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Indonesia's Municipal Solid Waste 3R and Waste to Energy Programs

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Abstract

Like most cities in the world, population in Indonesia continues to grow every year. Problems that can arise from this are the increasing amount of municipal solid waste (MSW) production and the growing demand for electricity. To deal with the problems, Indonesian government runs 3R (Reduce, Reuse and Recycle) and WTE (Waste to Energy) Programs simultaneously. 3R program aims to reduce the number of waste, while WTE program aims to generate electricity as an alternative energy source. This study aims to find out the optimal proportion of MSW treated through the 3R and WTE programs. For the purpose, a goal programming model has been developed and solved using LINGO 11. The results showed that the optimal proportion of MSW through the 3R program is 49.90%, 12.37% through WTE program. This leaves 37.73% of waste untreated. The electricity generated from WTE program reached 1,229.695 GWh, total emissions that can be saved is 1,809,208.2 tons CO_2 equivalent and total land-use for the programs is 4,036,239.1 m^2. This study was enriched by performing some scenarios, i.e. adding budget allocation of WTE program, tightening the limit of total emission from waste management and reducing the limit of land-use for waste treatment.

Abstract

Optimasi Program 3R dan WTE untuk Sampah Perkotaan di Indonesia. Seperti umumnya kota-kota di dunia, penduduk kota-kota besar di Indonesia terus bertambah tiap tahun. Keadaan ini memunculkan dua permasalahan yaitu bertambahnya jumlah sampah kota (MSW) dan bertambahnya permintaan akan listrik. Untuk mengatasi permasalahan tersebut, pemerintah memunculkan program 3R (Reduce, Reuse, and Recycle) dan program WTE (Waste to Energy) secara bersamaan. Program 3R bertujuan mengurangi jumlah sampah yang dibuang sedangkan program WTE bertujuan memanfaatkan sampah sebagai alternative untuk menghasilkan listrik. Penelitian ini untuk menjawab berapa porsi sampah yang optimal untuk digunakan untuk membangkit listrik dan berapa untuk 3R. Untuk tujuan tersebut telah dibuat model goal programming dan dipecahkan dengan menggunakan software optimasi Lingo release 11. Hasil running dari model yang dibangun menunjukkan bahwa porsi MSW yang dapat dikelola lewat 3R adalah 49,90%, lewat WTE 12,37%. Sisanya 37,73% sampah tidak terkelola. Listrik yang dihasilkan dari program WTE ini mencapai 1.229,695 GWh. Emisi yang dapat dikurangi sebesar 1.809.208,2 tons CO_2 equivalen dan total lahan yang digunakan adalah 4.036.239,1 m^2. Dalam penelitian ini juga dilakukan beberapa skenario yaitu penambahan alokasi dana pada program WTE, pengetatan emisi dan berkurangnya luas lahan yang dapat digunakan.

Keywords: 3R, goal programming, MSW, Optimization, WTE

1. Introduction

According to the Statistics Central Bureau (BPS), Indonesia's population in 2014 has reached over 252 million. This number will continue to grow with the rate 1.4% [1]. Some problems among others that can arise from this phenomenon are the increasing amount of waste production and the growing demand for electricity [2]. For the first problem, the increasing amount of waste generated by the residents of Indonesia was of 0.7 kg per day [3]. Indonesia is also facing electricity problem. According to data from the State Own Electric Company (PLN) in 2014, electricity sales continue to grow at an average rate of 7.8% in the last five years. However, this growth is not offset by the supply. The supply on that period only grew on average by 6.5% [4],[5].

MSW management in Indonesia still largely relies on landfill (TPA). According to KLHK, only 69% of the total MSW generated is dumped to TPA while the rest is handled privately, burned or dumped to the river [6]. Currently, Indonesia has about 500 landfills which majority are open dumping type of landfill. With the growth of MSW production on one side and relying on TPA on the other side, the need for land for TPA site conflicts with other land used such as for agriculture, residential and industrial needs. This situation is complicated with the fact that two third of Indonesian territory are sea. Another issue from the open dumping landfill is landfill gas (LFG) generated when the waste decomposed [7]. LFG is mostly composed of Methane (CH_4) and carbon dioxide (CO_2) that categorized as greenhouse gases (GHG). CH_4 is considered as at least 21 time CO_2 equivalent to GHG problem [8].

