IPCC Analysis with Backpropagation Neural Network Algorithm for Decennial CH4 Potential: A Review on City Waste to Energy

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***Abstract*—Biogas as one potential renewable energy can be arranged from a proper CH4 production system commonly introduced at landfill site. City waste has been one of many resources to generate methane which can be daily transported from all over the city into the nearest landfill site. City waste to energy is the main focus of this research to be converted into potential CH4 production within certain amount of time. The aim of this research is to provide a decennial analysis on CH4 production using Intergovernmental Panel on Climate Change Analysis (IPCC) method with Backpropagation Neural Network (BPNN) over the whole state. The sample has been taken from 20 major cities in Indonesia. BPNN algorithm has been used as an artificial intelligent computing method to provide a less error decennial prediction on the daily transported garbage from the late decade (2007 to 2017) into the next decade (2018 to 2027). The result on the decennial garbage has been processed using IPCC method to provide the amount of CH4 generated form each city. Decennial analysis has finalized a trend showing that most city, 11 of 20, will have enough produced methane in an increasing state up to the next ten years, while 5 of 20 will have a reduced methane potential. This trend should be an enough bases for each city government to decide a decennial policy on city waste management, the development on landfill site, or to the improvement of biogas generation facility.**

Keywords—City waste management, methane production, decennial prediction, artificial intelligent

I. Introduction

The emerging renewable energy race on replacing fossil fuels runs it mostly coverage into bioenergy such as biogas from biomass, from landfill, or from wastewater treatment. Non-petroleum-based renewable source has become popular within the last decade especially ones within the close proximity to the consumer. In this case, municipal solid waste is a daily produced material which is located close to every consumer. It come to more attention that the large consumer in the urban area, such as high populated city which equipped with enough garbage trucks and adequate landfill site, should be able to use daily produced municipal solid waste as a reliable methane (CH4) source.

Methane gas can be produced form the transported city waste which is usually systematically gathered into landfill site under city office jurisdiction. The amount of methane gas being generated can be estimated using IPCC methodology [1][2]. The method has also been preferably used since it is a considerably simple approach to perform the first order decomposition model that has a linear correlation with maximum potentials of methane production per weight unit of waste, providing an estimated annual methane emission [3]. Previous research on landfill by Andriani *et al* [4] was focused on the potential landfill gas production and waste management policy which is not covering a large geographical diversity yet. Similar research on greater scale would add higher impact on the field.

Annual methane production can promise a renewable energy supply to the nearest city. Moreover, continuous methane supply, such as in the next ten years, can help the city government to issue a long term policy and made an investment on city infrastructure. This research tried to implement a long term prediction on the methane production over the state. There are numerous methods on predicting such process as a statistical methods (i.e., ARMA, ARIMA, SARIMA, and ES) and other intelligent computing methods such as fuzzy logic and neural network [5][6]. The selected method to be used in this research was back propagation neural network (BPNN) algorithm especially to calculate the decennial potential of produced methane form the transported city waste.

BPNN algorithm is a part of an intelligent method that aims to reduce an error rate in predicting. This method was altering its weight based on the designated output and target any differences [7][8]. The advantages of BPNN is that this algorithm is capable to handle all data pattern, noisy case, missing data, and unstructured data. BPNN can complete the task which cannot be finished by linear program because the network still continuously work even when one element is failed. BPNN could also find a more complex pattern and trend to be recognized by the user or by the other computational technique. Moreover, in the modelling design,

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BPNN is depending on the input and output data, so the used data would brought a significant impact for the better BPPN model.

This research aims is to predict the CH4 production potential on the next decade to acquire knowledge on how to treat city waste as a potential energy source. The BPNN algorithm has been conducted to predict the waste production at the smallest error especially on the value on transported garbage for the next decade. The final methane analysis was conducted using IPCC to convert the amount of transported garbage into possible methane production (ton/year). The result will provide an important information to assist on city office on developing facilities, equipment, or policies for waste management and landfill gas power generation.

