The Prediction of Methane (Ch_4) Gas Emission from Muara Fajar Landfill, Pekanbaru Using Dynamic System Model

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***Abstract*—Prediction of methane gas emissions has been made to the Muara Fajar Landfill which is the final disposal site for all waste in the city of Pekanbaru. Prediction was made to find out the amount of methane gas emissions resulting from waste that has been piled up for a long time. The method used for prediction is the dynamic system model using powersim software. The prediction results of the amount of methane gas produced in 2018 were 8.28 Gg/year and increased by 1.94% per year until 2028. Two model scenarios were made as a mitigation effort. The first scenario is by assuming the processing of waste, namely by trying to separate and process plastic waste, and the second scenario is by assuming an increase in population migration by increasing the number of scholarships for students. The result obtained from the first scenario is that there will be a reduction in methane gas emissions by 0.53% per year. Furthermore, the result for the second scenario if done reveals that there is a reduction in methane gas emissions of 0.184% per year.**

Keywords—Methane gas, Dynamic System Model, Powersim, landfill

I. INTRODUCTION

An increase in population will affect the increase in the amount of waste. This is because the increase in population will be in line with the increase of activities and increased needs. Pekanbaru as one of the strategic provincial capitals also experiences a significant increase in population. BPS data states that there was an increase in population of 2.4% from 2016 to 2017 (BPS, 2018). The percentage increase in population is almost close to the percentage increase in population in large cities such as the city of Semarang which has a population growth rate of 2.7%/year (Arsandi, 2017). This certainly has an impact on increasing the amount of waste generated in the city of Pekanbaru each year.

There are several landfills in Pekanbaru, and the biggest is the Muara Fajar Landfill. The Muara Fajar Landfill has been operating since 1982 with an open dumping treatment system (stacked and piled without further processing of waste). Until now, the amount of waste in Muara Fajar Landfill has reached a height of 35 m from the ground surface (IKPLHD, 2017). Long-term piles of garbage will produce several gas emissions, one of which is methane (CH_4) (Bahrin, 2011). Methane gas is the most gas produced from the garbage heap, which is 50%-60%. The gas comes from decomposition of organic waste (IPCC, 2006). Emissions of methane gas that evaporates freely into the air have a 21-fold adverse effect compared to CO_2 (carbon dioxide) greenhouse gas emissions (IPCC, 2006). This has implications for increasing temperatures on earth or better known as global warming (Bahrin, et al., 2011).

Several studies have been conducted by previous researchers on the Muara Fajar Landfill. One of them is about the Analysis of Energy Utilization from Landfill Method Processing in the Muara Fajar Landfill Pekanbaru in 2018 by Monice and Perinov. This research explains about the amount of methane gas emissions produced by the Muara Fajar landfill from 2010 to 2017, which is an average of 2,650,971 m3 / year and the potential use of methane gas as a power plant that produces an average of 3380 kWh of electrical energy. This study, on the other hand, predicts the amount of methane gas emissions generated from the Muara Fajar landfill in 2018 to the next 10 years by using a dynamic system model using Powersim. The amount of emissions is calculated based on increasing population and the amount of waste. This research also made two scenarios to see what percentage of reduction in the amount of methane gas emissions. The first scenario is by managing waste through separation and processing of plastic waste, and the second scenario is created by increasing the amount of population migration by increasing the provision of out-of-town scholarships for students.

II. RESEARCH METHOD

2.1. Research Place and Time

This research was carried out in November-January 2019. The research location was at the Muara Fajar landfill in the city of Pekanbaru, and the location of data processing was carried out in the Integrated Basic Physics Laboratory of Universitas Muhammadiyah Riau.

2.2. Research Flow

The flow in this study can be seen in Figure 2.1.

2.3. Thinking Framework

The creation of thinking framework aims to see the direction of research to be carried out. The research framework can be seen in Figure 2.2.

2.4. Variable Identification

Variable identification is done to select and calculate all the variables to be used in the model. The variables used in the model are grouped into two, namely the variables used to calculate and predict the population, and the variables used to calculate and predict the amount of waste and methane gas. The variables identified can be seen in Table 2.1 and Table 2.2.

2.5. Making Causal Loop Diagram (CLD)

Causal Loop is to state the relationship between variables. Causal loop is grouped into two, namely the causal loop for the population model and the causal loop for the garbage quantity model. The relationship between variables can be seen in Table 2.3 and Table 2.4.

