

Potentials of Organic Waste Conversion in a Green Campus Concept

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Abstract – Development of waste-to-energy plant is regarded as one of a solution to reduce fossil energy dependency and switch to another alternative energy sources, thus needs to be implemented immediately. Research on the potential of organic waste by taking case studies at UMY green campus program can be an illustration that in the future UMY can process this potential into an alternative renewable energy. This research was conducted by studying waste management and data collection methods, such as field observations, discussions with related parties about the waste cycle, and calculations with the concept of gasification. Calculation of biomass produced by organic waste is then supplied to the motor generator for electricity production. Annually, 31.8 tons of organic waste could produce 7.9 kiloliters of biomass and channel it to the power plant system for generating electricity energy as much as 5.3 MWh per year. This number equals to the electricity supply of five small-housing in Indonesian typical house.

Keywords: *waste-to-energy plant, UMY, Gasification, Biomass*

I. Introduction

Yogyakarta Muhammadiyah University (UMY) was designated as one of the Green Campus by the Indonesia Green Award (IGA) in 2016. Waste production at UMY continues to increase along with the number of students studying here. With a 25-hectare campus area, a lot of waste is produced from trees that grow around the campus environment, e.g. falling leaves and tree branches. Organic and non-organic waste itself is only disposed of at the TPS, not fully utilized. For non-organic waste e.g. paper and plastic waste, the campus opens an opportunity for scavengers from outside to be resold to collectors.

In general, the waste in UMY comes from 60% organic waste and 40% non-organic waste. Renewable energy sources can be generated from the use of organic waste to produce renewable energy, namely biomass. The biomass energy results, in addition to being used for electricity generation, can also be used for gas needs in the

campus canteen thereby reducing the amount of the budget for electricity needs and gas purchases.

In several scientific journals on renewable energy power plants that utilize biomass, fermented organic waste involves thermochemical processes which will later produce biomass with various kinds of gases in it e.g. methane (CH₄), carbon dioxide (CO₂), and also other gases [1-3]. In another study, the amount of electricity power generated from waste management at the Benowo Surabaya landfill is 10 megawatts. The amount comes from the total waste that goes into the Benowo landfill, which reaches 1,400 tons every day. Further processing produces 2 megawatts of electricity using the landfill process, while 8 megawatts uses a gasification system [4].

On the other hand, one of the private universities in Indonesia namely Telkom University and Bandung Techno Park develops biodigesters from organic waste that are made into renewable energy that produces 1000 liters of gas (biogas) which can be used for 3-4 canteens and used as fuel for cooking in the Telkom University Canteen [5].

II. Method

Waste is a collection of the rest of the activities of living things in the form of liquid, solid and gas which has no economic value. The type of waste based on its nature is organic and inorganic waste. Organic waste consists of tree scraps, food scraps, vegetable and fruit scraps that are easily degraded by microbes, while inorganic waste consists of cans, plastics, iron, glass and other materials that cannot be degraded by microbes.

A. Waste Management

Various waste treatment methods and how to apply as follows:

1) Open Dumping

By means of simple disposal where garbage is disposed of at a location and then left open without safety it is also left after the location is full.

2) Controlled Landfill

This method is an increase in open dumping, where garbage that has been piled up is covered with a layer of soil in order to avoid the potential disruption caused by waste. In its operations, leveling and compaction is carried out so that solid waste is denser and more efficient in land use.

3) Sanitary Landfill

This method is a method developed from the controlled landfill method in which the landfill process is followed by compaction with the soil. This is done continuously in accordance with the plan implemented. Coatings of rubbish with cover soil are carried out every day at the end of operating hours.

4) Incineration

The incineration method is carried out by burning the collected garbage to reduce the volume of solid waste.

5) Composting

This method is done by changing organic waste into compost as a fertilizer for plants.

B. PLTSA (Pembangkit Listrik Tenaga Sampah)

A PLTSA or a waste-to-energy power plant is a power plant that utilizes waste as its main energy source. There are 2 types of energy raw materials that can be used, namely from biomass and biogas.

1) Gasification

Gasification is the process of a thermochemical energy conversion where the decomposition of biomass is carried out in a device called a gasifier reactor. Decomposition is done by heating using temperatures around 900° C. Usually the raw

material used is from organic waste. There are also types of gas produced from the gasification process, i.e. CO, H₂, CH₂, N₂, and CO₂. Gasification gas e.g. methane gas can be used for various purposes i.e. a fuel source to run a combustion engine, for cooking as a stove fuel, or as fuel for a simple power plant. The process inside the gasifier reactor occurs in several stages such as drying, pyrolysis, oxidation, and reduction explained as follows.