II. Materials and Methods

City waste samples were taken from 20 major cities in Indonesia to acquire the updated trend on the last ten years (2007 to 2017). The data has been processed using back propagation neural network method to predict the possible waste amount in the next ten years. IPCC method later implemented to provide the potential CH4 production as one of near city renewable energy source.

A. Cities Sample and Waste Management

This research was conducted only in Indonesian area and focused in major cities only. From many major cities in Indonesia, the samples were taken from 20 most populated cities and limited only to those with complete city waste data. Several highly populated cities with incomplete late ten year waste data, e.g. Manado, Jayapura, and Manokwari, were omitted from this research. The list of the sample cities can be seen in Table I [9] and the geographical location of each city can be found in Figure 1.

B. BPNN Methods

Back Propagation neural network algorithm has been used in this research as a part of an intelligent method that aims to reduce an error rate in predicting. BPNN is having two main stage: Propagation phase and weight update phase which were conducted repeatedly until the network is stable enough [10][7]. Moreover, BPNN principle is a multilayer training method by using three layers, namely input layer, hidden layer and output layer, and also weight update process [8].

TABLE I. City sample and waste production in 2017

No	City	Population	Daily Waste Production (m^3/day)
1	Banda Aceh	238,814	275.00
2	Medan	2,210,624	1,892.00
3	Padang	883,767	624.24
4	Pekanbaru	886,226	764.19
5	Jambi	609,620	1,534.35
6	Bandar Lampung	1,175,397	800.00
7	DKI Jakarta	10,154,584	7,164.53
8	Bandung	2,404,589	1,600.00
9	Semarang	1,653,035	5,163.72
10	Yogyakarta	636,660	1,048.00
11	Surabaya	2,827,892	9,710.61
12	Denpasar	638,548	3,719.00
13	Mataram	419,506	350.00
14	Kupang	438,005	684.00
15	Pontianak	655,572	1,802.50
16	Palangkaraya	258,550	892.50
17	Banjarmasin	647,003	568.00
18	Samarinda	766,015	686.56
19	Palu	363,867	1,058.42
20	Makassar	1,334,090	6,485.65

BPNN algorithm was developing a prediction process from a single layer which consist of an input and an output layers. The algorithm added a hidden layer to reduce the error value on the network compared to the single layer. The designated hidden layer has been act as a place to update and adjust the weight. Thus, the new weight values are obtained then directed towards the desired output target [8]. The BPNN architecture and flowchart can be seen in Figure 2.

Fig. 1. City waste samples taken from 20 major city throughout the country.

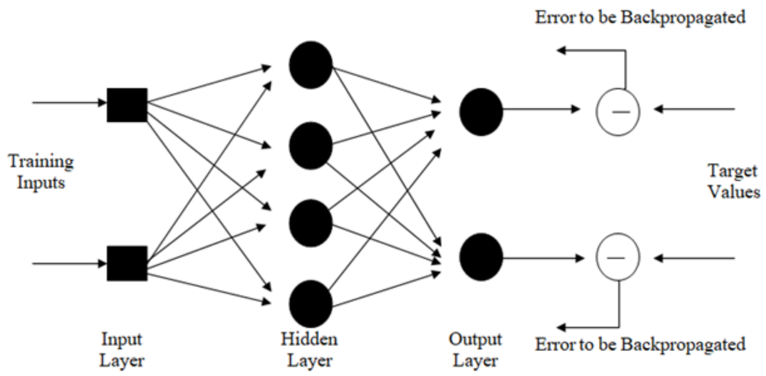

Fig. 2. BPNN Architecture.

Figure 2 shows an activation function in a neural network for the calculation of the actual output value at the output layer. BPNN Parameter can be defined as follow:

- Epoch represent an iteration or step which has been performed at BPNN learning stage. If Epoch reach the designated maximum number, the learning process will be stopped.
- The maximum iteration process in this research has been set at 10000 steps for each input data.
- Learning rate has been set at 0.01.
- Momentum value was set at 0.9

The BPNN network architecture was consist of 1 input layer, 1 hidden layer, and 1 output layer. BPNN Model has been designed with two neuron at the input layer, while the output layer has been equipped with one layer. At last, the hidden layer is having two neurons.