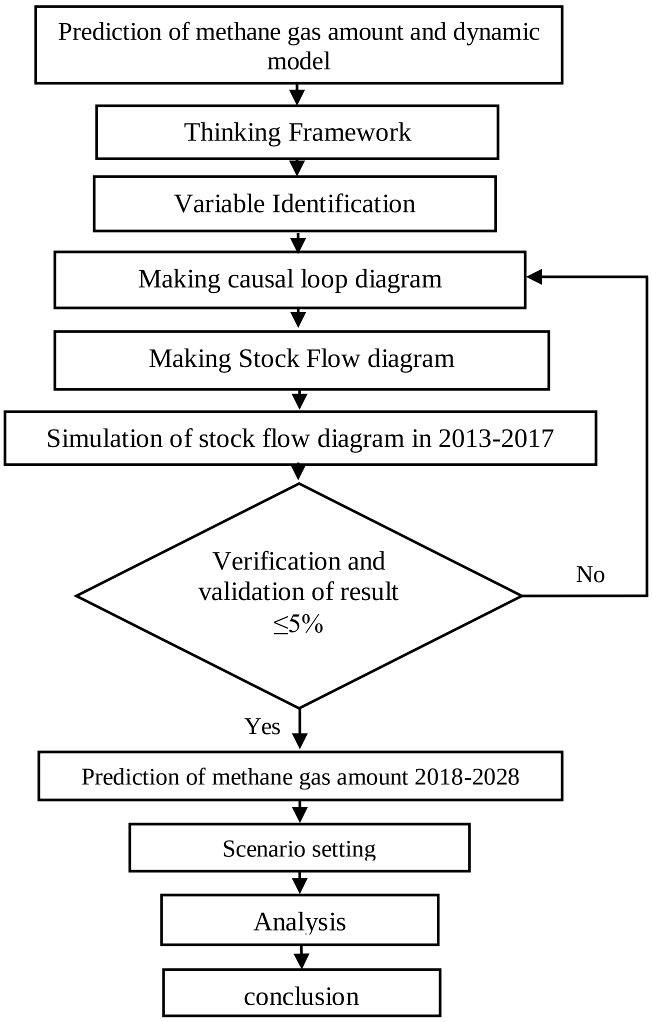

Figure 2.1 Research Flowchart

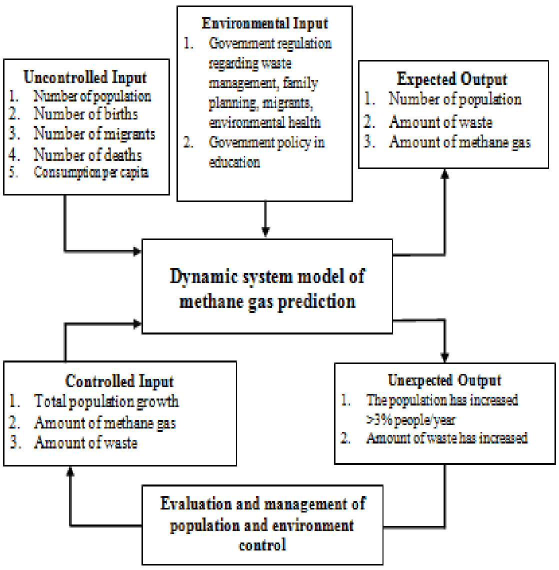

Figure 2.2 Thinking Framework

Table 2. 1. Total Population Variable

No	Variables to be predicted	Influencing variable	The equation used
1	Number of population	Percentage of Death	$AKK = \frac{M2-M1}{M1} \times k$
		Percentage of Birth	$Jkl = \frac{B2-B1}{B1} \times k$
		Percentage of Migration	$m = \frac{m2-m1}{m1} \times 100\%$
		Percentage of Emigration	$K = \frac{K2-K1}{K1} \times 100\%$
		Percentage of Urbanization	$Pu = \frac{u2-u1}{u1} \times k$
		Percentage of Ruralization	$Pu = \frac{u2-u1}{u1} \times k$
		Percentage of Marriage	$APK = \frac{Bp2-Bp1}{Bp1} \times k$

