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# MODEL OF GREENHOUSE GAS EMISSION REDUCTION WASTE SECTOR IN DEPOK CITY

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**Abstrak.** Waste is one of the largest sources of greenhouse gas emission (GHG) at the global, national, and Depok city levels. The purpose of this study was to analyze various alternative of reduction policy scenarios of the GHG waste sector used simulation model with dynamic system approach. The simulation applied from 2020 to 2050. There are four scenarios: BAU scenario, the current waste management; A scenario, based on the Jakstrada program; B scenario, the application of methane gas captured technology on Cipayung landfill, IPAL communal, and Septic tank; C scenario which is the application of Jakstrada program and methane gas captured technology on Cipayung landfill, IPAL communal, and septic tank. The amount of GHG waste sector in Depok 2020 is 414.966,80 Tons CO2/year. The largest amount of emission was originating from wastewater and waste accumulation in landfills, which is 232.053 Tons CO2/year and 173,864,8 Tons CO2/year. A scenario GHG is decreasing by 3,38%. B scenario is decreasing the GHG into 93,6% with 21,99% unmanaged waste and 7% bumt waste. C scenario was successfully decreasing 96,11% and 100% managed waste which is the most. For decreasing the GHG waste sector, it needs the waste management and the technology application are done simultaneously.

**Keywords:** greenhouse gas emission; waste; model simulation; system dynamic

## I. INTRODUCTION

Waste is one of sources of greenhouse gas emission (GHG). Direct emissions from the waste sector are generated from landfills, waste incineration, biological waste management or composting and wastewater treatment and disposal (Intergovernmental Panel On Climate Change /IPCC **[1][2][3]**). GHG is a gas that causes global warming, resulting in climate change. The most produced GHG from the waste sector are methane gas ($CH_4$) in addition to carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$) **[4][5][6]**. Every one ton of waste produces 50 kg of $CH_4$ (Sudarman, 2010). $CH_4$ has the potential to damage 21 times greater than $CO_2$ **[1]**. The waste sector is one of the five priority sectors for reducing GHG in Indonesia (RAN-GRK Perpres No. 6 **[7]**). In the city of Depok the waste sector is one of the three largest emitting sectors, where the waste sector contributes 9.61% (Depok City GHG Inventory 2020). Thus, efforts are needed to reduce GHG in the waste sector in Depok City, as part of the it support to the central government to achieving Sustainable Development Goals/SDGs (Monk, **[8]**). GHG reduction efforts are the contribution of the city of Depok to the implementation of the RAN-GRK and RAD of West Java Province. This study aims to analyze GHG reduction policies in the waste sector using a model simulation with a system dynamic approach **[9][10][11]**. The simulation is carried out from 2020 to 2050. It is hoped that the model simulation results can provide policy recommendations for the Depok City Government in reducing GHG in the waste sector and become a reference for other cities in Indonesia.

## II. RESEARCH METHODS

The waste studied in this study is domestic liquid waste and solid waste or household waste. The amount of GHG from the waste sector in Depok City is calculated using the Intergovernmental Panel On Climate Change (IPCC) method, 2006. Meanwhile, to determine strategies or policy recommendations for reducing GHG using the dynamic system method. The model structure was built using the powersim studio 10 program.

The amount of GHG in the waste sector is determined by population, waste generation, waste composition, waste management and community participation **[1][12]**. Solid waste processing in Depok City consists of reducing waste at the source by applying the 3R principles (reduce, reuse and recycle), biological waste processing, namely by composting organic waste, landfilling waste in landfills and burning waste that is not managed in the community. While the management of liquid waste is processing in communal WWTPs, septic tanks and others **[13]**. The preparation of scenarios and policy recommendations for reducing GHG emissions in the waste sector in the city of Depok in 2021 to 2050 is compiled through the following stages:

*Needs Analysis*

The needs analysis aims to identify the needs of every stakeholder involved in reducing GHG, namely the government, community, business actors, Non-Government Organizations (NGOs) and academics.

*Dynamic System Model Design*

The model is built based on the variables that affect the amount of GHG in the waste sector in Depok City. The results are represented in the form of a causal loop diagram (CLD). After The CLD is formed and then a model structure

*Volume 04, Number 02, September 2021, Page 30-33*
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is built using the Powersim Studio 10 program called the Stock Flow Diagram (SFL).