On 2012, KLHK issued regulation Number 13 of 2012 on guidelines for the implementation of 3R (Reduce, Reuse and Recycle). The regulation targeted to reduce waste generation to 20% in 2019. The 3R program is expected to reduce the amount of waste disposed to landfill so can reduce the need for the availability of the landfill. While, on 2015, the government through the Minister of Energy and Mineral Resources (ESDM) issued regulation Number 0074/21/MEM/2015 for planning to install 35,000 MW power plant for the period 2015 to 2024. This plan will install 7,000 MW each year to cope with the prediction of Indonesian electricity demand. According to Farizal, et al. [9], landfill gas from MSW can contribute at least 9% of Indonesian electricity mix in 2021. This means MSW can be one potential source to be included to fulfill the 35,000 MW demand.

Both 3R and WTE programs aim to manage and utilize MSW. 3R program focuses to reduce the amount of waste dumped to TPA, while WTE focuses to utilize the dumped waste to generate the energy. These two programslook conflicted one another. With each benefits and costs, how could we manage the MSW so that we can solve the waste problem and at the same time fulfill the energy demand. Within available budget, how much portion of the waste go to 3R program and how much go to WTE program in order to optimize its benefits. This is the statement problem addressed on this paper. For the purpose, goal (multiobjective) programming was used.

Literature Review. Related to 3R program, several studies and researches have been done. According to Samiha [10], described the importance of the 3Rs principle in waste management to achieve sustainable development. Research conducted in China revealed that the principles of the 3Rs is a good way to protect the environment and stimulate the economy of a country. Aadal, et al. [11], proposed the concept of 3R for the management of construction waste at the construction site. This study suggested that the construction industry needed a waste management to gain its benefits, especially for environmental and social problems. Yang, et al. [12], proposed a framework program for stimulating circular 3R consumption in society. Circular consumption is an integral part of a circular economic system to sustain economic growth and reduce environmental degradation and resource depletion.

In recent years, a number of WTE studies and research have been done. Tozlu, et al. [13], explained three basic waste management to energy. The first is the method of changing waste into heat energy (Incineration, pyrolysis and gasification), the second is the method of changing waste through biochemicals and the last is land filling that converts LFG into electrical energy. Another study by Münster, et al. [14], optimized the use of waste for the future of energy in Denmark. This research was motivated by a European Union (EU) agreement that in 2016 members of the EU are required to reduce their biodegradable waste in landfill by at least 35% of their waste in 1995, increase waste recycling by at least 50% of the total weight of waste. In China, an intensive search of the WTE has been done by Cheng [15]. The result showed that the waste can be a potential source of renewable energy in the future in the country with a vast population. This study utilized three WTE methods, namely land filling, composting and incineration.

2. Methods

Goal Programming Model. The mathematical model of 3R and WTE optimization was developed using goal (multi objective) programming. This type of model was used due to its ability to deal with more than one (conflicting) objective simultaneously [16]. The complete goal programming model is written as follows:

$$\boldsymbol{Min z} = \boldsymbol{s_1}^- + \boldsymbol{s_2}^+ + \boldsymbol{s_3}^- + \boldsymbol{s_4}^+ \quad (1)$$

s.t

$$\sum_{j=1}^{n} BS_{1j} \times e_{1j} - s_1^+ + s_1^- = E_1 \quad (2)$$

$$\sum_{i=1}^{2}\sum_{j=1}^{n} BS_{ij} \times GHG_{ij} - s_2^+ + s_2^- = TRGHG \quad (3)$$

$$\sum_{j=1}^{n} BS_{2j} - s_3^+ + s_3^- = TPS \quad (4)$$

$$\sum_{j=1}^{n} BS_{1j} \times LLW + \sum_{j=1}^{n} BS_{2j} \times LLR - s_4^+ + s_4^- = \mathrm{TLL} \quad (5)$$

$$\sum_{j=1}^{n} \mathrm{BS_{ij}} \times \mathrm{C_{ij}} + \sum_{j=1}^{n} \mathrm{BS_{ij}} \times \mathrm{FC_{ij}} \le \mathrm{D_i} \quad \text{for i} \quad (6)$$

$$\sum_{j=1}^{n} \mathrm{BS_{ij}} \ge \mathrm{TRS_i} \quad \text{for i} \quad (7)$$

$$\sum_{j=1}^{n} \mathrm{BS_{ij}} \le \mathrm{CS_i} \quad \text{for i} \quad (8)$$

$$\sum_{i=1}^{2} \mathrm{BS_{ij}} \le \mathrm{TS_j} \quad \text{for j} \quad (9)$$