Table 2. 2. Variable of Waste Amount Prediction

No	Variables to be predicted	Influencing variable	Note
1	Amount of waste	a. Amount of waste per day (rubbish heap)	Calculated using equation 2.2
		- Amount of waste per capita	DLHK
		- Number of population	Table 3.1
		b. Processed waste	
		- Compost	DLHK
		- Recycling	DLHK
		- Garbage picker	DLHK
		- Garbage Bank	DLHK
2	Methane gas emission	Waste heap	It is known from the large amount of waste produced by the community every day

Table 2. 3. Relationship between Total Population Variable

Diagram	Variable	Relationship
Number of Population	Population Growth	+
	Birth	+
	Marriage	+
	Migration	+
	Urbanization	+
	Emigration	-
	Ruralization	-
	Death	-

Table 2. 4. Relationship between Amount of Waste Variable

Diagram	Variable	Relationship
Amount of Waste	Amount of waste per capita	+
	Number of population	+
	Compost	-
	Recycling	-
	Garbage picker	-
	Waste Bank	-
	Treated Waste	-

2.6. Verification and Validation

Verification and validation in this study were done by calculating the difference between the results of the simulation of the population and the amount of waste in 2013-2017 with data on the number of residents and the amount of waste originating from BPS. Percentage of difference in results must be ≤5%. If it exceeds 5%, it is necessary to re-identify the variable and make a causal loop again. If the difference presentation meets the requirements, the model is considered valid and can be predicted further.

2.7. Prediction of the Amount of Methane Gas 2018-2028

Prediction of the amount of methane gas in this study was carried out after passing the verification and validation process of the causal loop diagram of the population and the amount of waste. Predictions are made for ten years starting from 2018 to 2028.

2.8. Scenario Setting

Two scenarios were made in this study as a model of efforts to reduce the amount of methane gas emissions:

1. Scenario 1

Scenario 1 is made as an effort to reduce the potential amount of methane gas by reducing the height of the pile of garbage through separating and managing the types of plastic waste generated from waste generation. Plastic waste which is successfully separated and managed is assumed as much as 70% of the total amount of plastic waste that arises.

2. Scenario 2

Scenario 2 is made as an effort to reduce the amount of methane gas through reducing the population with an increase in the emigration variable. The increase in emigration comes from an increase in the number of scholarships given to residents aged 18-23 years to continue their education to universities that are outside the city or abroad. The number of scholarships awarded is assumed to increase by 2% per year.

2.9. Data Analysis

Data analysis was done by analyzing the graphs generated from modeling simulations. The graph analyzed is a graph of the amount of methane gas from waste predicted for the next 10 years using PowerSim.

III. DISCUSSION

3.1. Variable Identification

a. Total Population and amount of waste

Variable identification results for the population and the amount of waste and methane gas emissions can be seen in Table 3.1 and Table 3.2.

Table 3. 1. Table of Population Variable

Variable to be predicted	Influencing Variables	Constant Number (%)
Total Population	Percentage of Death	0.2000
	Percentage of Birth	0.0059
	Percentage of Migration	0.1590
	Percentage of Emigration	0.2300
	Percentage of Urbanization	0.0720
	Percentage of Ruralization	0.0360
	Percentage of Marriage	0.0180

3.2. Dynamic Model

a. Causal Loop Diagram

Causal loop diagrams of population, amount of waste, and methane gas emissions can be seen in Figure 3.1, Figure 3.2 and Figure 3.3.

b. Stock Flow Diagram

Stock flow diagram of the population in this study can be seen in Figure 3.4. Stock flow diagram of the amount of waste can be seen in Figure 3.5. and a stock flow diagram of the amount of methane gas emissions can be seen in Figure 3.6

3.3. Simulation of Prediction Results of Population, Amount of Waste and Methane Gas Emissions.

Prediction results for the population in 2018-2022 can be seen in Table 3.3. In Table 3.3 the total population in 2019 is 1.090.674 inhabitants and increased by 2.49% from 2018. The population increase is constant every year with an average increase of 2.4%, and graphs of the simulation results can be seen in Figure 3.7.

The predicted results of the amount of waste in 2018-2028 can be seen in Table 3.4. Based on the simulation results, the population of 1.064.000 people generated 774.051 tons of garbage. The increase in the amount of waste in 2019 is 2.6% of the amount of waste in 2018. A significant increase in the amount of waste occurrs in 2024 to 2028 with a percentage increase of 2.81% to 3.02% and a graph of the simulation results can be seen in Figure 3.8.