*Data Needs*

The data required in this study are: 1. Population data in Depok City. 2. Data on waste processing and waste composition in Depok City. 3. Data on domestic wastewater treatment in Depok City. 4. Depok City RPJPD and Depok City RPJMD

*Model Validation*

Model validation is the stage of testing the level of confidence in the accuracy of the model structure being built. Model validation is done by comparing the simulation results with real data using Absolute Means Error (AME) and Varriation Error (AVE) values, where the accepted deviation limit is <10% (Muhammadi, **[14]**).

## III. RESULTS AND DISCUSSION

Based on the results of the calculation of the amount of emissions using the IPCC method, 2006 it is known that the total GHG of the waste sector in Depok City in 2020 are 414,966.80 Tons of $CO_2$/year. The largest number of emissions resulted from the treatment of liquid waste and the accumulation of waste in the TPA, namely 232,053 tons of $CO_2$/year and 173,864.8 tons of $CO_2$/year. Both of these activities need to be addressed in the future in order to reduce GHG. The amount of GHG from the waste sector in Depok City in 2020 is presented in table 4.1

Table 1 Total GHG Emissions in the Waste Sector in Depok City in 2020 Using the IPCC Method.

| | |
|---|---|
| Biological Waste Treatment Emissions (Ton CO2/Year) | 4.614,35 |
| Emissions of Garbage Buildup in TPA (Ton CO2/Year) | 173.864,8 |
| Emissions of Open Incineration of Waste (Ton CO2/Year) | 15.830,63 |
| Emission of Liquid Waste (Ton CO2/Year) | 232.053,00 |
| Waste Sector Emissions (Total) (Ton CO2/Year) | 414.966,80 |

Source: calculation results using the IPCC method

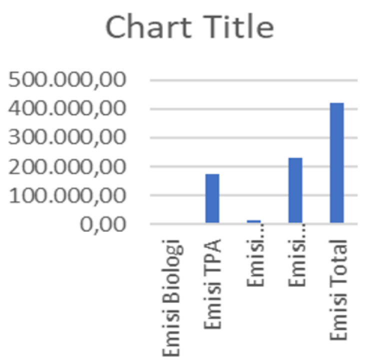


Figure 1. GHG in the Waste Sector in Depok City
Source: calculation results using the IPCC method

Based on the results of the calculation of the amount of emissions using the IPCC method, 2006 **[14].** it is known that the total GHG of the waste sector in Depok City in 2020 are 414,966.80 Tons of $CO_2$/year. The largest number of emissions resulted from the treatment of liquid waste and the accumulation of waste in the TPA, namely 232,053 tons of $CO_2$/year and 173,864.8 tons of $CO_2$/year. Both of these activities need to be addressed in the future in order to reduce GHG.

*Dynamic Model Design*

The CLD in this research is directed to calculate the amount of GHG from the waste sector from various waste processing activities in Depok City. This model is also built to be able to predict GHG reductions through the application of policies and technology **[15]**. The simulation year for this model is from 2020 to 2050. The total GHG of Depok City in 2020 are presented in table 1.

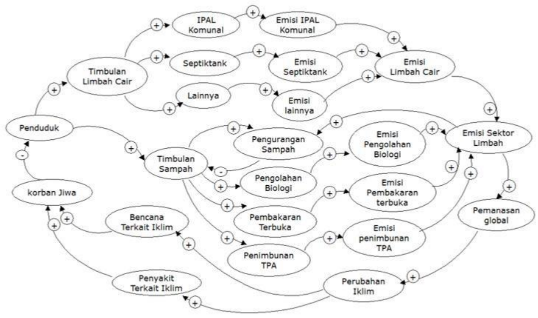


Figure 2. Causal Loop Diagram (CLD)
Source: 2021 analysis

The model for reducing greenhouse gas emissions in the Waste Sector in Depok City is designed based on the causal loop diagram that has been made. The model structure is built using the Powersim Version 10 program and is presented in the form of a stock flow diagram in Figure 4.2. The system analysis is carried out for 30 years, from 2020 to 2050 with the initial year of analysis being 2020

Figure 3. Stack flow diagram

*Volume 04, Number 02, September 2021, Page 30-33*
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This model aims to describe the prediction of greenhouse gas emissions in the waste sector in the city of Depok in the next few years. The simulation is carried out using the increase in population and waste treatment activities that determine the amount of GHG emissions in the waste sector in Depok City. The variables in this model are the number of residents, the amount of waste water. the amount of waste generated, the amount of waste reduction, the amount of waste that is biologically processed, the amount of waste that is piled up in the TPA and the amount of unmanaged waste that is burned openly in the community.

