Journal of Theoretical and Applied Information Technology
31st March 2024. Vol.102. No 6

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

DETERMINATION OF LFG QUALITY FOR OPTIMIZING PRODUCTION WASTE POWER PLANT USING FUZZY ANALYTICAL HIERARCHY PROCESS

MUHAMAD HADDIN[1], AGUS FAHRUDDIN[2], ARIEF MARWANTO[3]
[123]Electrical Engineering Department, Universitas Islam Sultan Agung Semarang, Indonesia
E-mail: haddin@unissula.ac.id

ABSTRACT

This study discusses the determination of the production quality of the Waste Power Plant (WPP). The purpose of this research is to calculate and predict a rough estimate of bio gas production, potential gas emissions and potential estimates of electrical energy generated from determining the quality of landfill gas production. The model is determined as WPP with input of waste volume, gas parameters, weather and the resulting output is quality gas production and electrical energy potential. The parameters used are volume of waste; stockpiling area; gas concentration: CH_4; CO_2; O_2; H_2S; and weather. With a constant average condition of waste methane decomposes 64% fast, 14% decomposes slowly, and 22% slowly decomposes. Furthermore, Fuzzy Analytical Hierarchy Process (FAHP) is used to establish the priority weights of the LFG criterion in decision support systems and fuzzy logic is implemented to determine the value of LFG production quality. The research object was carried out at the Jatibarang WPP, Semarang, Indonesia. The results showed that the FAHP can provide an output value of gas quality with an accuracy rate of 79%, with the sanitary landfill model producing a maximum potential of 2.6 MW of electrical energy. Meanwhile, gas emissions released into the air in 2021 are 24,780 tons/year of CH4 and 1,425 tons/year of CO2, while the factors that most influence the quality of LFG gas are: methane gas content, carbon dioxide and weather conditions.

Keywords: *LFG Quality, Waste Power Plant, Fuzzy AHP*

1. INTRODUCTION

The increase in population is directly proportional to the increase in population consumption, the quantity of waste created will continue to rise yearly, as will the need for electrical energy consumption. This of course raises several problems, including increasing waste production, extensive land management, waste management transportation and the environmental impact of the pollutants produced. [1]-[4]. Waste that is not correctly handled pollutes the environment. One solution to this problem is to make waste be processed into alternative energy using a Waste Power Plant (WPP). In this study, the results of gas output and the quality of LFG gas production will be known [5]-[13].

Following the Government's New and Renewable Energy Program, which has a target of 23% by 2025, waste-based power plants (WPP) are targeted to be built and developed in 9 provinces spread throughout Indonesia [5], [14]-[17]. Efforts have been made to reduce waste from sources or at intermediary facilities, such as Temporary Disposal Sites (TDS), TDS 3R (Reduce, Reuse, Recycle), and Waste Banks. However, because of the high waste output level, the national waste reduction level is low. Under the National Waste Policy and Strategy (Jakstranas), The government aspires that by 2025, 100% of waste can be managed by processing 70% and 30% by reducing waste [7].

The increase in electrical energy consumption is proportional to the interconnection system for electricity production. To meet population growth which is directly proportional to electricity demand, an estimation system is needed [18]-[22]. The estimation model is determined based on the indicator parameters of population growth and electricity demand using a neural network forecasting database.

The selection of waste management methods or technology is influenced by the quality and amount of waste, the availability of land, fiscal capacity, and the existing waste business ecosystem, as well as the advantages and disadvantages of each technology [23], [24]. One of the potential renewable energy sources to be developed is biomass, biogas, and municipal solid waste. Landfills contain organic waste that can emit LFG (Landfill Gas). LFG has the highest percentages of methane and carbon dioxide, both of which are greenhouse gases. Furthermore, methane gas in the landfill might result in flames and even explosions. The principle in the design of gas utilization is the quality of gas following the needs of the use and capacity of the system planning, where the design capacity of the system is calculated based on the projected gas that can be produced, the level of gas production, and the estimated percentage. Usable gas [23], [25], [26]. Generators with intermittent supply will reduce engine efficiency and result in engine damage. To determine the amount of LFG recoverable for burning or use in LFG energy conversion projects, multiply the model's expected LFG generation by the percent collection efficiency [16]-[18].

Several studies on the quality of LFG to optimize the determination of waste power plant (WPP) production include: research using the Land GEM software simulation method has been carried out by [27]-[29] with input parameters of waste income per year and professional epsilon to see the output power as well as increase in efficiency and power system to get mass flow with operating time creating real conditions. Several types of primary and supporting criteria, some tangible and others intangible, are included in the multi-criteria decision-making problem (MCDM). These criteria can be represented by a hierarchical structure that demonstrates their connection. One MCDM method that utilises this structure is the analysis of process hierarchy analysis (AHP) for sustainable energy management with waste from research results and monitoring the problem criteria in choosing the appropriate method [11]. According to research using multi-criteria decision making (MCDM) for energy management and resource efficiency of wastewater treatment, biogas is the ideal gas fuel, natural gas is second, liquefied natural gas is third, compressed natural gas is fourth, and gas is fuel and fifth on the list in the waste power plant [30]-[35]. This research study only focuses on one of the potential parameters of a waste power plant, but no one has discussed landfill gas quality. This study focuses on the problem of determining the quality of gas emissions produced by Landfill Gas Emissions using Fuzzy-AHP, where the quality of landfill gas production is influenced by the levels of methane, carbon dioxide, oxygen and sulfur dioxide, which are influenced by weather conditions.

2. THE PROPOSED METHOD

WPP is a waste or methane gas-fueled thermal power plant that uses supercritical steam. The sanitary landfill method utilities gas acquired from trash, namely gas produced from waste power plants. The Sanitary Landfill approach involves placing garbage into a hole, leveling and compacting it, and then covering it with loose dirt to form layers. The next step is to install a conduit to release the LFG so that it may be utilized as fuel to use the gas that has been created.