The simulation results of the amount of methane gas can be seen in Table 3.5. Based on the predicted results, methane gas emission in 2019 is 8.19 Gg with an increase of 2.8% from 2018. Significant increase in methane gas emissions begins to occur in 2023 to 2028 with a percentage increase of 2.8% to 3.03%. The increase of methane emissions is caused by an increase in the amount of waste generated by the population, and a prediction graph can be seen in Figure 3.9.

Table 3. 2. Table of Result of Waste Amount Identification

Variables to be predicted	Influencing Variables	Constant number	Sources
Amount of waste	- Amount of waste per capita	0,7	DLHK
	- Total population		Table 3.1
	- Compost	0,21%	DLHK
	- Recycling	0,75%	DLHK
	- Waste picker	0,26%	DLHK
	- Waste bank	0,15%	DLHK
Methane gas emission	- Waste heap fraction	0,0009	IPPC 2006
	- Methane emission Fraction	0,71	
	- Organic carbon degradation (DOC)	0,17	
	- Fraction from DOC	0,5	
	- Fraction from CH4	0,5	
	- Recovery CH4	0,94	
	- Oxidation factor	0,1	

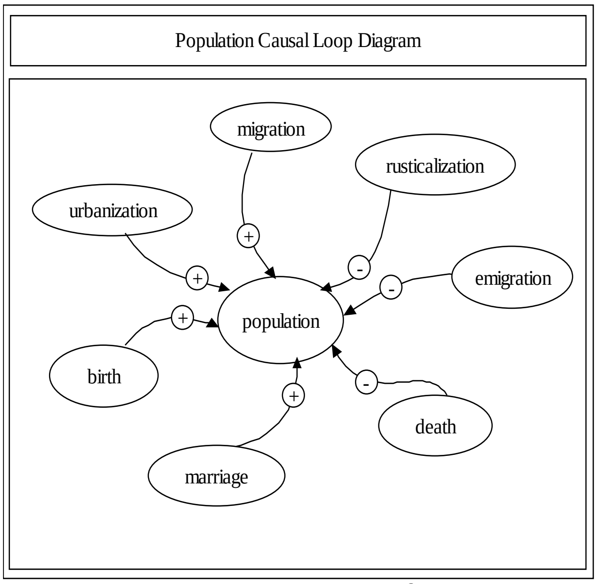

Figure 3. 1. Causal Loop Diagram of Total Population

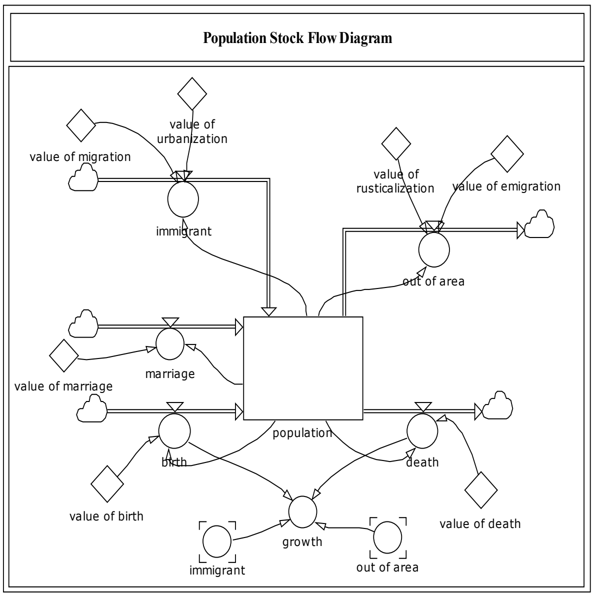

Figure 3. 4. Stock flow Diagram of Total Population

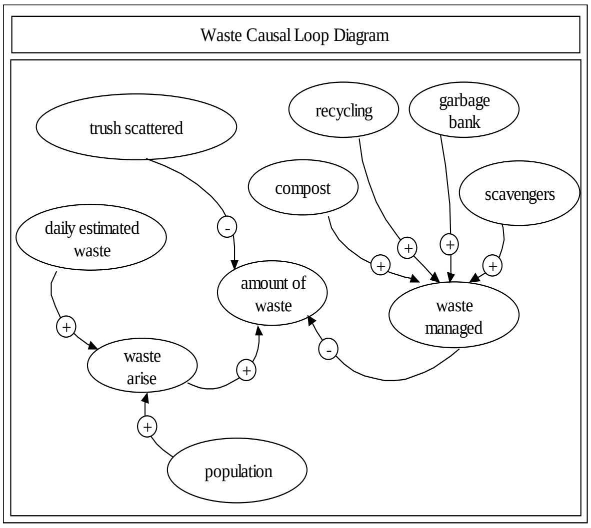

Figure 3. 2. Causal Loop Diagram of Waste Amount

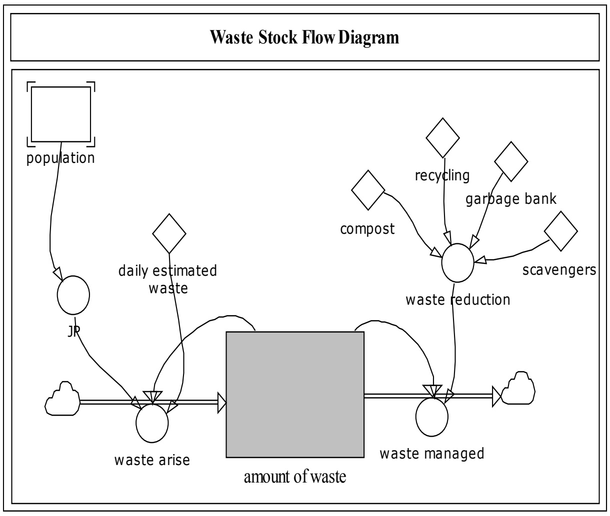

Figure 3. 5. Stock flow Diagram of Waste Amount

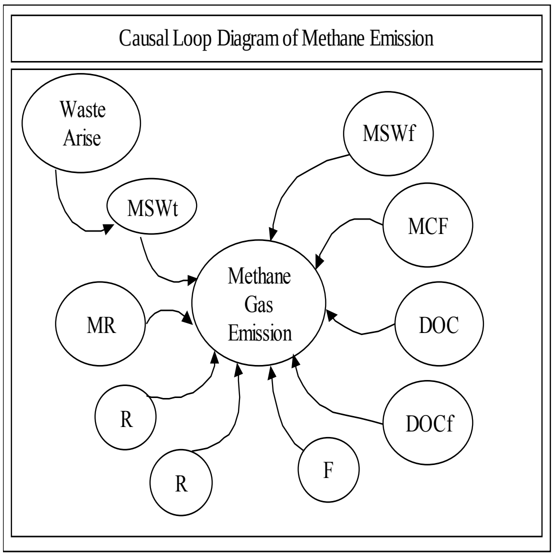

Figure 3. 3 Causal Loop Diagram of methane gas

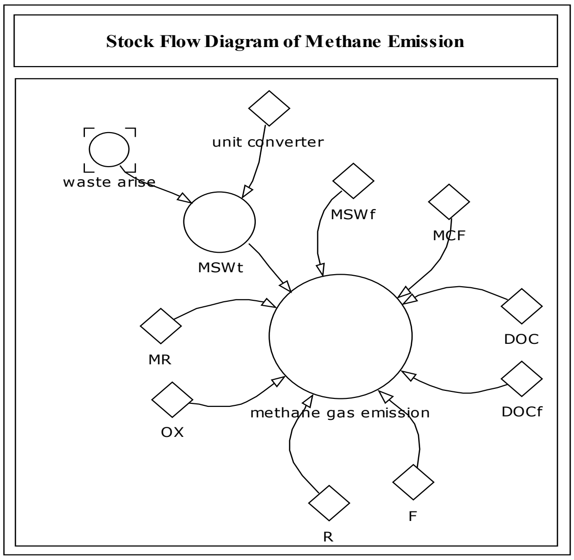

Figure 3. 6. Stock flow Diagram of Methane Gas Emission

Table 3. 3 Simulation Results of Total Population Prediction in 2018-2028

Year	Number of Population
2018	1.064.000
2019	1.090.674
2020	1.118.017
2021	1.146.046
2022	1.174.777
2023	1.204.229
2024	1.234.419
2025	1.265.366
2026	1.297.089
2027	1.329.607
2028	1.362.940