Description index:

i : MSW management program, where 1 = WTE program and 2 = 3R program

j : Cities in Indonesia = 1, 2, …., 44

Parameter:

BS_{ij}: waste manage by program i at city j, e_{1j}: energy produced per unit weight of waste in the city j, E_1: Energy produced by WTE program, GHG_{ij}: Total GHG released per unit weight of waste processes by the program i in city j, *TRGHG*: Target GHG emissions from waste management for 2019, *TPS*: Target 3R waste reduction program for 2019, *LLW*: WTE program constants land area in the city j, *LLR*: 3R program constants land area in the city j, *TLL* : The total area of land used by 3R program and WTE program, C_{ij}: Operating costs incurred for the program i in city j, D_i: Total budget for the program i, FC_{ij}: Capital Costs incurred for the program i in city j, TRS_i: Target of waste made by the government to run the program i, CS_i: The maximum of waste that can be managed by program i, TS_j : waste in city j

Equation 1 is the objective function of the model. It says that the goal of the model is to minimize the total unreached targets. In this study, four targets were considered, namely: a) Maximizing the WTE program which means maximizing the production of electricity from MSW (Eq. 2); b) Minimizing GHG (CO_2 and CH_4) emissions from MSW (Eq. 3); c) Maximizing the 3R program which means reducing the amount of waste dumped to the landfill (Eq. 4); d) Minimizing of land use for both the 3R and WTE programs (Eq. 5).

Eq. (6) is budget constraints which says that both WTE and 3R programs can only be run within the allocation of government budget limit. Eq. (7) is the amount of MSW minimum processes limit, while Eqs. (8) and (9) are total available MSW constraints each program and total available MSW for each city, respectively.

Data Collection and Processing. The primary data needed is MSW generation for every 44 big cities in Indonesia. These data are obtained from the BPS for period 2010 to 2014. To estimate the amount of waste up to the year of 2019, forecasting with linear regression method was used. This data will be used as a parameter CS_i in the Eq. (8) and parameter TS_j on the Eq. (9). Estimated MSW generation is used to calculate the potential methane gas produced from landfill.

Landfill methane potential was calculated using MSW data forecasted for period 2014 to 2019. These estimated data will be the input to find the coefficient calculation e_{1j}. This coefficient will be used as a parameter of the power produced per ton of waste in Eq. (2) on the model. The potential of methane is calculated by using USA EPA Land GEM [17]. From the cal-culation of the potential for methane gas, then proceed to calculate the potential electrical energy. Converting the amount of methane gas into electricity is 1 m^3 of methane worth 9.39 KWh.

Both WTE program and 3R programs in waste management will produce emissions. By WTE utilization, LFG in a landfill gas project (PLTSa) will produce carbon dioxide emissions of 147.8 grams of CO_2/KWh and 0.00203 grams of methane emissions CH_4/KWh [18]. This data will be used as the calculation to find the coefficient GHG_{ij} of WTE program in the Eq. (3). Waste management through the 3R program generates carbon dioxide emissions from converting waste into compost. Composting with anaerobic method will produce CO_2 emissions by 40 kg/ton of waste and methane emissions by 0.05 kg CH_4/ton [19]. This data will be used in Eq. (3) as the coefficient GHG_{ij} of the 3R program.

Assuming landfill depth is 10 m, one ton of MSW needs 0.2083 m^2 of landfill [20]. This data will be used as the coefficient of land area (LLW) for WTE program in Eq. (5). As for the area of land used for the 3R program refers to the attachment of four Regulations Minister of Public Works no. 03/PRT/M/2013, which states that the 3R program can reduce waste dumped in landfill as much as four times the waste without 3R program. It can be calculated one ton of waste through the 3R program requires a land area of 0.052083 m^2. This data will be used as the coefficient of land area (LLR) for the 3R program in Eq. (5).