C. IPCC Methods

According to IPCC methodology, methane emission from a city waste transported into landfill is estimated by applying the following equation (1) [1][2]:

$$CH_4 \text{ emissions [ton]} = MSWT \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 \quad (1)$$

where MSWT is the total MSW generated (tonnes), MSW_F is the fraction of MSW disposed of to landfills, MCF is the methane correction factor, DOC is the fraction of degradable organic carbon, DOC_F is the fraction of total DOC that actually degrades, and F represent fraction of methane in LFG.

In a typical situation, MCF has default values of 0.4 to 1.0, depending on different practices of MSW landfill operation. If most of observed city's landfills are considerably unmanaged, the MCF value is set at 0.6 [2]. Technically, an MCF value represents the possibility of aerobic decomposition of top-layer waste fraction that leads to less-than-theoretically-possible methane production in landfills [11]. According to IPCC, DOC ranges from 0.08 to 0.21, while its estimation is expressed as equation (2)

$$DOC = 0.4P + 0.15K + 0.3W \quad (2)$$

where P is the fraction of papers in MSW, K is the fraction of kitchen garbage in MSW, and W is the fraction of woods/leaves in MSW.

In this research, the default DOC value was set at 0.16. The value was applied by considering organic carbon fraction in waste that was accessible to anaerobic decomposition. On the other hand, the default DOC_F value was set at 0.77 by considering the biodegradation of DOC to not completely occurring over a long period of time. In fact, only a fraction of DOC was practically converted into CH_4 and CO_2, while the rests were stored in a landfill as stable organic matters or degrade through other biological or chemical processes.

III. Result and Discussion

A. Transported Waste in Major Cities

Each city in Indonesia has its own method on waste management. Most of all, the city government divided the city waste into three stages: daily garbage production, daily transported garbage, and percentage of treated garbage. Daily produced garbage commonly higher in amount than transported garbage because most garbage trucks in the city cannot transport all the produced garbage completely to the landfill site. This research using the daily transported garbage as the main processed data since daily garbage production cannot be presented as the possible CH4 source.

The acquired data of transported garbage from 20 major city in Indonesia can be seen in Table II [12][13][14][15][16][17][18][19][20][21][9], while the five years trend of the transported garbage can be seen in Fig. 3. The last year of acquired data is 2017 because the data for 2018 is not released yet by the time this research conducted.

Figure 3 shows various trends from each city because each city has different waste management method and implementation. How the garbage was transported was different for each city. The number of garbage truck and the capacity of the landfill site were also fluctuated in the last decade. This fluctuation made each city having different waste amount than the other city. Some cities increase its transported garbage amount because the city office increases the number of garbage truck. The other cities decrease the amount of its transported garbage because they implement zero garbage campaign or self-maintain garbage for its resident. Aside this differentiation, the city waste still produced daily and transported in certain amount throughout the year. The number will be later processed using BPNN algorithm.

BPNN algorihm was implemeted to predict the number of transported garbage on each city for the next 10 years from 2018 into 2027 (Table III). Because the amount of transported garbage for each city is different, the decennial trend of each

TABLE II. CITY SAMPLE AND TRANSPORTED WASTE IN THE LAST DECADE 2007 TO 2017 (M^3/DAY)