TABLE I

Stages of the gasification process inside the gasifier reactor

Drying	Drying is the initial stage for the gasification process, where the water contained in the biomass is evaporated with hot gas from combustion at the bottom of the reactor, the temperature used ranges from 150 ° C.
Pyrolysis	Furthermore, in the process of pyrolysis (charcoal), the fuel that has dried will experience heating at a temperature of 500-700 ° C by using hot air so that there will be incomplete combustion making the fuel will decompose into charcoal, organic acids and also in the form of substances the other.
Oxidation	This process multiplies the oxidation reaction, where the substances produced are burned with the help of air and produce a gas that is able to burn completely, on the other hand a CO ₂ gas will be formed which is accompanied by the generation of heat energy. The output produced in this process is the type of gas that can be withdrawn or removed from the reactor. The reactions that occur in the combustion process are as follows: $C + O_2 \longrightarrow CO_2 + 393.77 \text{ kJ/mol}$ Another burning reaction that takes place is the oxidation of hydrogen contained in the fuel to form water vapor and energy. The reactions that occur are as follows: $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O + 742 \text{ kJ/mol } H_2$
Reduction	This process is the final process where there will be an exchange of water vapor and CO ₂ reduction by carbon charcoal. From this process, the gas produced will increase

significantly. In this process several chemical reactions also occur, e.i. the water-gas reaction, Bourdour reaction, shift conversion, and CO methanation.

III. Waste Potentials in UMY

Data is collected by interviewing the parties who know the waste cycle in UMY. Parties involved in the waste problem at UMY include the General Bureau of the Environment section as well as cleaners who know the waste cycle and also second parties such as PJM Gamping (third parties for waste collection), DLH (Local Government division for Natural Environment Services), and scavengers. The following is the estimated data of the total number of waste temporary landfills and tanks in the entire UMY area per month collected from UMY bureau, on-site interviews and observations.

TABLE 2
Overall garbage volume at UMY

NO	MONTH	YEAR	WASTE ON UMY LANDFILL (KG)	WASTE ON TANKS (KG)	TOTAL (KG)
1	October	2017	5700	300	6000
2	November	2017	5500	300	5800
3	December	2017	5500	300	5800
4	January	2018	2400	80	2480
5	February	2018	2800	100	2900
6	March	2018	5000	100	5100
7	April	2018	5300	300	5600
8	May	2018	5000	108	5108
9	June	2018	2400	80	2480
10	July	2018	3000	100	3100
11	August	2018	2400	80	2480
12	September	2018	6000	480	6480
Average per month			4,256	169	4,425
Average per day			139.4	5.6	145.5
Total annually			5,107.2	2,028	53,100

When viewed according to UMY's area, which is approximately 191,293.46 m², from the data in the field, the interview results show that the volume of landfill depends on the weather cycle and the amount of food leftovers from BOGA canteen and SPORTORIUM. If seen in this one-year period UMY could produce 53.1 tons per year and if it is

averaged it will produce 4,425 kg per month or 145.5 kg per day. Of the 53.1 tons, waste is estimated to consist of 60% in the form of organic waste and 40% inorganic waste.

A. Collecting Process at Temporary Landfills and Tanks

The average volume of landfill per month can reach 4,000 kg depending on the number of rain cycles. The amount only came from trees falling in the UMY region. To accommodate around 6,000 kg, a landfill with size of 6m X 7m X 3.5m is needed. The process of collecting garbage from every spot of UMY area dustbin to temporary landfill is carried out every day from morning to evening, transported by 11 yellow carts that can hold up to 50 kg waste per cart. After being collected at the TPS, it will then be transported by a third party to be disposed of at the Piyungan Landfill every day around 10AM local time.

B. Potential of Organic Waste at UMY

Based on the area of UMY's green area which reaches around 10,473.1 m², UMY can produce 31.8 tons of organic waste per year or in average it equals to 88.3 kg daily. The following table is collected from October 2017 to September 2018 about the garbage output in UMY.