A waste power plant is an electrical energy generator that uses waste as its main fuel. The principle of generating WPP is carried out in 2 ways, namely the Incineration process, namely by burning waste and Gasification, namely by collecting gas which is then converted into electrical energy. Incinerator technology is a method of processing waste by burning waste at high temperatures. The high temperature combustion system is also known as heat treatment. In the process of burning waste, the fuel used must be of good quality [14]. Incineration method as shown in Figure 1.

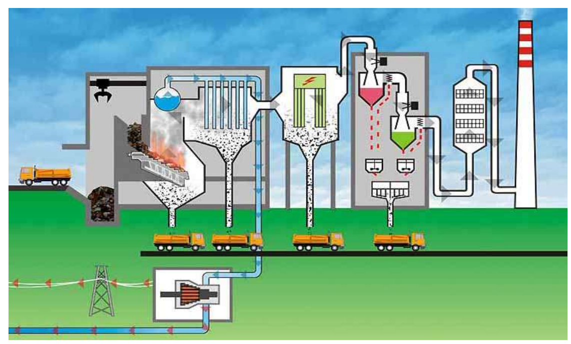

Figure 1: Incineration Method [4]

Incineration is a type of thermal waste treatment that may be considered a controlled combustion process. The most common WTE process is incineration, which converts the heat generated by burning into electric power. The waste's organic content is burnt, generating heat, while the inorganic content contributes to ash production. Incineration produces ash, heat, and combustion gases as by-products [4]. The following are the benefits of this technique: it results in an almost full elimination of harmful organic matter when tight monitoring measures are stressed, the treatment technology is low when correctly handled, it eliminates liquids, creates solid waste, and is easy to transport. Some major disadvantages of incineration are its relatively high cost, the possible release of radioactive material into the environment, and finally, the direct re-release of carbon dioxide into the atmosphere [7].

Gasification is a thermochemical process that includes heating plastic waste at 700-1100 °C with regulated proportions of oxygen, air, oxygen-enriched air, and steam to create "synthesis gas" or syngas. Syngas is a gas combination mostly composed of hydrogen (H_2) and carbon monoxide (CO), with lesser percentages of other gases such as carbon dioxide

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

(CO_2) and hydrocarbons such as methane (CH_4)[17]-[18]. A gasification plant typically includes a gasification reaction process, syngas catalytic conversion, gas separation and purification, and gas separation and purification. CO, CO_2, H_2, and CH_4 are the primary by-products of gasification. Feedstock qualities, catalyst type, gasifier type, and operating circumstances affect the yield and gas composition. Example: temperature, pressure, and residence time. Gasification Method as shown in Figure 2.

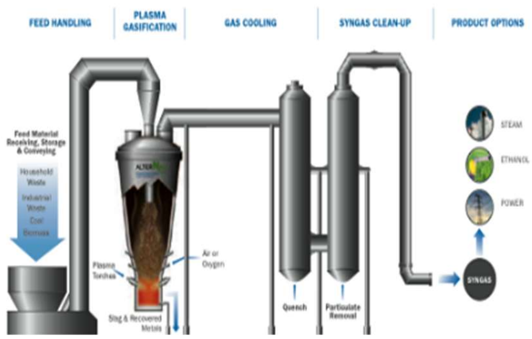

Figure 2: Gasification Method [17]

This research has several steps, as shown in Figure 3 the steps that must be taken:

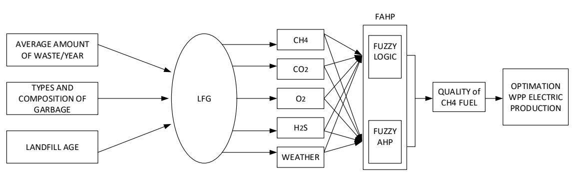

Figure 3: Research System Model

Figure 3 shows that the potential for electrical energy production at a waste power plant is obtained through predictions using moving averages, where data is obtained from historical data from the previous year. Then after the waste data is obtained, it can be calculated the potential for gas emissions and the potential for LFG to produce electrical energy. After getting the output of electrical energy conversion, then optimization will be carried out using the fuzzy AHP method which will get maximum results for the optimum month output to optimize the output of electrical energy from the waste power plant.

2.1. LFG Potential

Research has shown that the potential for methane gas contained in LFG is available in large quantities, which is around 50%. The US Environmental Protection Agency (EPA) calculation model is used to calculate the potential LFG generated in a sanitary landfill. According to research [8], the formula used to de-normalize data is shown in Eq. (1).

$$Qt = 2Lo\ Mo\ (e^{Kt} - 1)e^{Kt} \quad (1)$$

where: *Qt* is the amount of gas produced (m^3 /year), *Lo* is the potential of *methane* produced (m^3 /year), *Mo* is a solid amount received (ton/year), *k* is the average *methane* constant (years), and *t* is landfill age, (year).

The efficiency of the operating gas collection and control system based on the condition information when performing calculations for the collection of LFG gas generated by the effluent is shown in Eq. (2).

$$\text{Production gas } (m^3/\text{year}) = 75\% \,.\, \text{the amount of gas produced} \quad (2)$$

According to the EPA, the quantity of methane gas used from the landfill is around 50%, as shown in the Eq. (3).

$$\text{Methane gas } (m^3/\text{year}) = 50\% \,.\, \text{gas recovery} \quad (3)$$

To calculate the amount of electricity generated, is shown in the Eq. (4).

$$\Sigma\text{: Methane . 9.39 kWh . Engine Efficiency} \quad (4)$$

The heat potential is utilized to convert methane gas into electrical energy, where 1 kg of methane gas equals 6.13 x 107 J and 1 kWh of electricity equals 3.6 x 106 J, or 1 m3 of methane gas equals 9.39 kWh of electricity produced, as shown in Table 1.