No	City	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	Banda Aceh	465.00	450.00	467.00	475.00	509.00	530.00	600.00	617.60	643.69	703.45	250.00
2	Medan	4,396.00	3,390.00	1,256.88	5,030.14	5,100.00	5,934.60	6,349.45	3,244.70	1,485.46	1,595.00	1,675.00
3	Padang	1,435.00	2,419.00	1,610.79	658.67	1,266.50	1,343.18	1,367.35	320.00	437.30	323.00	495.50
4	Pekanbaru	1,900.00	526.00	500.42	525.00	530.80	763.00	3,657.54	2,106.50	409.80	332.54	362.28
5	Jambi	640.00	680.00	696.00	715.00	833.00	900.00	910.00	1,015.00	1,037.45	924.74	1,059.01
6	Bandar Lampung	548.00	550.00	6,580.00	2,384.67	2,555.00	690.00	753.20	966.75	1,082.54	1,158.32	700.00
7	DKI Jakarta	26,962.00	27,756.00	24,323.00	23,699.00	20,776.29	6,004.20	5,636.90	6,212.05	6,419.14	6,016.30	6,872.18
8	Bandung	1,968.00	4,050.00	3,705.00	*1,618.82	1,100.00	1,035.00	1,290.00	1,389.00	1,050.00	1,100.00	1,120.00
9	Semarang	19,250.00	3,339.00	3,395.39	3,543.97	3,696.56	3,853.25	4,014.13	4,179.00	4,349.00	4,445.00	4,544.00
10	Yogyakarta	1,116.00	1,200.00	1,149.00	895.00	834.36	722.00	760.09	760.00	780.39	880.00	1,040.00
11	Surabaya	4,933.00	3,814.00	5,286.54	4,098.35	4,170.59	3,897.57	4,646.00	4,853.33	4,925.50	5,234.70	5,427.45
12	Denpasar	1,954.00	1,913.00	1,954.00	2,126.00	2,264.00	2,703.00	2,938.00	3,418.56	3,547.00	3,625.00	3,275.55
13	Mataram	704.00	737.00	856.00	878.00	898.00	927.00	942.00	944.00	196.65	196.50	280.00
14	Kupang	1,884.00	296.00	303.00	161.21	161.21	*473.22	378.00	486.00	480.00	504.00	552.00
15	Pontianak	1,385.00	1,144.00	1,160.27	1,505.27	1,105.27	1,203.98	1,380.30	1,295.44	1,434.00	1,486.00	1,547.00
16	Palangkaraya	366.00	212.00	232.00	261.30	361.00	424.00	430.00	410.00	421.00	425.00	435.00
17	Banjarmasin	680.00	1,269.00	652.00	526.00	650.00	948.27	383.97	441.29	2,882.50	437.00	545.30
18	Samarinda	1,274.00	1,269.00	1,309.60	1,622.82	1,143.07	1,262.33	1,827.79	1,792.38	1,938.58	520.78	217.24
19	Palu	700.00	676.00	608.36	374.07	360.27	534.11	757.00	783.00	600.00	456.00	456.00
20	Makassar	3,662.00	3,315.00	3,278.12	3,373.42	3,520.07	3,642.56	3,776.23	4,063.10	3,962.63	5,623.61	6,163.42