TABLE 3
Overall garbage volume at UMY based on its type

NO	MONTH	YEAR	ORGANIC (KG)	IN-ORGANIC (KG)
1	October	2017	3600	2400
2	November	2017	3480	2320
3	December	2017	3480	2320
4	January	2018	1488	992
5	February	2018	1740	1160
6	March	2018	3060	2040
7	April	2018	3180	2120
8	May	2018	3064.8	2043.2
9	June	2018	1488	992
10	July	2018	1860	1240
11	August	2018	1488	992
12	September	2018	3888	2592
Average per month			2,651.4	1,773.6
Average per day			88.3	59.1
Total annually			31,816	21,283.2

C. UMY's Electrical Conditions

The capacity of the electric power source from PLN (Electricity Distribution company owned by Government) is 20kv medium voltage and the transformer brand TRAFINDO is installed with a capacity of 1250Kva. But this does not guarantee the absolute availability of electricity supply without interruption. So as to meet the need for electricity in the lecture building during the blackout, an electric back-up system in the form of a 500 KVA and 700 KVA generator set are installed. So that the electricity demand can be met when a blackout occurs. The needs of electrical energy during recovery and practicum in all departments in UMY is presented in Table 4.

TABLE 4
Electricity condition at UMY

NO	MONTH	YEAR	ELECTRICITY (MWH)
1	September	2017	307
2	October	2017	403
3	November	2017	477
4	December	2017	426
5	January	2018	439
6	February	2018	331
7	March	2018	341
8	April	2018	468
9	May	2018	478
10	June	2018	452
11	July	2018	228
12	August	2018	307

IV. Result and Discussion

In this study, an analysis of the potential of electrical energy from organic waste was carried out at Yogyakarta Muhammadiyah University. This research uses organic waste media which is disposed of at TPS behind UMY which has the potential to make renewable energy (biomass) using the Gasification method.

A. Organic into Electricity

The general formula for the method of gasification to make renewable biomass energy can be seen below.

$$L = \frac{S}{4} \quad \dots (1)$$

where:

- L : biomass produced in kg/ha (liter)
- S : total waste in kg

4 : gasification ratio kg to liter

The energy generated is then used to drive a 5 KVA BG generator (5,000 WATT biomass power generator) from PT BBI which produces electricity. From the above estimates, within one year, UMY could produce 7,954 liters per year and if averaged, it would produce 662.85 liters monthly or 22 liters daily. The following diagram is presented in the last one year from October 2017 to September 2018.

TABLE 5
Estimates of electricity production from the gasification process

NO	MONTH 2017-2018	ORGANIC WASTE (KG)	BIOMAS (LITER)	ELECTR I-CITY (KWH)
1	October	3600	900	600
2	November	3480	870	580
3	December	3480	870	580
4	January	1488	372	248
5	February	1740	435	290
6	March	3060	765	510
7	April	3180	795	530
8	May	3064,8	766,2	510,8
9	June	1488	372	248
10	July	1860	465	310
11	August	1488	372	248
12	September	3888	972	647,3
Average per month		2.651,4	662.85	441,8
Average per day		88,3	22,075	14,7
Total annually		31.816,8	7.954,2	5.302,1

With this energy, it can be used to drive a 5 KVA BG generator unit (5,000 watt power biomass generator) from PT BBI which produces electricity. Where the generator of 1.5 liters of biomass gas energy will rotate the generator at 1500 rpm per minute and produce 1 KWh electricity.

B. The Use of Renewable Energy

From the calculation of the use of 1 streetlight with a power of 20 W which lights up for 12 hours, it will spend 0.24 Kwh using the formula:

$$Kwh = \frac{P \times t}{1000} \quad \dots (2)$$

where:

- P = power
- t = hour
- Kwh = /1000

$$\text{so: } \frac{20 \times 12}{1000} = 0,24 \text{ Kwh}$$

Assuming the use of streetlight in the amount of 61 pieces with a power of 20 W that lights up for 12 hours, it will consume a power of 14.64 Kwh.

So if: 1 Kwh = Rp. 1,250,-

Total power saving of:

Per day 14.7 Kwh = Rp. 18,375,-

Per month 441.8 Kwh = Rp. 552,250,-

Per year 5,302.1 Kwh = Rp 6,627,625,-

That way the electricity budget that can be saved is Rp. 6,627,625,- per year or in average is about Rp. 552,250,- /month.

V. Conclusion

Based on the results of research and calculations that have been done, the following conclusions are obtained:

1. Waste generated at UMY per year is around 31.8 tons of organic waste and around 21.3 tons of non-organic waste.
2. The gasification method can convert from organic waste to biomass. By converting around 31.8 tons of organic waste into biomass, within one year, UMY could produce 7,954.2 liters per year.
3. The biomass energy can drive a 5 KVA BG generator (0.5 MW biomass power generator) that generates electricity. It is estimated that UMY can produce electricity at 5,302.1 Kwh per year.

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