Table 1: Methane Conversion

Energy Conversion	
1 Kg Gas Methane	6.13 x 10^7J
1 kWh	3.6 x 10^6J
1 m^3 gas Methane	9.39 kWh

2.2. Moving Average (MA)

This method takes a group of observed values from the Jatibarang WPP data and then looks for the average value. Then after that, the average will be used for the next period. Table 2 shows the results of moving average prediction calculations. The input used is data from 2011 to 2020 which produces predictive output for the next 10 years, namely 2021 to 2030, shown in Table 2.

Table 2: Moving Average Forecasting Results in 2021-2030

Years	Quality (ton/day)	Quality (ton/years)
2021	1,028	375,220
2022	1,070	390,587
2023	1,089	397,587

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2024	1,105	403,325
2025	1,119	408,508
2026	1,131	412,706
2027	1,139	415,845
2028	1,145	417,743
2029	1,146	418,254
2030	1,143	417,195

2.3. Gas Emissions Calculation

The calculation of gas emissions calculation (GHG) from biological waste management is shown in Eq. (5) and (6).

$$CH_4 \text{ emissions} = \Sigma((((\mathrm{Mi} \,.\, \mathrm{EF})^{10^{-3}}) - \mathrm{R}).\mathrm{GWP}) \quad (5)$$

$$CO_2 \text{ emissions} = \Sigma((((\mathrm{Mi} \,.\, \mathrm{EF})^{10^{-3}}) - \mathrm{R}).\mathrm{GWP}) \quad (6)$$

where Mi is Gas mass (Gg/years); EF is gas emission factors (g); EF CH_4 is value CH_4 4 g CH_4/kg; EF CO is value CO 0.90 g CO_2/kg; R is amount of gas recovery; and GWP is Global Warming Potential.

2.4. Fuzzy AHP (Analytical Hierarchy Process)

The conventional AHP analytical technique combines the AHP and Fuzzy concept approaches, where fuzzy AHP outperforms standard AHP in describing ambiguous decisions [35].

The steps for Fuzzy AHP are: creating a hierarchical structure. Determining the pairwise interest comparison matrix between criteria with the Fuzzy Triangular Number scale; To determine the value of the fuzzy synthesis (Si) to obtain the relative weights for the decision-making elements shown in Eq. (7).

$$\tilde{S}i = \sum_{j=1}^{m} \tilde{M}_{ci}^{j} \left[\sum_{i=1}^{n} \quad \sum_{i=1}^{n} \tilde{M}_{ci}^{j}\right]^{-1} \quad (7)$$

where Si is fuzzy synthesis; $\sum_{j=1}^{m} \tilde{M}_{ci}^{j}$ is an operation for adding fuzzy extent analysis *M* values for a partial matrix using the addition operation for each triangular fuzzy number in each row. Eq. (8) calculates the degree of membership by comparing fuzzy synthesis values to generate a vector.

$$V(M_2 \geq M_1) = \begin{cases} 1 & \text{if } m2 \geq m1 \\ 0 & \text{if } l1 \geq u2 \\ \frac{(l1-u2)}{(m2-u2)-(m1-l1)}, & \text{other} . \end{cases} \quad (8)$$

The normalization of the vector weight or the priority value of the criteria that has been obtained is used Eq. (9).

$$W' = (d'(A_1), (d'(A_2), \ldots (d'(A_n))T \quad (9)$$

where A_1 (i = 1, 2, … n) is n the elements; and d '(A_i) is a value that describes the relative choice of each decision attribute.

The vector acquired after normalizing the vector weights is no longer a fuzzy number. Thus, the next option is to rank the vector weights, with the total ranking created by multiplying the evaluation vector of each beneficiary with the priority vector. Making judgments based on the best overall ranking.

2.5. Research Flow

The LFG production mitigation flowchart and research procedure algorithm will explain the steps for calculating LFG gas quality is shown in Figure 4.

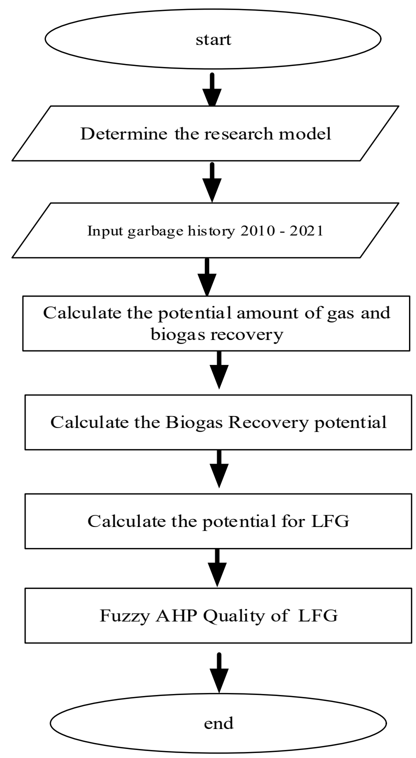

Figure 4: Flowchart of LFG Production Determination.

Figure 4 shows that to determine the quality of LFG, it is necessary to input some data concerning 5 parameters, namely: methane gas CH_4 % mmol; carbon dioxide gas CO_2 % mmol; oxygen gas O_2 % mmol; hydro dioxide sulfur H_2S % mmol, and weather. The selection of these 5 parameters was based on information and data obtained from the Environmental Office of Semarang and PT. BPS JATI BARANG who manages and operates WPP Jatibarang. The system processed the data using fuzzy Mamdani and fuzzy AHP to determine the quality of WPP is shown in Figure 5.