The capital costs of a PLTSa with capacity 3MW and 15-year project duration is \$ 5.15 million. While operating costs are \$ 526,000 per year [8]. Acquired capital cost is \$ 20.10 per MWh, equivalent to 261,300 IDR (assuming \$ 1 is equal to 13,000 IDR) and operational cost is \$ 30.79 per MWh, equivalent to 400,270 IDR. From this data it can be calculated coefficient WTE fee that will be used in Eq. (6). 3R program costs consist of costs in temporary treatment station (TPS) and transfer station (SPA). The SPA operational costs by regulation Public Works No. 03/PRT/M/2013 was 23,936.15 IDR per ton of waste. While operating costs TPS 94,470.04 IDR per ton of waste. The total operating cost of waste management using the 3R is 118,406.19 IDR per ton of waste. The total operating cost of 3R will be used in Eq. (6) as the operational costs of the 3R program.

Other data needed is program's budget. This data used for the right hand site in the Eq. (6). WTE program funding budget from 2015 to 2019 is set at 915.2 billion IDR [21], while for 3R, the budget is 12,252,613,176,877 IDR. TPS parameters in Eq. (4) are obtained based on waste generation in Indonesia by 69% or 43,035,930.01

Table 1. Data Research and Processing

No	City	Total Waste 2015-2019	Methane (m3) 2015-2019	Energy Produce (KWh)	Coefficient (KWh/ton waste) (e1j)	Emission WTE (ton CO_2 equivalen)		Cost (IDR) (Operational-Capital)	
						Coefficient GHG1j	Coefficient GHG2j	WTE	3R
1	Banda Aceh	372,026.25	5,507,416.36	44,578,019.39	101.25	0.018	0.041	79,276.70	118,406.19
2	Medan	3,730,953.81	80,654,873.16	652,835,061.20	150.03	0.026	0.041	115,766.26	118,406.19
3	Padang	1,443,345.96	20,663,890.71	167,257,250.89	100.62	0.017	0.041	76,667.78	118,406.19
4	Pekan Baru	1,811,381.39	38,693,900.64	313,195,396.67	149.68	0.026	0.041	114,394.16	118,406.19
5	Jambi	743,339.84	11,091,236.81	89,774,467.17	101.52	0.018	0.041	79,903.14	118,406.19
6	Palembang	2,250,988.76	48,622,202.71	393,556,860.72	149.71	0.026	0.041	115,673.15	118,406.19
7	Bengkulu	378,619.06	5,364,476.86	43,421,041.28	100.19	0.017	0.041	75,874.55	118,406.19
8	Bandar Lampung	2,447,626.12	35,381,931.11	286,387,719.17	100.21	0.017	0.041	77,411.90	118,406.19
9	Pangkal Pinang	502,459.46	7,429,318.74	58,677,290.76	99.77	0.017	0.041	77,262.26	118,406.19
10	Tanjung Pinang	327,123.04	4,804,551.55	38,888,905.07	101.20	0.018	0.041	78,652.58	118,406.19
11	Batam	1,804,353.77	39,388,631.55	318,818,673.69	149.23	0.026	0.041	116,901,60	118,406.19
12	DKI Jakarta	13,902,788.86	302,251,383.23	2,446,477,101.09	149.49	0.026	0.041	116,422.69	118,406.19
13	Bekasi	4,149,792.50	91,021,886.49	736,747,371.28	149.03	0.026	0.041	117,460.17	118,406.19
14	Tangerang	3,349,182.78	73,294,948.30	593,262,504.63	149.12	0.026	0.041	117,194,29	118,406.19
15	Depok	3,089,980.03	67,775,858.46	548,589,998.03	149.03	0.026	0.041	117,460.17	118,406.19
16	Tangerang Selatan	2,402,714.23	52,582,025.85	425,608,382.01	149.12	0.026	0.041	117,194,29	118,406.19
17	Bogor	1,689,039.31	37,047,517.60	299,869,276.01	149.03	0.026	0.041	111,970.89	118,406.19
18	Tasikmalaya	968,071.99	14,471,595.15	117,135,696.05	101.57	0.018	0.041	80,053.44	118,406.19
19	Bandung	5,105,437.50	106,749,742.23	864,051,628.58	151.87	0.025	0.041	111,970.89	118,406.19
