Million BTU)
Corrugated Containers	3.35	(2.27)	-	-	NA	NA	1.08
Newspaper	0.51	(0.23)	-	-	NA	NA	0.28
Office paper	9.15	(2.52)	-	-	NA	NA	6.63
Textbooks	1.42	(0.04)	-	-	NA	NA	1.38
Food Waste	22.78	NA	-	-	1.14	-	23.92

HDPE	6.11	-	-	-	NA	NA	1.63
PET	50.02	28.59	-	-	NA	NA	21.43
PP	7.51	(0.09)	-	-	NA	NA	7.42
PVC	29.22	NA	-	-	NA	NA	58.44
Mixed Plastics	2.18	(0.04)	-	-	NA	NA	2.14
Aluminium Cans	4.48	(0.46)	-	-	NA	NA	4.03
Mixed Metals	1.53	(0.13)	-	-	NA	NA	1.39
Mixed Recyclables	NA	(1.98)	-	-	NA	NA	(1.98)

4. Conclusions

Total GHG emissions from standard MSW generation and management are -5.24, while total Green House Gas emissions from alternate MSW management and generation are -6.50. The total energy used for MSW management and generation at the baseline level is -58.79 million BTU, while the total energy used for alternate MSW management and generation is -92.68 million BTU. Both imply that, as opposed to baseline management, the alternative scenario would produce bigger emission reductions. The waste reduction model (WARM) may be used to evaluate and analyze the GHG emission in terms of CO_2 equivalents and energy savings. It is best to calculate the waste using prediction models based on the data given. In some cases, the modeling algorithms can give an estimation of emissions for the months to come. Calculating emission reductions is a crucial tool in the fight against climate change.

Choosing the finest waste management techniques may considerably help to cut GHG emissions when taking into account the relevance of GHG emissions and the influence of population growth in TPS3R Flamboyan that boosted garbage generation. The government may also benefit economically from selecting the appropriate waste management system. Based on the type of waste and the facilities presently present at TPS3R Flamboyan Reni Jaya, a practical choice for waste treatment should be chosen in order to be both environmentally and financially viable.

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Author Contribution

Both authors contributed equally to the study’s conceptualization, data collection, analysis, manuscript writing, literature review, result interpretation, and final approval.

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The authors declare no conflict of interest.

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