Journal of Theoretical and Applied Information Technology
31st March 2024. Vol.102. No 6

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

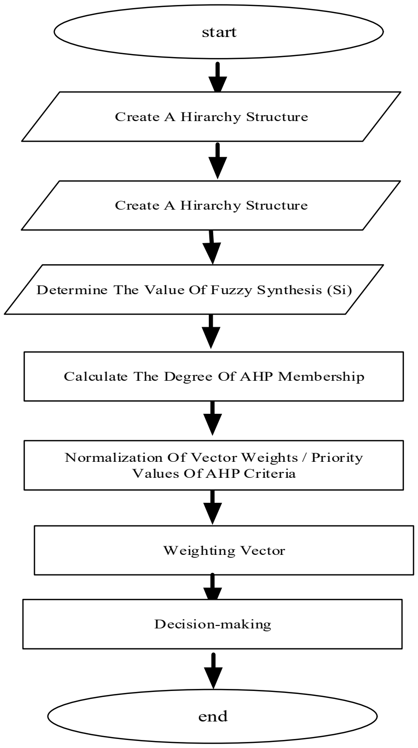

Figure 5: Flowchart of LFG Production Determination

The flowchart of the AHP fuzzy design for LFG determination is shown in Fig. 5. The steps for Fuzzy AHP's work in identifying the quality of gas output are as follows: Make a hierarchical problem structure; Using the Fuzzy Triangular Number scale, create a pairwise interest comparison matrix between criteria. To acquire relative weights, calculate the fuzzy synthesis value (S_i). The degree of membership is calculated by comparing fuzzy synthesis (S_i) results.

3. RESULTS AND DISCUSSION

Referring to the research model in Figure 1 and the data on landfills in Table 2. The potential results are obtained:

Table 3: Calculation of Gas Potential and Electrical Energy

No	Recoverable Biogas (m^2/years)	Amount of Methane Gas Collected (m^2/years)
1	5,733,293	2,866,647
2	5,968,092	2,984,046
3	6,070,711	3,035,356
4	6,162,734	3,081,367
5	6,241,929	3,081,367
6	6,306,066	3,153,033
7	6,354,029	3,177,015
8	6,383,031	3,191,515
9	6,390,839	3,195,419
10	6,374,665	3,187,332

Table 3 is the result of calculating the potential for gas to be generated for the next 10 years. By knowing the above results are in accordance with the calculation of the data that has been obtained, it can be analyzed that in the second to eight years it has increased every year.

Referring to Table 3 and Eq. (3) and (4), the results of the potential for electrical energy will be obtained as shown in Table 4.

Table 4: Energy Potential Result

No	Energy (Kwh/year)	Power (Kwh/hour)	Mega Watt (MW)
1	23,203,158	2,648.76	2.6
2	24,153,405	2,757.24	2.8
3	24,568,714	2,804.65	2.8
4	24,941,138	2,847.16	2.8
5	25,261,649	2,883.75	29
6	25,521,217	2,913.38	2.9
7	25,715,329	2,935.54	2.9
8	25,832,699	2,948.94	2.9
9	25,864,299	2,952.55	2.9
10	25,798,842	2,945.07	2.9

Table 4 is the result of calculating the potential conversion of gas to electrical energy generated for the next 10 years. By knowing the above results are in accordance with the calculation of the data that has been obtained, it can be analyzed that in the second to eight years it has increased every year. Furthermore, the determination of the quality of LFG gas will be determined using the Fuzzy AHP method.

3.1. Potensial Gas Emissions

Refers to Eq. (5), (6) and Table 2. Greenhouse gas emissions obtained are presented in Table 5.

Table 5: Potential Gas Emissions

No	Gas Emissions	
	CH_4	CO_2
1	24,943.99	1,425.37
2	30,433.80	1,739.07
3	31,754.77	1,814.56
4	33,111.17	1,892.07
5	34,503.71	1,971.64
6	35,933.80	2,053.36
7	37,401.78	2,137.24
8	31,236.91	1,784.97

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

9	23,103.41	1,320.19
10	27,170.16	1,552.58

Table 5 is the result of the calculation of potential greenhouse gas emissions, which is deduced annually. The emission reduction in the first year is very large with the resulting emissions. for CH_4 which has a content of 40-60% in LFG, the remaining in the first year is only 24,780 tons/year, and for CO_2 which has a 40% content in LFG 1,425 tons/year.

3.2. Membership Function

The membership function is a curve that depicts the transformation of data input points into membership degrees with intervals ranging from 0 to 1. The Gaussian trapezoid function is used to determine the quality of the biogas. Table 6 shows the field data used to establish the set of membership functions for each gas.

Table 6: Percentage of Substance Content

Chemical Content	Percentage
CH_4	50 – 70 %
CO_2	30 - 40 %
O_2	1 – 40 %
H_2S	< 0.1 %

3.2.1 Membership Function of Methane

The variable CH_4 which consists of 3 fuzzy sets, namely LOW, MEDIUM, and HIGH. The degree of membership of methane is shown in Table 7. The membership set of methane gas which consists of three classifications:

Table 7: Membership Function of Methane

Parameter	CH_4
LOW	$\mu_{low}[x] = \begin{cases} 1 & , \quad x \leq 10 \\ \frac{30-x}{20} & ,10 \leq x \leq 30 \\ 0 & , \quad x \geq 30 \end{cases}$
MEDIUM	$\mu_{medium}[x] = \begin{cases} 0 & ,x \leq 20 \\ \frac{x-20}{15} & ,20 \leq x \leq 35 \\ \frac{50-x}{15} & ,35 \leq x \leq 50 \end{cases}$
HIGH	$\mu_{high}[x] = \begin{cases} 0 & ,x \leq 40 \\ \frac{x-60}{20} & ,40 \leq x \leq 60 \\ 1 & ,x \geq 60 \end{cases}$

3.2.2 Membership Function of Carbon Dioxide

The variable CO_2 which consists of 3 fuzzy sets, namely LOW, MEDIUM, and HIGH. The degree of membership of carbon dioxide is shown in Table 8. The membership set of carbon dioxide gas which consists of three classifications:

Table 8: Membership Function of Carbon Dioxide

Parameter	CO_2
LOW	$\mu_{low}[x] = \begin{cases} 1 & , \quad x \leq 5 \\ \frac{10-x}{5} & ,5 \leq x \leq 10 \\ 0 & , \quad x \geq 10 \end{cases}$
MEDIUM	$\mu_{medium}[x] = \begin{cases} 0 & ,x \leq 10 \; atau \; x \geq 30 \\ \frac{x-20}{10} & ,20 \leq x \leq 30 \\ \frac{40-x}{10} & ,30 \leq x \leq 40 \end{cases}$
HIGH	$\mu_{high}[x] = \begin{cases} 0 & ,x \leq 30 \\ \frac{x-30}{10} & ,30 \leq x \leq 40 \\ 1 & ,x \geq 30 \end{cases}$