20	Semarang	2,350,310.28	51,537,667.44	417,155,157.02	149.04	0.026	0.041	117,427,77	118,406.19
21	Yogyakarta	254,562.86	4,314,828.20	34,924,996.09	104.30	0.020	0.041	90,769.45	118,406.19
22	Surakarta	723,137.22	10,859,716.53	87,900,864.56	101.69	0.018	0.041	80,421.25	118,406.19
23	Malang	1,177,444.21	17,696,861.89	143,241,585.59	101.72	0.018	0.041	80,487.27	118,406.19
24	Surabaya	4,787,838.23	104,696,553.52	847,432,749.55	149.17	0.026	0.041	117,536.13	118,406.19
25	Serang	1,300,631.88	18,831,601.59	152,426,372.93	99.90	0.017	0.041	77,536.13	118,406.19
26	Denpasar	2,025,569.33	29,195,998.38	236,317,666.17	100.75	0.017	0.041	77,187.59	118,406.19
27	Mataram	660,905.50	9,823,845.45	79,515,973,39	101.41	0.018	0.041	79,600.06	118,406.19
28	Kupang	648,253.69	9,393,454.82	76,032,314,17	100.71	0.017	0.041	77,598.19	118,406.19
29	Pontianak	831,385.71	12,037,844.26	97,436,648.77	101.38	0.018	0.041	79,254.41	118,406.19
30	Palangkaraya	367,965.62	5,393,461.57	120,602,061.36	101.16	0.018	0.041	78,493.12	118,406.19
31	Banjarmasin	1,013,144.64	14,899,849.20	188,027,142.36	101.00	0.018	0.041	78,755.64	118,406.19
32	Samarinda	1,602,868.76	23,2290,918.58	103,294,442.96	100.48	0.017	0.041	77,610.59	118,406.19
33	Balikpapan	858,680.30	12,761,569.79	62,623,084.21	101.40	0.018	0.041	79,587.31	118,406.19
34	Tarakan	515,791.64	7,736,804.00	222,749,079.64	101.66	0.018	0.041	80,326.45	118,406.19
35	Manado	1,921,207.16	27,519,659.76	49,607,455.27	100.38	0.017	0.041	76,707.90	118,406.19
36	Palu	515,791.51	6,128,780.84	397,191,224.65	101.71	0.018	0.041	80,555.26	118,406.19
37	Makasar	2,251,607.16	49,071,212.24	45,958,537.53	149.22	0.026	0.041	116,709.27	118,406.19
38	Kendari	381,452.38	5,677,973.25	118,025,120.20	101.41	0.018	0.041	79,712.10	118,406.19
39	Gorontalo	1,046,274.78	14,581,479.56	17,880,630.31	99.52	0.017	0.041	74,632.35	118,406.19
40	Mamuju	159,717.16	2,209,072.48	93,483,051.42	99.87	0.017	0.041	74,067.83	118,406.19
41	Ambon	817,052.50	11,549,415.93	34,169,173.68	100.01	0.017	0.041	75,697.46	118,406.19
42	Ternate	289,801.33	4,221,449.69	13,018,255.63	100.93	0.017	0.041	78,006.81	118,406.19
43	Manokwari	113,456.60	1,608,347.68	13,018,255.63	100.42	0.017	0.041	75,913.93	118,406.19
44	Jayapura	1,005,928.96	14,195,149.35	114,898,093.98	99.96	0.017	0.041	75,569.04	118,406.19
	TOTAL	77,963,641.32	151,1789,928.49	12,236,699,803.37					

tons of waste [6]. While TRS_i parameter in Eq. (7), for a minimum target of WTE program is 5% or a total of 3,898,182.07 tons of waste. While 3R targets set by KLHK is 20% or 15,592,728.26 tons of waste. Data research and data processing can be seen in Table 1.

3. Results and Discussion

The mathematical model developed was solved using LINGO 11 [22]. For further evaluating the model toward some different conditions, this study carried out three different scenarios. The goal is to see what will happen to the programs if there is a changing in WTE program budget, a tighter emissions limits, and a less available land for landfill.

The results of the model are tabulated in Table 2. The table shows that the proportion of MSW treated via WTE program reached 12.37% and 49.90% via 3R program. This situation left 37.73% of MSW untreated.