**Median imputation have been implemented*

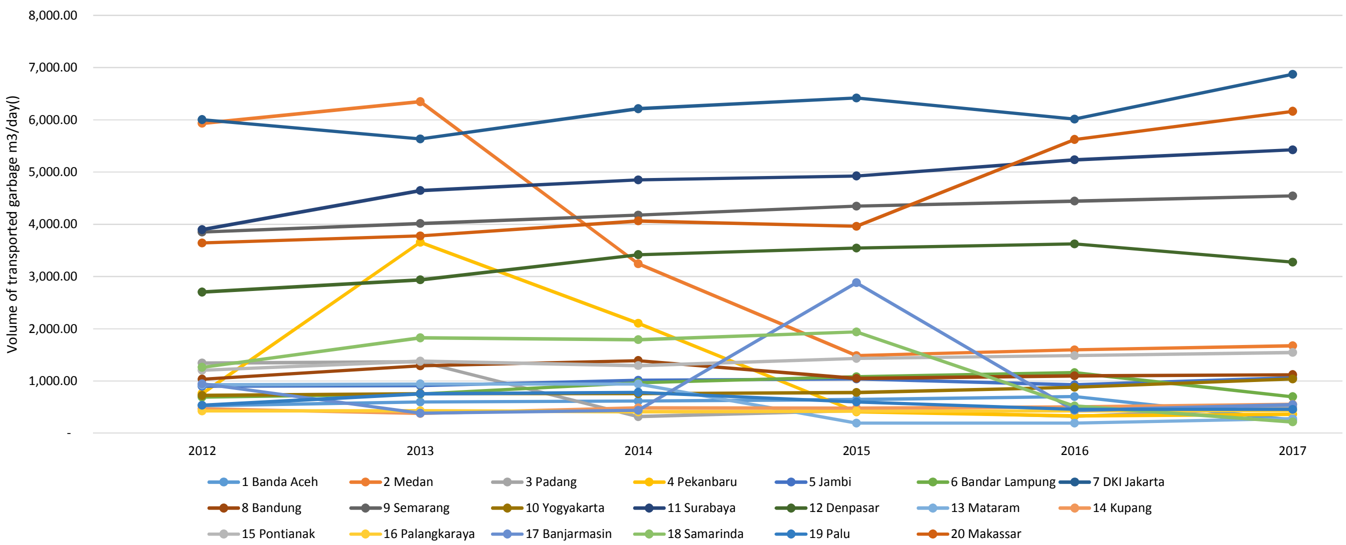

Fig. 3. Five years (2012 to 2017) trend of the transported garbage from 20 major cities.

city doesnot similar with other city. The thrend shown in Table II is varied based on the previous data of 2007 to 2017. Aside form this variation, methane production for the next ten years will determine the prospect of renewable energy at each city waste.

B. CH4 Potential

The amount of transported garbage in Table II has been processed using BPNN algorithm to acquire the prediction of the possible transported garbage for the next ten years, 2018 to 2027. The amount can be seen in the first line of each cell at Table III. The second line of each cell in Table III provides calculation results of methane generated form the transported garbage in the first line. The conversion has been conducted using IPCC methodology [1].

A linear forecast trend line was later added on each city progress to show whether the methane production is going up or down. Every city show the decreasing and increasing trend for the next ten year, however, there were several city that showed a very limited trend where it can be concluded that the disparity is very small or can be said as having no significant change. This trend is the main basis to acknowledge whether the city should pay attention to its daily produced waste as an alternative energy source in the next ten years.

C. *City Waste to Energy Decennial Analysis*

Decennial analysis showed that there are three city categories that having different methane production potential i.e. cities with potentially increasing methane production, cities with stagnant methane production, and cities with potentially decreasing methane production.

1) Cities with decreasing methane production; Four cities showing a reduced methane production trendline (Figure 4) i.e. Medan, DKI Jakarta, Kupang, and Palu. The trend line was alternated on R-squared value from 0.0343 to 0.6032. At some point in the next few decades, these cities' current waste management will bring the city to reach zero waste condition which has a very good impact on creating a green environment but offering no potential on generating methane from city waste. In this case, the government should observe another renewable energy source such as solar, wind, or geothermal rather than to develop any methane production facility in the area.

2) Cities with stagnant methane production; There are five cities with stagnant methane production i.e. Banda Aceh, Padang, Bandar Lampung, Palangkaraya, and Samarinda (Figure 5). These cities have less than 0.01 R-square trends which is varied from 0.0003 to 0.0064. City government can put the city waste as a stable renewable energy source and the

TABLE III. CALCULATION RESULT FROM TRANSPORTED GARBAGE TO GENERATED METHANE IN THE NEXT TEN YEARS (2018 TO 2027)

