Is Yogyakarta City Worthy of Waste-Based Energy Development?

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Abstract. The city of Yogyakarta is the most significant waste contributor at the Piyungan Integrated Waste Disposal Site (TPST), Dukuh Ngablak. The need for land in landfill is getting higher and negatively impacts the environment, so processing waste into energy is one option. This study aims to answer whether the city of Yogyakarta is feasible in processing waste into energy. This study uses secondary data from the generation and composition of waste from the 2020 National Waste Management System. At the same time, the calorific value data is used from the literature study. The waste generation rate in 2020 in Yogyakarta City reached 0.09 kg/person/day. However, the waste generation produces a total dry weight of 274900.3 kg dry weight/day, while the complete potential energy recovery is 2290773.3 MJ/day. Therefore, the total calorific value of the Yogyakarta City waste generation is 6.37 MJ/kg, indicating a low value. This answers that waste processing with a thermal process is not suitable if applied with a mixture; therefore, high moisture waste must be separated first to produce a high calorific value.

Keywords: Waste to energy, Waste generation, Caloric value

1 Introduction

Municipal solid waste management is one of the issues that has not been adequately addressed. As a result, it has a detrimental impact on the surrounding community, causing pollution and disrupting public health [1][2]. Yogyakarta City is one location that still has issues with waste management. According to Densus data from 2020, Yogyakarta City has 3,882,288 people [3]. According to waste

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generation data given by the Ministry of the Environment, Yogyakarta City will produce 131,689.29 tons of waste per year in 2020 [4]. The most significant waste contributor is at the Piyungan Integrated Waste Disposal Site (TPST), Dukuh Ngablak, Yogyakarta City [5][6][7]. The Piyungan TPST cannot accommodate the massive volume of waste generated, necessitating the expansion of the landfill area. However, with the community near the Piyungan TPST rejecting the landfill land extension, this has become a new challenge. As a result, we require an innovation that would aid in the reduction of waste concerns in Yogyakarta City [8].

On the other hand, waste includes energy converted into alternative energy using the waste-to-energy concept [9][10][11]. Waste to energy converts waste into energy by incineration or gasification or converting waste into fuel in hydrogen, methane, or synthetic fuels [12]. Therefore, the calorific value of waste is a crucial characteristic to consider when using waste as an alternative energy source. The calorific value of the components of paper waste is around 2598 kcal/kg, plastic with a calorific value of 5000-13000 kcal/kg, food and market waste with a calorific value of 4400-9800 kcal/kg, wood waste with a calorific value of 4700 kcal/kg, leaf and grass waste has a calorific value of 4000 kcal/kg, textile and rubber waste has a calorific value of around 4200-4800 kcal/kg [13].

Based on data, the waste capacity entering the Piyugnan landfill is increasing every time [14]. This, if left unchecked, will also harm the land around the Piyungan landfill because it will continue to be expanded until there is no limit. The right solution to reduce the increasing volume of waste is the construction of a Waste Power Plant (PLTSa). PLTSa is a type of new renewable energy in waste to energy (WtE) [15]. WtE utilizes the rest of human activities (in the form of waste) to be processed and used its heat energy to generate a boiler engine which is connected by a turbine and generator. The rotating generator will produce electromagnetic waves to produce electricity that can be distributed to households and industries. The technology for processing waste into energy has many choices depending on the work process. Choosing technology also needs to go through the right decision so that the use of WtE technology follows the characteristics of Yogyakarta City waste. Our research team strives to solve the difficulties in Yogyakarta City by converting the energy contained in the waste into alternative energy that the surrounding community can use due to the high potential of the calorific value of waste.

2 Method

This study uses secondary data from the Indonesian national waste information system in Yogyakarta. From the generation analysis, it is known that the composition of the waste and the characteristics of the waste from the city of Yogyakarta. Calorific value analysis was carried out using a bomb calorimeter. The principle used refers to ASTM D5865 and used a bomb calorimeter. In this study, the calorific value used is derived from a literature study. Calculation of potential calorific value is carried out to determine the potential of the calorific value of waste in the city of Yogyakarta. The potential calorific value of waste is used as a reference for waste to be used as RDF. Calculation of potential calorific value follows equation 1 [16].

$$Caloric\ Value\ Potential\ \left(\frac{MJ}{day}\right) = Total\ Waste\ Generation\left(\frac{kg}{day}\right) x\ caloric\ value\ \left(\frac{MJ}{kg}\right) \quad (1)$$

3 Results and discussions

The amount of waste generated is expected to increase due to the community's increasing needs or consumption patterns. This condition is also quite crucial in the city of Yogyakarta. Based on data from the Piyungan TPST (Integrated Waste Management Site), the City of Yogyakarta is the largest supplier of waste to the Piyungan TPST. This statement is also supported by the statement that every person in Yogyakarta City has the potential to produce 900 grams of waste every day [17]. It can be seen in Table 1 that this value will decrease in 2021. This can be estimated from the community's socio-economic conditions, which reduce public consumption in the City of Yogyakarta.

Applying social restrictions and working from home in various parts of the world can reduce pollution levels in the highest air-polluting countries [18]. The quarantine policy is allegedly improving air quality in several areas. However, this will not be the case with solid waste management. With lockdown or social restrictions, people will produce more household solid waste with various hazardous solid waste related to personal protection against the Covid 19 outbreak, such as masks, gloves, face shields, and other protective equipment [19][20].