Figure 1 depicts the proportion of waste. Further analysis revealed that the untreated waste was due to the target of the emission limit has been reached. The result

Table 2. Result of the Model

	Waste (ton)	Emision (ton CO2)	Cost (million IDR)	Land use (m^2)
WTE	9,646,745.40	204,478.6	915,003.00	2,009,417.1
3R	38,902,534.4	1,604,729.5	4,606,293.00	2,026,822.0
Untreated	29,414,361.52			
	TOTAL	1,809,208.2	5,521,296.00	4,036,239.1

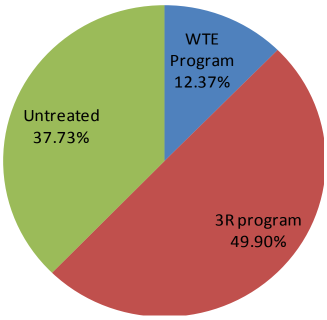

Figure 1. Proportion of Waste Management Program

showed that the emission was 1,809,208.2 tons CO_2 equivalent. This value is a bit away from the emissions limit, which is 1,809,205.24 tons. Treating more MSW, either using a WTE or 3R program, will lift up the emissions even more. The untreated waste is the consequence of the goal to minimize the unreaching target.

This study showed that the KLHK's target of 3R program at 2019 is achieved. The result, 49.90%, was even more than double of the Ministry's target, 20%. This is due to the assumption used in this study that the 3R waste processing cost took into account only the physical cost. Physical costs used in this study were the cost of managing waste into compost through UPS and the cost of sorting the waste through the SPA. The non-physical costs such as the cost of education and socialization 3R program to the community were not included in this study. The operation cost in the form of UPS and SPA workers' wage and fuel were excluded since they have been subsidized by the government via different account. Meanwhile, the proportion of MSW treated trough WTE program was only 12.37% or a total of 9,646,745.40 tons. With this portion, the electricity generated was 1229.695 GWh. WTE program budget provided by KESDM is 915.2 billion IDR. This funding has been used for the program. What is going to happen if this funding added?

Scenario of Adding Allocation Budget for WTE Program. When WTE budget was doubled, tripled and quadrupled the proportion of waste treated increased. The larger the addition of the budget, the more the proportion of waste can be treated via WTE. This reduced the proportion treated via 3R and the proportion of untreated waste as well. The proportion of waste when the budget was doubled increased to 24.70%, the proportion of waste via 3R decreased to 43.54% and the proportion of untreated waste dropped to 31.76%. The calculation results for this scenario are shown on Figure 2.

Scenario of Tightening Emissions Limits. One benefit, among others, of WTE program is reducing GHG emissions (CO_2 and CH_4) that contribute to global warming. This is possible since the MSW in landfill is confined so that the emitted gases are not released to the sky. In the initial scenario results gas emissions was 1,809,205.24 tons CO_2 equivalent. The Indonesian government has set for reducing emissions from the waste sector by 6%. What will happen if the limit is tighten to 10%, 20%, and 30%?

Tightening emission limits are reducing the 3R portion. The more tighten the limits, the more the reduction. When the limit was set to 10%, the proportion of 3R dropped to 44.27%. The proportion will further dropped to 33.02% when the limit was set to 30%. However, this scenario was not impacted the proportion of WTE (due to WTE budget restriction). The loss portion of 3R program pushed up the portion of untreated waste. With 10% limitation, the proportion of untreated waste increased from 37.73%, to 43.35%. Emission limitation reduction scenarios can be seen in Figure. 3.

Scenario of Land Use Availability. This scenario is to see the impact of land use availability if the permitted land use limits of waste facilities was reduced by 12.5%, 25%, and 37.5%. In another saying the available 3,500,000 m^2, 3,000,000 m^2, and 2,500,000 m^2, respectively.

The results of land-use availability were the decline of WTE portion. The results are not surprising since landfills utilize a considerable large area. In this scenario, reducing the land availability by 12.5% dropped WTE