No	City	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Trend
1	Banda Aceh	623.03 26.95	658.60 28.49	729.34 31.55	60.82 2.63	826.20 35.74	752.11 32.53	773.23 33.45	57.88 2.50	894.91 38.71	614.44 26.58	0.0003
2	Medan	7,469.10 323.10	7,641.13 330.54	364.54 15.77	785.36 33.97	1,510.02 65.32	1,101.96 47.67	8,152.72 352.67	1,033.33 44.70	225.00 9.73	558.83 24.17	0.2331
3	Padang	1,828.16 79.08	45.87 1.98	109.47 4.74	310.99 13.45	18.42 0.80	1,846.08 79.86	223.72 9.68	2,724.60 117.86	854.65 36.97	48.09 2.08	0.0064
4	Pekanbaru	314.69 13.61	356.33 15.41	2,153.22 93.14	262.34 11.35	216.38 9.36	601.62 26.02	333.83 14.44	2.037.99 88.16	598.64 25.90	1,183.87 51.21	0.0567
5	Jambi	1,076.90 46.58	1,040.99 45.03	986.60 42.68	1,210.70 52.37	1,102.87 47.71	1,040.30 45.00	936.35 40.50	1,222.36 52.88	972.66 42.08	1,184.07 51.22	0.0199
6	Bandar Lampung	7,525.73 325.55	4,614.69 199.62	483.16 20.90	102.30 4.43	10,560.47 456.82	6,083.97 263.18	976.99 42.26	4,431.89 191.71	12,771.31 552.46	274.91 11.89	0.0016
7	DKI Jakarta	6,600.25 285.51	731.61 31.65	1,299.17 56.20	574.26 24.84	4,851.47 209.86	2,061.94 89.20	7,346.00 317.77	29.81 1.29	1,186.36 51.32	1,711.27 74.03	0.6032
8	Bandung	330.61 14.30	65.11 2.82	1,044.40 45.18	829.98 35.90	311.67 13.48	88.65 3.83	1,641.84 71.02	23.86 1.03	51.27 2.22	1,388.77 60.08	0.0394
9	Semarang	5,931.21 256.57	4,500.81 194.70	4,504.93 194.87	4,688.05 202.80	8,507.42 368.01	5,220.90 225.85	4,354.40 188.36	5,446.45 235.60	8,592.98 371.72	9,345.10 404.25	0.3195
10	Yogyakarta	687.60 29.74	652.41 28.22	1,136.12 49.15	1,063.06 45.99	600.81 25.99	1,007.68 43.59	580.06 25.09	1,100.20 47.59	1,141.57 49.38	768.56 33.25	0.0520
11	Surabaya	5,116.87 221.35	5,604.36 242.43	5,530.32 239.23	5,543.32 239.79	5,206.71 225.23	6,209.02 268.59	5,753.68 248.89	5,692.56 246.25	5,134.30 222.10	6,271.81 271.31	0.1883
12	Denpasar	3,471.62 150.18	3,559.54 153.98	3,666.23 158.59	1,822.91 78.86	4,201.06 181.73	3,965.81 171.55	3,831.33 165.74	1,718.66 74.35	4,548.48 196.76	4,522.34 195.63	0.0522
13	Mataram	994.96 43.04	400.25 17.31	1,024.39 44.31	142.37 6.16	293.20 12.68	27.38 1.18	915.60 39.61	158.89 6.87	1,368.12 59.18	2,013.17 87.09	0.1525
14	Kupang	211.59 9.15	588.09 25.44	690.89 29.89	893.05 38.63	180.83 7.82	195.00 8.44	766.64 33.16	950.60 41.12	88.87 3.84	111.03 4.80	0.0343
15	Pontianak	1,512.94 65.45	1,560.80 67.52	1,582.96 68.48	1,653.42 71.52	1,663.68 71.97	1,591.43 68.84	1,620.41 70.10	1,747.98 75.61	1,667.05 72.11	1,676.52 72.52	0.6032
16	Palangkaraya	460.96 19.94	534.30 23.11	479.16 20.73	469.09 20.29	492.44 21.30	539.95 23.36	382.97 16.57	394.98 17.09	551.37 23.85	540.38 23.38	0.0038
17	Banjarmasin	1,575.41 68.15	3,178.43 137.49	207.23 8.96	3,441.25 148.86	686.77 29.71	3,184.18 137.74	4,023.26 174.04	4,333.46 187.46	889.84 38.49	3,322.27 143.71	0.0908
18	Samarinda	884.37 38.26	1,959.17 84.75	2,401.51 103.88	281.18 12.16	198.40 8.58	249.59 10.80	290.08 12.55	2,620.62 113.36	2,880.05 124.59	179.08 7.75	0.0004
19	Palu	806.82 34.90	821.61 35.54	813.49 35.19	851.81 36.85	354.30 15.33	674.68 29.19	867.95 37.55	925.09 40.02	241.50 10.45	861.46 37.27	0.0492
20	Makassar	4,150.52 179.54	3,187.97 137.91	6,811.86 294.67	6,244.58 270.13	3,562.49 154.11	4,066.46 175.91	8,500.72 367.72	6,531.77 282.55	3,369.64 145.76	6,834.36 295.64	0.0947