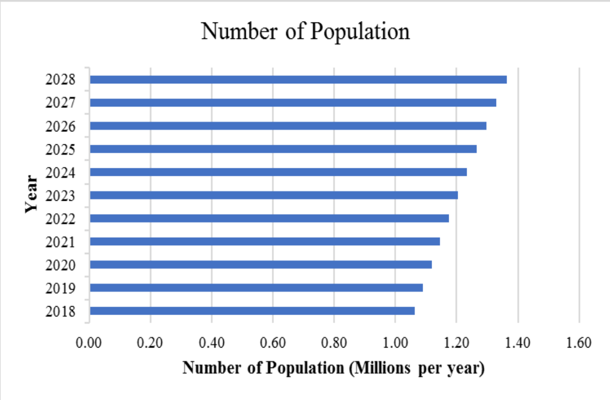

Figure 3. 7 prediction results

Table 3. 4

Year	Waste amount (Ton/Year)
2018	774.051
2019	1.046.709
2020	1.424.833
2021	1.952.702
2022	2.694.603
2023	3.744.505
2024	5.240.695
2025	7.388.108
2026	10.492.595
2027	15.013.910
2028	21.648.236

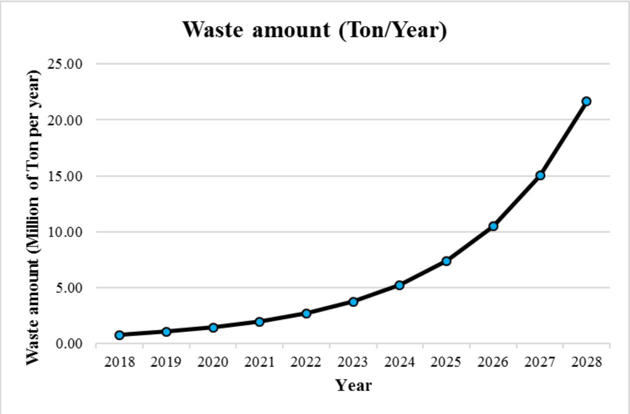

Figure 3.8

Table 3.5

Year	Result of Methane Gas Prediction (Gg/Year)
2018	8.21
2019	11.71
2020	16.67
2021	23.76
2022	33.97
2023	48.74
2024	70.30
2025	101.96
2026	148.82
2027	218.69
2028	323.63

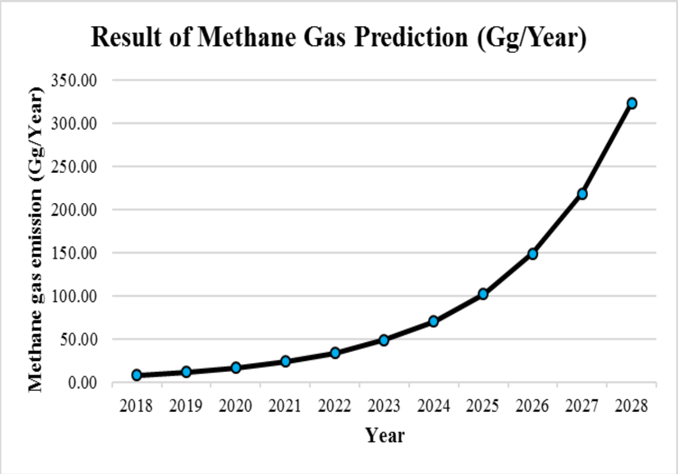

Figure 3. 9

3.4. Scenario Implementation Result

a. Scenario 1

The amount of waste used will reduce the amount of waste generation. This will affect the amount of garbage heap, and one of the variables that determines the amount of methane gas emissions is the amount of waste generation and the height of the garbage heap. The results of reducing methane gas emissions from scenario 1 can be seen in Figure 3.10.

Based on the simulation results of scenario 1, the amount of methane gas will decrease by an average of 0.5% per year until 2028. A significant amount of decline will be seen from 2023 to 2028. This is due to the predicted population in that year which also experiences a significant increase. For the previous year, a significant increase in emissions can be done by increasing the percentage of the amount of plastic waste managed.

b. Scenario 2 Addition of Higher Education Scholarship Quota

The dynamic model of scenario 2 is created by adding the scholarship recipient variable to the population system. Scenario 2 is done by adding the percentage of scholarships to 2% per year or adding 960 of the scholarship recipients in the previous year.