*Model Simulation*

In 2021 the population of Depok City will be 2,578,402 people, in 2050 the end of the simulation will reach 7,247,298 people. During 30 years from 2021-2050 the additional population of Depok City is 4,668,896 people with an average growth of 3.628 percent per year. The population growth of Depok City in 2050 is almost three times the current population. The increasing population causes the generation of waste and liquid waste to increase. At the end of the analysis, namely in 2050 the amount of waste generated in Depok City reached 1,668,889.91 tons/year while the amount of organic matter that could be degraded from liquid waste (TOW) was 105,938, 23 tons/year. Based on the model simulation results, it is known that the amount of GHG emissions in the waste sector in Depok City in 2050 will reach 1,206,946.82 tons of CO2/year. The largest number of emissions in 2050 will come from liquid waste processing and waste accumulation in the landfill, namely 541,875.7 tons CO2/year and 641,953.45 tons CO2/year

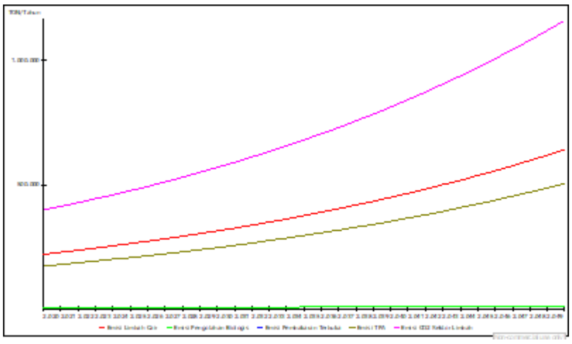

Figure 4. Graph of Total Waste Sector Emissions in Depok City

*Model Validation*

Model validation is done using Mean Absolute Percentage Error (MAVE) and Absolute Mean Error (AME). The results of model performance are compared with actual data in the field. The model validation test was carried out on Depok City population data from 2010 to 2020 with MAVE results of 0.42 and AME 0.66%. These results indicate that there is a deviation or deviation of 0.42% and 0.66% between the model and the actual data/real conditions.

*Model Scenario*

The model scenario consists of a business as usual (BAU) scenario, scenario A, scenario B and scenario C. The BAU scenario is a scenario based on current conditions, namely 21.99% of unmanaged waste and 78.01% of managed waste, which consists of: waste reduction 12.7%, biological treatment 4.6%, open burning 7%, and landfill 58.12% while wastewater treatment consists of 6% communal WWTP, 93.58% septic tank and 1.85% others. Both scenarios A follow the government program based on the Depok Mayor Regulation Number: 65 of 2018 concerning Depok City Policies and Strategies in the Management of Household Waste and Types of Household Waste, namely 100% managed waste consisting of 30% waste reduction and 70% waste handling . This means no more waste that is burned and no more waste that is not handled. 70% of the treated waste consists of 10% biological processing and 60% landfilling in the landfill. The three B scenarios use technology, namely completing the Cipayung TPA, communal WWTP and septic tank with methane catcher. The four C scenarios are a combination of scenarios A and B, namely following Jakstrada and completing the Cipayung TPA, communal WWTP and septic tank with methane catcher installations.

The results of the model simulation with scenario A reduce GHG emissions by 3.38%. Scenario B reduces emissions by 93.6% with unmanaged waste by 21.99% and burning waste by 7%. Scenario C reduces GHG emissions the most, which is 96.11% with 100% of waste being managed. To reduce GHG emissions in the waste sector, it is necessary to carry out waste management and the application of technology simultaneously.

## IV. CONCLUSION

The implementation of waste management by implementing the Jakstrada program in 2050 is only able to reduce GHG emissions in the waste sector by 3.38%. Application of methane gas capture technology in communal WWTPs, septic tanks and landfills can reduce emissions by 93.6%. The reduction in GHG emissions by implementing this scenario is very large but there is still 21.99% of untreated waste and 7% of open-burning waste. The implementation of the Jakstrada program combined with the application of methane capture technology in communal WWTPs, septic tanks and landfills can reduce GHG emissions by the most among the three other scenarios, which is 96.11% with better waste management, which is 100% managed. To reduce GHG emissions in the waste sector, it is necessary to carry out waste management and the application of technology simultaneously.

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