Note: the first line in each cell represents the amount of daily transported garbage (m^3/day), and the second line represents the produced CH4 (ton/years).

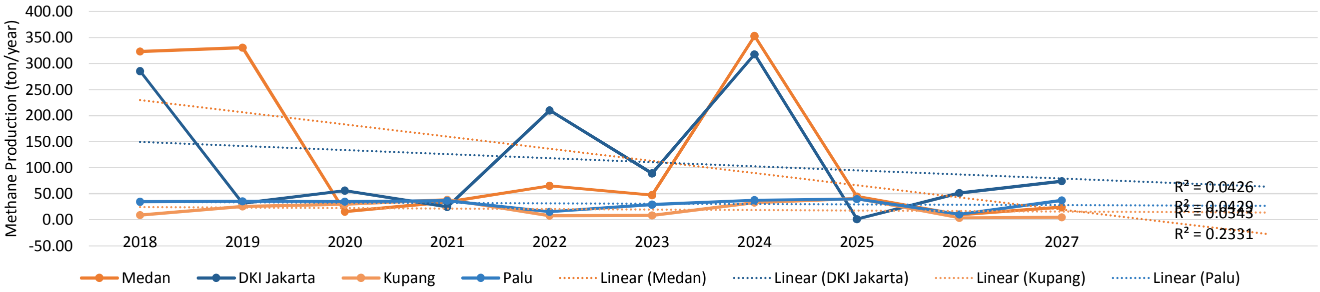

Fig. 4. Cities with decreasing CH4 production potential in the next ten years (2018 to 2027).

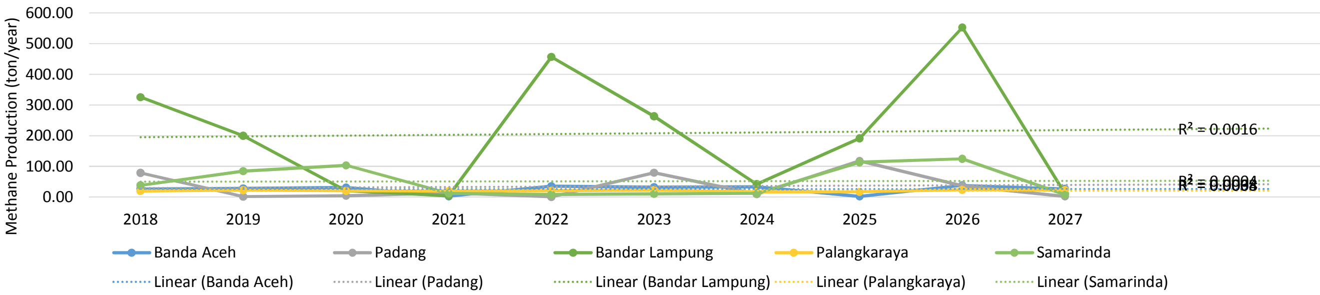

Fig. 5. Cities with stagnant CH4 production potential in the next ten years (2018 to 2027).