The reduction in population due to migration has an impact on reducing the amount of waste and will certainly be able to reduce the amount of methane gas. The simulation results of the prediction of methane gas reduction with scenario 2 can be seen in Figure 3.11. Based on the results of scenario 2, it can be seen that a reduction in population with an increase in emigration of 2% will reduce the amount of methane gas by an average of 0.184% per year. Significant reduction also begins from 2026 to 2028. This is because the predicted increase in population in that year is quite high.

When compared to the results of scenario 1 and scenario 2, it can be concluded that for this dynamic model, scenario 1 is more effective in reducing the amount of methane gas emissions. Comparison of the results of scenario 1 and scenario 2 predictions can be seen in Figure 3.12.

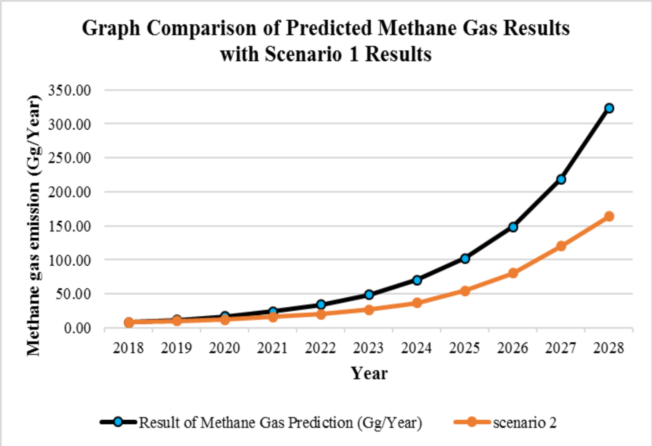

Figure 3.10.

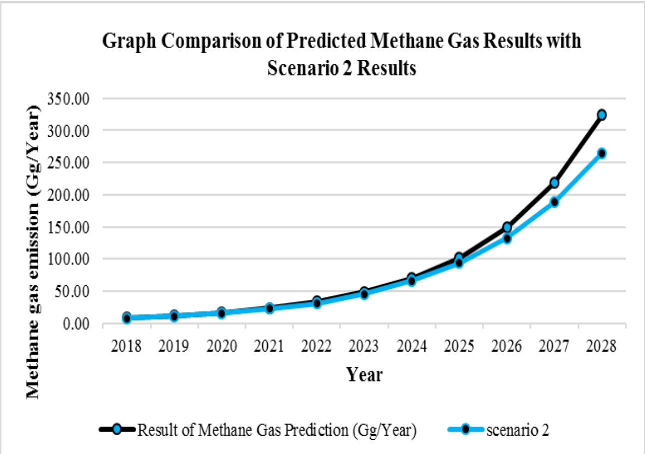

Figure 3. 11.

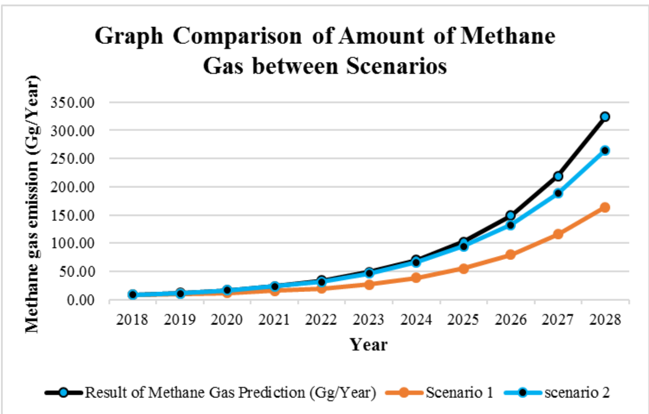

Figure 3. 12.

IV. CONCLUSION

The conclusions obtained from this study are:

1. Prediction of the average increase in population for 10 years, from 2018 to 2028 is 2.49% per year or 32,615 people per year.
2. Prediction of an increase in population of 2.4% over 10 years results in an increase in the amount of waste of 2.6% per year.
3. An increase in waste of 2.6% per year will produce methane gas in average of 26.91Gg per year.
4. The selection and management of plastic waste by as much as 70% will reduce the amount of methane gas production by 0.54%
5. Increasing scholarships by 2% per year will reduce methane gas production by 0.184% per year

V. ACKNOWLEDGEMENT

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