3.2.3 Membership Function of Oxygen

The variable O_2 which consists of 2 fuzzy sets, namely LOW and HIGH. The degree of membership of oxygen is shown in Table 9. The membership set of oxygen gas which consists of two classifications:

Table 9: Membership Function of Oxygen

Parameter	O_2
LOW	$\mu_{low}[x] = \begin{cases} 1 & ,0{,}2 \leq x \leq 0{,}5 \\ \frac{0{,}5-x}{0{,}3} & ,0{,}3 \leq x \leq 0{,}5 \\ 0 & , \quad x \geq 0{,}5 \end{cases}$
HIGH	$\mu_{high}[x] = \begin{cases} 1 & ,0{,}7 \leq x \leq 1 \\ \frac{x-0{,}5}{0{,}2} & ,0{,}5 \leq x \leq 0{,}7 \\ 0 & , \quad x \leq 0{,}5 \end{cases}$

3.2.4 Membership Function of Hydrogen Sulfide

The variable H_2S which consists of 2 fuzzy sets, namely LOW and HIGH. The degree of membership of hydrogen sulfide is shown in Table 10. The membership set of hydrogen sulfide gas which consists of two classifications:

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 10: Membership Function of Hidroden Sulphide

Parameter	H_2S
LOW	$\mu_{low}[x] = \begin{cases} 1 & ,0{,}2 \le x \le 0{,}5 \\ \frac{0{,}5 - x}{0{,}3} & ,0{,}3 \le x \le 0{,}5 \\ 0 & , \quad x \ge 0{,}5 \end{cases}$
HIGH	$\mu_{high}[x] = \begin{cases} 1 & ,0{,}7 \le x \le 1 \\ \frac{x - 0{,}5}{0{,}2} & ,0{,}5 \le x \le 0{,}7 \\ 0 & , \quad x \le 0{,}5 \end{cases}$

3.2.5 Membership Function of Weather

The variable weather which consists of 3 fuzzy sets, namely BRIGHT, CLOUDY and RAIN. The degree of membership of weather is shown in Table 11. The membership set of weather gas which consists of three classifications:

Table 11: Membership Function of Weather

Parameter	Weather
BRIGHT	$\mu_{BRIGHT}[x] = \begin{cases} \frac{29 - x}{9} & ,20 \le x \le 29 \\ 0 & , \quad x \ge 29 \end{cases}$
CLOUDY	$\mu_{CLOUDY}[x] = \begin{cases} 0 & ,x \le 27 \text{ atau } x \ge 33 \\ \frac{x - 27}{3} & ,27 \le x \le 30 \\ \frac{33 - x}{3} & ,30 \le x \le 33 \end{cases}$
RAIN	$\mu_{RAIN}[x] = \begin{cases} 0 & ,x \le 31 \\ \frac{x - 31}{9} & ,31 \le x \le 40 \\ 1 & ,x \ge 40 \end{cases}$

3.3. Rules Base

In order to obtain accuracy, several basic rules were obtained to be used in assessing and evaluating the quality of LFG. The rules obtained were based on 5 parameters, so 108 rules combinations were obtained shown in Table 12.

Table 12: Membership Function of Weather

No	Parameter			
	CH_4	CO_2	CO_2	CO_2
1	LOW	LOW	LOW	LOW
2	LOW	LOW	LOW	LOW
3	LOW	LOW	LOW	LOW
4	LOW	LOW	LOW	HIGH
5	LOW	LOW	LOW	HIGH
...	...	...	...	...
108	HIGH	HIGH	HIGH	HIGH

No	Output		
	Weather	LFG	Connection
1	RAIN	DN	LOSS
2	CLOUDY	DN	LOSS
3	SUNNY	DN	LOSS
4	RAIN	DN	LOSS
5	CLOUDY	DN	LOSS
...	...	...	...
108	RAIN	N	SINC

3.4. Implication Function

After rules were formed, the implication function application was carried out. The sample cases taken in the measurement had the following parameters: CH_4: 53.5 % mmol; CO_2: 39.3 % mmol; O_2: 0.4 % mmol; H_2S: 0.4 % mmol; Weather: 37^0C. Based on Table 5. From the case data, the predicate rules for parameter assessment include Table 13.

Table 13: Membership Function of Weather

Sampling	Parameter	Measurement Resuls	Membership		
			Low	Medium	High
CASE 1	CH_4	53.5		0.15	0.675
	CO_2	39.3		0.14	0.4
	O_2	0.4	0.33		
	H_2S	0.4	0.33		
	Weather	37.0			0.66

Table 14: Parameter of Assessment

No	No. Rules	Rules	Min Value A-Predicate
1	R99	IF CH4 (HIGH) AND CO2 (HIGH) AND O2 (LOW) and H2S (LOW) and Weather (HIGH) Then NORMAL	0.33
2	R87	IF CH4 (HIGH) AND CO2 (MEDIUM) AND O2 (LOW) and H2S (LOW) And Weather (HIGH) Then NORMAL	0.14
3	R63	IF CH4 (MEDIUM) AND CO2 (HIGH) AND O2 (LOW) and H2S (LOW) And Weather (HIGH) Then Below Normal	0.15
4	R51	IF CH4 (MEDIUM) AND CO2 (MEDIUM) AND O2 (LOW) and H2S (LOW) And Weather (HIGH) Then NORMAL	0.14

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3.5. Rules Composition

The overall conclusion of the rules composition is obtained by taking the maximum membership level from each subsequent application of the implication function and merging all of the conclusions of each rule. As a result, the Fuzzy solution area was obtained as follows:

$\mu_{sf}(x) = \max\{0.33\}$

The intersection point of rules was when μ LFG Quality = 0.33, then the x value can be determined as: X = 40 + 20. (0.33) = 46.6; Therefore, membership function of the solution area was obtained, as shown in the following:

μ Quality LFG $= \{0.33;\ 46.6 \le X \le 60\}$

3.6. Defuzzification

Defuzzification or affirmation is conversion of fuzzy sets into real numbers. The input of the affirmation process is fuzzy set, whereas the resulting output is a number in the domain of fuzzy set. In this research, the method used in the defuzzification process was the centroid method (composite moment). In this method, the researcher assumed that the existing variables were discrete numbers. For example, for the LFG value obtained in the rule composition process, then Z* was optimal, generally formulated as the following:

$$Z = \frac{\int_{46.6}^{60} (0{,}33)x\,dx}{\int_{46.6}^{60} (0{,}33)\,dx}$$

$$= \frac{0{,}165\,x2\,\big]_{46.6}^{60}}{0{,}33\,x\,\big]_{46.6}^{60}}$$

$$= 50.7$$

The LFG quality vulnerability value of 50.7 was categorized as normal and synchronous to State Electricity Company (PLN).

3.7. Mean Absolute Percentage Error

From the results of the application of the Mamdani fuzzy in the MATLAB program, the comparison between the Mamdani fuzzy and the gas production of Jatibarang WPP was obtained. Then by using the Mean Absolute Percentage Error (MAPE), the average error can be calculated by comparing the measurement results from the PT. BPS Jatibarang with the results of calculations using the Matlab application. Table 15 shows that the result of the Mean Absolute Percentage Error Presentation.

Table 15: MAPE (Mean Absolute Percentage Error)

No	Date	LFG PT. BPS (y) % mmol	LFG FUZZY (ŷ) %mmol	Y-ŷ	(y – ŷ)/y
1	27/01/2020	47.1	45	2.1	0.044586
2	10/05/2020	41	37.8	3.2	0.078049
3	03/03/2020	30	18.1	11.9	0.396667
4	30/01/2020	42.6	34.9	7.7	0.38
5	26/01/2020	30	18.6	11.4	21.60%
MAPE					21.60%

Table 15 presents the percentage error is 21%, which means that it is in accordance with the MAPE percentage value classification including accurate values, with an accuracy rate of 79%.

3.8. Fuzzy AHP (F-AHP) Analysis

The steps in determining LFG quality using the AHP fuzzy method are as the following:

3.8.1 Hierarchy Structute

The hierarchical structure of LFG quality selection problem is presented in the following Figure 6.

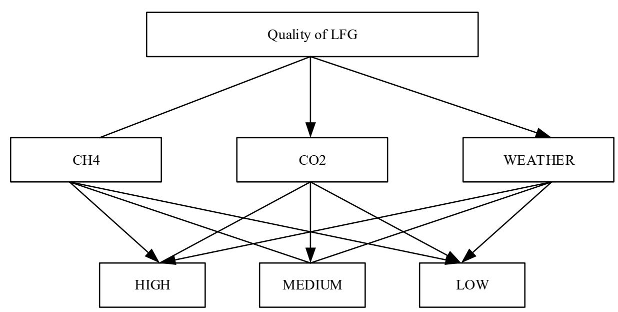

Figure 5: Hierarchical Structure of Quality LFG

Where Goal: Determining the best month of quality landfill; Criteria: CH_4; CO_2 and Weather; and Sub-criteria: H = High; M = Medium; L = Low.

3.8.2 Determination of Synthesis Value

The decision support system will provide a variable and a range of values for each criterion. then represented using a fuzzy triangle, which is then compared in pairs with the input parameters can be seen in Table 16.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 16: Paired Matrix Comparison

	CH4			CO2			WEATHER			NURMBER OF LINE		
	H	M	L	H	M	L	H	M	L	H	M	L
CH4	1	3	1	1	2	1	1	3	2	3	8	4
CO2	0,33	1	3	0,5	1	2	0,33	1	3	1,16	3	8
Weather	0,17	0,33	1	1	0,5	1	0,5	0,33	1	1,67	1,16	3
Amount										5,83	12,16	15

The value of Table 16 is obtained from the comparison between 1 element of the CH4 parameter criteria: CO_2 and Weather. After the calculation, the value of the number of rows and columns is obtained, then we will look for the fuzzy synthesis value of each criterion (Ski) where I = 1, 2, ….., ..., according to Eq. (7).

$$SCH_4 = (3.5\,.\,4.5\,.\,5.5)\,.\,(1/11.1/13.1/17)$$
$$= (0.318\,.\,0.346\,.\,0.196)$$
$$SCO_2 = (4\,.\,5\,.\,7)\,.\,(1/11.1/13.1/17)$$
$$= (0.364\,.\,0.385\,.\,0.250)$$
$$S_{WEATHER} = (3.5\,.\,3.5\,.\,4.5)\,.\,(1/11.1/13.1/17)$$
$$= (0.318\,.\,0.269\,.\,0.161)$$

Then, the results were input into the calculation of fuzzy synthesis (S_i) criteria shown in Table 17.

Table 17: Conclusion of Calculation Fuzzy Synthesis Value (Si) Criteria

Synthesis (Si)			
Criteria	**High**	**Medium**	**Low**
CH_4	0.201	0.656	0.684
CO_2	0.077	0.246	1.318
Weather	0.111	0.095	0.513

3.8.3 Determination of Vector Value (V) and Defuzzification Ordinate Value (d')

To get the vector value and the ordinary value, Eq. (8). is used

Criteria 1 (CH_4), vector value: 0.639

Criteria 2 (CO_2), vector value: 3.634

Criteria 3 (WEATHER), vector value: 0.773

Based on the ordinate values of CH_4, CO_2, WEATHER, the value of vector weight could be determined as

$$W' = \underbrace{(0.339,\ 0.472,\ 0.189)}$$

3.8.4 Normalization Vector Weight Value (W)

Norrmalization of the vector weight value is obtained by Eq. (9). where each weight vector element is divided by the number of weight vector itself.

$$W_{local} = 0.339,\ 0.472,\ 0.189$$

amount W_{local}= 1

So that the criteria (local) weights obtained are 0.127, 0.720, 0.153. Sub-criteria and alternative FAHP calculation completion is the same as the criteria.