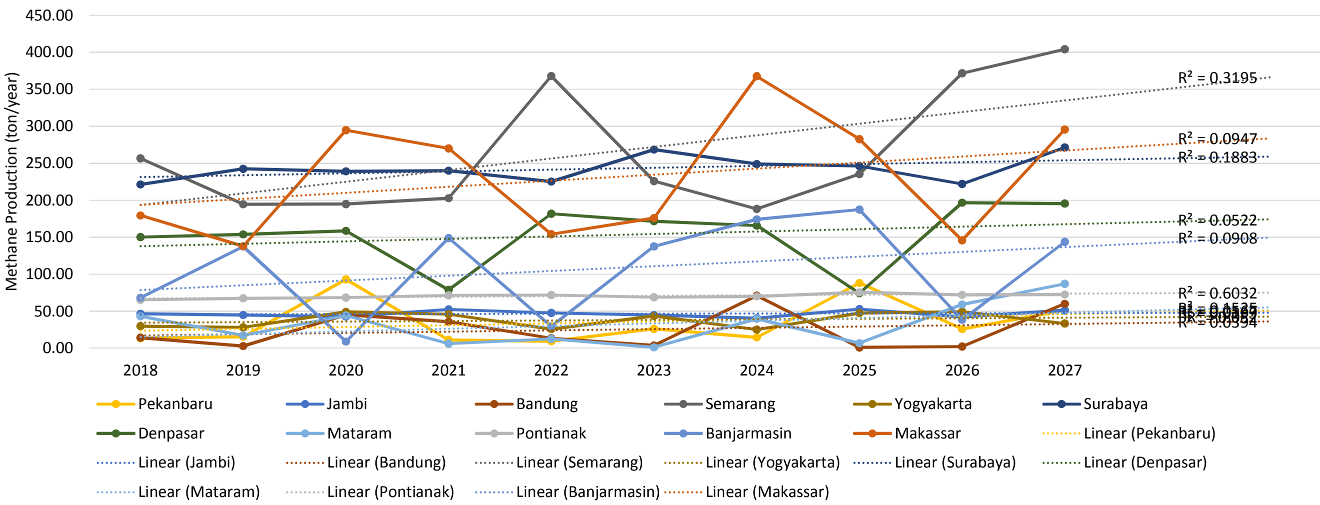

Fig. 6. Cities with increasing CH4 production potential in the next ten years (2018 to 2027).

produced methane can still be considered as a reliable energy reserve even for a small percentage to the utility grid. However, further investment should be reconsidered not to promise a significant contribution to the city total energy consumption.

3) Cities with increasing methane production; The rest of the cities was happen to have increasing methane production (Figure 6). The trendline was wide-ranging from 0.0199 to 0.6032 on R-squared value. In the next decade this cities should have tons of methane, therefore, city office should be able to facilitate the improvement on landfill gas facility at an increasing rate. By another option, the city government can develop a methane canister to be exported into another area.

Methane can also be converted into electricity source. Methane collected at the landfill site is pumped out and then underwent pretreatment to remove CO2. Energy from methane can be transformed into cogeneration system or supplied to power plant and natural gas pipeline. Power generation from methane includes organic Rankine cycle (ORC) and Stirling cycle engine (SCE) to add the traditional reciprocating internal combustion engine (ICE) and gas turbine (GT).

IV. Conclusions

This research conclude that city waste management could fluctuate the daily transported garbage in to the landfill site. The storaged amount of city waste in the landfill site will affect the produced methane per year. The BPNN algorithm have shown the possible transported garbage in the next ten years, and the IPCC method calculated the CH4 production in each major city. The result shows that several city will continuously decrease its garbage volume but most city has increasing trend of transported city waste to the landfill site. Decennial analysis showed that most city in Indonesia have opportunity to enhance the biogas development as one of the renewable source for the next ten years. This result can be a main basis for city office to decide a necessary decennial policy on waste management, and also long term investment and development on biogas and landfill gas facility. Future research could be conducted to provide more detailed on possible generated electricity on each city by the next decade.

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