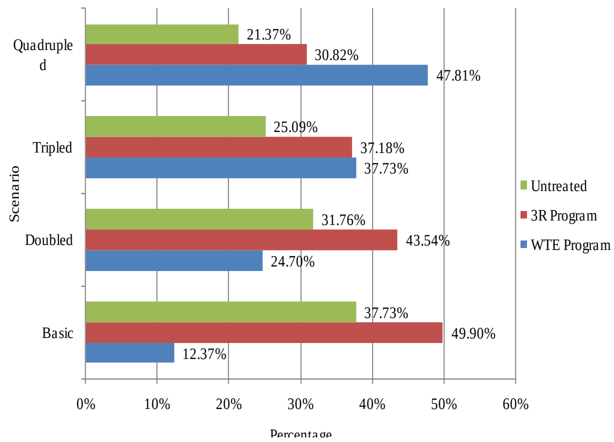

Figure 2. The Proportion of Waste with Addition of WTE Budget Allocation

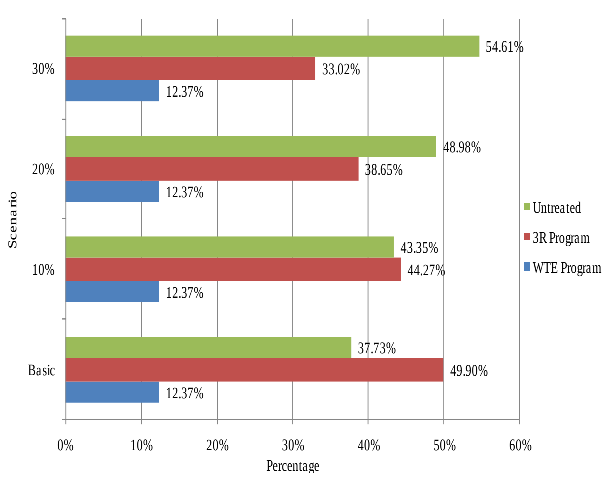

Figure 3. Proportion of Waste with Emission Limitation Reduction Scenarios

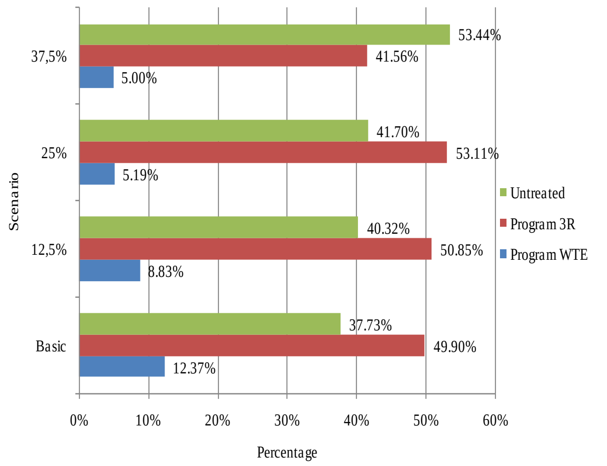

Figure 4. Proportion of Waste to Land Use Limitation Reduction Scenarios

portion to 8.83%. On the other side, the portions of 3R program were growing. Restricting the land to 12.5% rose 3R portion from 49.9% to 50.85%. However, when the restriction was set to 37.5%, not only WTE portion was dropped but 3R portion was also dropped significantly to 41.56%. This scenario will create more than half of MSW untreated. Results of land use limitation scenarios are displayed in Figure 4.

4. Conclusion

Solving the model, the optimal proportion of waste for Indonesia was 12.37% for WTE program and 49.90% for 3R program. This portion will cause the untreated waste of 37.73%. With this proportion, the electrical energy generated through WTE program reached 1,229.695 GWh, total emissions can be saved from waste manage-ment through both programs was 1,809,208.2 tons CO_2 equivalent, and total land use of 4,036,239.1 m^2.

When WTE program's budget was increased to four times, the proportion of waste processed through this program was increased four times too (47.81%). The proportion of waste processed through 3R is dropped to 30.82% and the untreated waste is dropped to 21.37 %. While the impact of this scenario was the electrical energy generated reached 4,781.252 GWh, total emissions produced reached 1,809,211.5 tons CO_2 equivalent and total land use reached 9,016,594.6 m^2.

When the emissions limits were decreased by 30%, the proportion of waste processed by 3R was dropped to 33.02%, the proportion of untreated waste was increased to 54.61%, and total land use reached 3,350,714.9 m^2. For this scenario, the proportion of waste through WTE program did not change.

The results of the land use limitation reduction scenarios (meaning that less land can be used for MSW management): when the land used was reduced by 37.5%, the proportion of waste through WTE was dropped to 5% and the proportion of 3R program was dropped to 41.56%, and unfortunately the proportion of untreated waste was increased to 53.44%. The electrical energy generated from this scenario reached 592.014 GWh, total emissions produced reached 1,434,017.4 tons CO_2 equivalent.

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