3.8.5 Determination of Vector Value (V) and Defuzzification Ordinate Value (d')

The assessments were classified as High, Medium, and Low for each criterion. Table 18 shows the monthly value data along with the assessment based on the given criteria which are then determined for the weighted value of each month with the assessment that has been given.

Table 18 it can be concluded that using the criteria of CH_4, CO_2, and weather as inputs and the input classifications consisted of 3 parameters, namely high, medium, and low. Then, the paired matrix comparison with the FAHP criterion was determined so that the synthesis value of each criterion was obtained. From the value of fuzzy synthesis, the values of vector and ordinate defuzzification were obtained to determine the value of vector weight used for global ranking and decision making, in which it showed that in 2021, February and August had the most optimum weight value, namely 0.3457750 compared to other months. The lowest months were February and August, namely 0.2535460.

Table 18: Global Ranking Conclusions

	CH_4	CO_4	WEATHER	Weight Global	Rank.
January	0,2318	0,1161	0,0969	0,444	8
February	0,2223	0,6220	0,0969	0,941	1
March	0,0681	0,6220	0,0209	0,711	3
April	0,0681	0,6220	0,0209	0,711	3
May	0,2223	0,1161	0,0969	0,435	11
June	0,2318	0,1161	0,0969	0,444	8
July	0,0681	0,6220	0,0209	0,711	3
August	0,2318	0,6220	0,0209	0,874	2
September	0,0681	0,6220	0,0209	0,711	3
October	0,2223	0,1161	0,0969	0,435	11
November	0,2318	0,1161	0,0969	0,444	8
December	0,0681	0,6220	0,0209	0,711	3
Global Weight Alternatif	0,339	0,472	0,189		

4. CONCLUSION

Fuzzy AHP can be used to optimize waste power plan by improving the quality of LFG, resulting in a methane gas concentration output reaching 30-60% mmol, producing an energy potential of 23,203,158 kWh or 2.6 MW with engine efficiency of 82.5% and continuing to increase of 1.19% per year.

REFERENCES:

[1] G. Liu *et al*. Environmental impacts characterization of packaging waste generated by urban food delivery services. A big-data analysis in Jing-Jin-Ji region (China). *Waste Management*, 2020. vol. 117, pp. 157–169.

[2] Chen, Heng; Zhang, Meiyan; Xue, Kai; Xu, Gang; Yang, Yongping; Wang, Zepeng; Liu, Wenyi; Liu, Tong. *An innovative waste-to-energy system integrated with a coal-fired power plant. Energy,* 2020. vol. *194, 116893*

[3] Teng, C., Zhou, K., Peng, C., & Chen, W. *Characterization and treatment of landfill leachate: A review. Water Research,* 2021. *vol. 203, 117525.*

[4] Sadi, M.; Arabkoohsar, A. *Modelling and Analysis of a Hybrid Solar Concentrating-Waste Incineration Power Plant. Journal of Cleaner Production.* 2018. vol.216. Pages 570-584

[5] Devarangadi, Manikanta; M, Uma Shankar. *Correlation studies on geotechnical properties of various industrial byproducts generated from thermal power plants, iron and steel industries as liners in a landfill- a detailed review. Journal of Cleaner Production*. 2020. *Vol. 216. 121207*

[6] Weiping Huang;Hadi Fooladi. *Economic and environmental estimated assessment of power production from municipal solid waste using anaerobic digestion and landfill gas technologies*. 2021. Vol. 7. Pages 4460-4469

[7] Yazdani, Shima; Salimipour, Erfan; Moghaddam, Mojtaba Saei. *A comparison between a natural gas power plant and a municipal solid waste incineration power plant based on an emergy analysis. Journal of Cleaner Production,* 2020. vol. 274. 123158.

[8] Purmessur, Bhuvaneshwaree; Surroop, Dinesh. *Power generation using landfill gas generated from new cell at the existing landfill site. Journal of Environmental Chemical Engineering.* 2019. Vol. 7 103060.

[9] G. S. Lakshmi; O. Rubanenko; G. Divya; and V. Lavanya. Distribution energy generation using renewable energy sources. *2020 IEEE India Council International Subsections Conference (INDISCON),* 2020. pp. 108–113.

[10] Kwon, Eilhann E.; Kim, Soosan; Lee, Jechan. *Pyrolysis of waste feedstocks in CO2 for effective energy recovery and waste treatment. Journal of CO2 Utilization,* 2019. vol. *31(), page 173–180.*

[11] Feng, Huijun; Chen, Weijian; Chen, Lingen; Tang, Wei. *Power and efficiency optimizations of an irreversible regenerative organic Rankine cycle. Energy Conversion and Management.* 2020. vol. 220, *113079.*

[12] A. Sihite; S. T. Kasim; and F. Fahmi. Waste power plant: waste to energy study in Medan city area. *IOP Conference Series: Materials Science and Engineering*. 2020. vol. 801, no. 1, p. 012065.