Table 1. Waste Quantity in Yogyakarta City

Parameters	Value	Unit	Source
Waste Generation 2020	131,689.26	ton/year	(Kementerian Lingkungan Hidup dan Kehutanan, 2021)
Total population 2020	3882288	capita	(Badan Pusat Statistik Provinsi DI Yogyakarta, 2021)
Waste Generation Rate 2020	0.09	kg/cap.day	
Waste Generation Rate 2016	0.9	kg/cap.day	(Mulasari et al., 2016)

Activities that take place in the city of Yogyakarta have different levels of intensity. Therefore, a detailed spatial plan is expected to guide determining the direction of the development of the city of Yogyakarta in the future. However, the development of a city that is quite complex can also have an impact on the environment, one of which can cause the area to have the potential for generating high volumes of waste in the future. Therefore, in determining the policy direction in anticipating the adverse impacts of urban development, it is necessary to have a projection picture of the potential waste generated from every activity in Yogyakarta.

In addition to composition, other physical and chemical characteristics are usually displayed in waste management. These characteristics vary widely, depending on the components of the waste. The uniqueness of waste from various places/regions and its different types allow different properties. Municipal waste in developing countries will differ from municipal waste in developed countries. Waste characteristics can be grouped according to their properties based on theoretical literature. The composition of wet and dry waste is quite different, 131689.3 and 100338.6, respectively (Table 2).

Table 2. Theoretical Waste Proximate Value in Yogyakarta City

Component	(%) Composition	(%) Water Content	(%)Ash Content	(%)Volatile Content	(%) Fix Carbon	Wet Weight (Ton)	Dry Weight (Ton)
Food Waste, Leaves, and Twigs	61.12	37.6	17.3	38.6	6.5	80488.5	50224.8
Plastic	10.79	0.4	26.2	32.8	40.6	14209.3	14152.4
Paperboard	6.18	5.9	10.4	75.3	8.4	8138.4	7658.2
Glass	10.66	0.02	0.3	4.9	94.78	14038.1	14035.3
Cloth	0.68	8.9	4.4	83.3	3.4	895.5	815.8
Metal	2.12	0.2	1.2	1.8	96.8	2791.8	2786.2
Rubber/Leather	0.13	1	10.5	17.9	70.6	171.2	169.5
Other	8.32	4.2	14	59.5	22.3	10956.5	10496.4
					Total	131689.3	100338.6

Experimental measurements in the laboratory using a bomb calorimeter were carried out using a small sample. Mathematical calculations are carried out using proximate analysis equations [9][11]. From these data, it can be seen that the calorific value of the high calorific value is directly proportional to the calorific value of the low calorific value. The higher the water content of the waste, the lower the Low Calorific Value obtained [21][22]. Table 3 shows the potential for energy recovery from waste in Yogyakarta City or around 2290773.3 MJ/day. RDF is an alternative fuel produced from combustible waste, such as plastic waste, rubber and leather, textiles, wood, paper, synthetic resins, wastewater treatment sludge, and processed sludge [23][22]. Urban waste processing with thermal energy includes incineration, pyrolysis, and gasification [24].

Table 3. Theoretical Potential of Waste Calorific Value in Yogyakarta City

Component	Wet Weight (kg/day)	Caloric Value (kkcal/kg)	Calorific Value (J/Kg Dry Weight)	Potential Calorific Value (MJ/Day)
Food Waste, Leaves, and Twigs	168019.1	1500.0	6276000.0	1054487.7
Plastic	29661.7	7500.0	31380000.0	930785.5
Paperboard	16988.8	3700.0	15480800.0	263000.8
Glass	29304.4	0.0	0.0	0.0
Textile	1869.3	4000.0	16736000.0	31285.0
Metal	5827.9	0.0	0.0	0.0
Rubber/Leather	357.4	7500.0	31380000.0	11214.3
Other	22871.7	0.0	0.0	0.0
Total	**274900.3**	**24200.0**	**101252800.0**	**2290773.3**

The energy-saving program has been carried out since the supply of petroleum fuel from fossil energy sources is running low while demand increases continuously [25]. This condition impacts increasingly high prices and is difficult to reach by most Indonesian people. One way to save fuel oil is to look for alternative energy sources that can be renewable. Alternative energy sources in Indonesia, especially waste in Yogyakarta. So far, the most widely used energy is hydropower. However, the development of other alternative energy sources such as waste is still needed.

Based on Table 4, the calorific value of Yogyakarta City waste only reaches a value of 6.37 MJ/kg. The calorific value of the waste is still below the standard value specified in SNI 8966:2021, which is a minimum of 10 MJ/kg . Therefore, old waste as raw material for RDF needs to be combined with other biomass to meet the required composition and parameter values in maintaining the performance of existing power plants. Waste has a relatively high calorific value with an LHV (Lower Heating Value) of around 3 – 6.7 MJ/kg. This method of biological city waste drying is used to reduce the water content in the waste using the help of microbial activity that produces heat from the biodegradation of the waste. The bio drying method is biological drying accompanied by aeration. In general, drying is defined as a process to reduce the water content in the material.

Table 4. The theoretical calorific value of Yogyakarta City Waste

Parameters	Value	Unit
Potential Calorific Value	2290773.29	MJ/Day
Waste Generation	359806.72	kg/Day
Calorific Value in Yogyakarta = (Potential Calorific Value/Waste Generation)	6.37	MJ/kg
	1521.67	kkal/Kg

4 Conclusions

The total calorific value of the Yogyakarta City waste generation is 6.37 MJ/kg, indicating a deficient value. This answers that waste processing with a thermal process is not suitable if applied with a mixture; therefore, high moisture waste must be separated first to produce a high calorific value.

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