[13] Sharma, Surbhi; Basu, Soumen; Shetti, Nagaraj P.; Kamali, Mohammadreza; Walvekar, Pavan; Aminabhavi, Tejraj M. *Waste-to-energy nexus: A sustainable development. Environmental Pollution,* 2020. vol. *26, 115501*

[14] Haddin, M., Marwanto, A., Ismail, M., Riansyah, A., & Cholid, F. A. *Data Acquisition in Determining Lab Work Assesment Ranking Using Fuzzy Analytic Hierarchy Process (FAHP). 2019 International Seminar on Application for Technology of Information and Communication (iSemantic).*

[15] Joseph, S.M.R.; Wijekoon, Prabuddhi; Dilsharan, B.; Punchihewa, N.D.; Athapattu, B.C.L.; Vithanage, Meththika. *Anammox, biochar column and subsurface constructed wetland as an integrated system for treating municipal solid waste derived landfill leachate from an open dumpsite. Environmental Research.* 2020. *vol 18. 109880,*

[16] Jayawardhana, Yohan; Gunatilake, Sameera R.; Mahatantila, Kushani; Ginige, Maneesha P.; Vithanage, Meththika. Sorptive removal of toluene and m-xylene by municipal solid waste biochar*: Simultaneous municipal solid waste management and remediation of volatile organic compounds. Journal of Environmental Management, 2019. 238(), 323–330.*

[17] Dharmendra D. Sapariya, Dr. Umang J. Patdiwala, Hitesh Panchal, Dr. P Ramana, Jignesh Makwana & Kishorkumar Sadasivuni. A review on thermochemical biomass gasification techniques for bioenergy

production, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2021.

[18] Fang, Y., Paul, M. C., Varjani, S., Li, X., Park, Y.-K., & You, S. *Concentrated solar thermochemical gasification of biomass: Principles, applications, and development. Renewable and Sustainable Energy Reviews,* 2021. *150, 111484.*

[19] Faisal A. Osra; Huseyin Kurtulus Ozcan;Jaber S. Alzahrani;Mohammad S. Alsoufi;. *Municipal Solid Waste Characterization and Landfill Gas Generation in Kakia Landfill, Makkah. Sustainability,* 2021. vol. 13*(3)*1462.

[20] Thomasen, Thilde B.; Scheutz, Charlotte; Kjeldsen, Peter. *Treatment of landfill gas with low methane content by biocover systems. Waste Management.* 2019. vol. *84, page: 29–37.*

[21] Aghdam, Ehsan Fathi; Scheutz, Charlotte; Kjeldsen, Peter. *Impact of meteorological parameters on extracted landfill gas composition and flow. Waste Management,* 2018. *vol. 87, Pages 905-914.*

[22] Xu, Qiyong; Qin, Jie; Ko, Jae Hac. *Municipal solid waste landfill performance with different biogas collection practices: Biogas and leachate generations. Journal of Cleaner Production,* 2019. vol. *222, pages 446–454.*

[23] Ayodele, T.R; Alao, M.A; Ogunjuyigbe, A.S.O. *Effect of collection efficiency and oxidation factor on greenhouse gas emission and life cycle cost of landfill distributed energy generation. Sustainable Cities and Society,* 2020. vol. *52, 101821.*

[24] Zheng, Qi-Teng; Rowe, R. Kerry; Feng, Shi-Jin. *Design of horizontal landfill gas collection wells in non-homogeneous landfills. Waste Management,* 2019. vol. *98,* pages: *102–112.*

[25] Yili Liu;Jianguo Liu. *Mechanism and dynamic evolution of leachate collection system clogging in MSW landfills in China. Waste Management,* 2021. vol. 120, Pages 314-321.

[26] Jung, Hyekyeng; Oh, Kyung-Cheol; Ryu, Hee-Wook; Jeon, Jun-Min; Cho, Kyung-Suk. *Simultaneous mitigation of methane and odors in a biowindow using a pipe network. Waste Management,* 2019. vol. *100,* pages: *45–56.*

[27] Srivastava, Abhishek N; Chakma, Sumedha. *Quantification of landfill gas generation and energy recovery estimation from the municipal solid waste landfill sites of Delhi, India. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* 2020. pages:*1–14.*

[28] Abdelli, Islam Safia; Addou, Farouk Yahia; Dahmane, Sanaa; Abdelmalek, Fatiha; Addou, Ahme. *Assessment of methane emission and evaluation of energy potential from the municipal solid waste landfills. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* 2020. pages: *1–20.*

[29] Mohsen, Riham A.; Abbassi, Bassim. *Prediction of greenhouse gas emissions from Ontario's solid waste landfills using fuzzy logic base model. Waste Management,* 2020. vol *102,* pages: *743–750.*

[30] Ghosh, Sadhan Kumar. *Waste Management and Resource Efficiency (Proceedings of 6th IconSWM 2016) || Selection of Suitable Landfill Site for Municipal Solid Waste Disposal: A Fuzzy Logic Approach.* 2019. *vol.10,* pages:*109–129.*

[31] ŞENER, Erhan; ŞENER, Şehnaz. Landfill site selection using integrated fuzzy logic and analytic hierarchy process (AHP) in lake basins. *Arabian Journal of Geosciences*, 2020, 13.21: 1130.

[32] Kolekar, K. A., Bardhan, B., Hazra, T., & Chakrabarty, S. N. Fuzzy Logic Modelling to Predict Residential Solid Waste Generation: A Case Study of Baranagar. Waste Management and Resource Efficiency, 2018. pages: 1155–1166.

[33] Di Nardo, Armando; Bortone, Immacolata; Chianese, Simeone; Di Natale, Michele; Erto, Alessandro; Santonastaso, Giovanni Francesco; Musmarra, Dino. *Odorous emission reduction from a waste landfill with an optimal protection system based on fuzzy logic. Environmental Science and Pollution Research.* 2018.

[34] Lyimo, Neema Nicodemus; Shao, Zhenfeng; Ally, Ally Mgelwa; Twumasi, Nana Yaw Danquah; Altan, Orhan; Sanga, Camilius A. *A Fuzzy Logic-Based Approach for Modelling Uncertainty in Open Geospatial Data on Landfill Suitability Analysis. ISPRS International Journal of Geo-Information,* 2020. vol. *9(12),* pages: *737-758.*

[35] Chabok, Majid; Asakereh, Abbas; Bahrami, Houshang; Jaafarzadeh, Neamat Ollah. *Selection of MSW landfill site by fuzzy-AHP approach combined with GIS: case study in Ahvaz,Iran.Environmental Monitoring and Assessment,* 2020. *vol. 192 pages: 433-448.*