Evaluation Study of Waste Materials for Renewable Energy through 3R Model in Bogor City

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***Abstract*— Waste is one the critical issues in Indonesia which can pose a badly influence both to human's health and nature preservation if it is not properly managed for productive use. Hence, the increasing production in municipal waste is directly proportional to the increasing number of population, in which raises the waste production in big cities in Indonesia, such as in Bogor. In Bogor, a waste processing facility (TPS) using biogas for renewable energy has been developed. The volume of wastes in Bogor at the year of 2016 has reached 2.734,03 m³ per day. There are 12 locations for waste processing facility with the TPS 3R (Reduce, Re-use and Recycle) model but there are only 3 locations that uses biogas for Renewable Energy. 3 of these biogas-based waste processing facilities can be found in the region of Taruna, Ceremai, and Dharmais. The wastes' capacity of each regions (Taruna, Ceremai, and Dharmais) consecutively is 3.300 kg, 2.400 kg, and 2.520 kg with the number of organic materials that are being processed into biogas for renewable energy is 85 kg, 85 kg, and 55 kg.**

Keywords: Biogas; renewable energy; waste processing; environment-friendly approach

I. INTRODUCTION

The increase of a city's waste materials production is directly proportional with the increase of resident population thus resulting in a higher production of waste especially in big cities in Indonesia like in this case, Bogor. Bogor have developed a place using TPS 3R model where these waste materials are reduced, re-used and recycled. This system is make use for the development of renewable energy, compost fertilizer processing, and the rest is dumped into the landfill, this model is developed with cluster system in which Bogor has 12 cluster locations.

The volume of dumped waste materials in Bogor in the year 2016 per day is 2.734,03 m³ which consists of 1.804,46 m³ organic waste, and 929,57 m³ of anorganic and residue. TPS 3R is using an approach starting from door-to-door collecting, waste sorting, waste management, and the construction of TPS 3R itself on various locations in Bogor. There are 12 locations of Bogor sanitary and park agency's TPS 3R.

From those 12 TPS 3R located in Bogor, there are 3 TPS 3R Development Model that process organic waste into biogas using the 2015's budget, in this case are Mulyaharja's TPS 3R Taruna, Cipaku's TPS 3R Ceremai, and Kencana's TPS 3R Dharmais. Biogas is a gas that is produced through anaerobic process (fermentation) of organic waste like human waste, household waste, and also animal's waste. The resource that is very essential for the making of biogases are methane and carbon dioxide.

Following with the increasing needs of energy, energies sourced from fossils eventually will ran out, so it is necessary to create renewable energy that is produced from the use of waste processing into biogases that can replace fuels like gasoline, solar, and firewoods.

II. BIOGAS TECHNOLOGY, C/N RATIO, POWER CALCULATION, AND 3R LOCATIONS

Biogas consists of methane, carbon dioxide, nitrogen, hydrogen, hydrogen sulfide and oxygen. In Indonesia, the source for biogas generation such as agriculture waste, animal manure, domestic waste, crops, household waste and others are widely available.

Using these materials as biogas sources can provide a number of advantages such as reduce the utilization of fossil fuel, increase farmers income and provide employment opportunities. In addition, biogas production has a great potential to produce neutral carbon dioxide that can prevent the occurrences of emission of greenhouse gases into the atmosphere and simultaneously reduce air pollution as well [1].

Anaerobic digestion is one of widely used process and attractive method for converting organic waste into for biogas as alternative energy sources. Anaerobic digestion is a natural process in which bacteria decompose the carbon in organic matter.

The digestion occurs in three process steps which are hydrolysis, acidogenesis and methanogenesis. In hydrolysis stage, complex organic compounds are broken down by hydrolytic bacteria. Subsequently, in the acidogenesis stage, compounds are further broken into simple molecules by acid-forming bacteria. Then, in methanogenesis stage, methanogenic bacteria will convert the acids into methane gas and carbon dioxide. These processes occur without the presence of oxygen [2].

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The quality is determined by the concentration of C (carbon) and N (nitrogen) in the material. Organic waste mostly have C/N ratio between 20-30. [3]

The process of creating biogas is through anaerobe fermentation (closed space) in which the organic waste are processed by the microorganism, resulting in a flammable gas. Chemically, the biogas creation process is complex and took long enough by passing through hydrofoil stage, enveloping stage, and methanogenic stage.

In reality, some of those organic waste often mixed with each other to optimize or adjust the C/N ratio. To calculate the C ratio, N ratio, and C/N ratio from various raw organic waste, an equation can be used as below: [4]

$$\text{C/N Ratio} = C / N \quad (1)$$

$$\text{TS Total} = \text{TS (\%)x Number of raw Material (in kg)} \quad (2)$$

Meanwhile the number of gases produced per day can be calculated as follows:

$$\text{Total TS (kg) x Produced Gas } (m^3) \quad (3)$$

To calculate the number of electric potential that can be generated:

Electrical Energy = Produced Gas (m^3) × Biogas energy value proportional with Electric Energy (kWh) (4)

For the electrical power defined as an electrical energy in a device for every unit of time. Mathematically, electrical power can be described as follows,

$$W = P \times T \quad (5)$$

In which:

P = Electrical Power (Watt)

W = Electrical Energy (Joule)

t = Time (seconds)

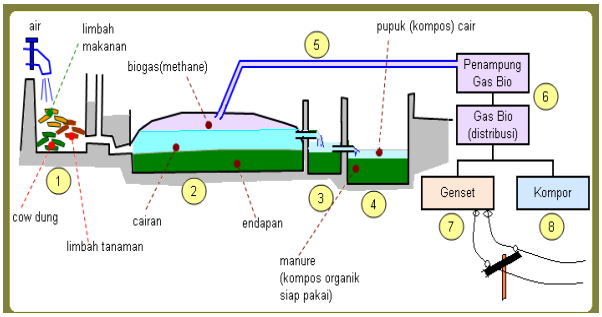

Fig. 1. Schematic model of Biogas-based Renewable Energy

Biogas Technology in 3 TPS-3R locations

The Increased production of waste is directly proportional to the increased number of populations which result to the high consumption of waste production. Meanwhile, Bogor has developed a system of development of waste disposal with the Concept TPS (landfill) 3R's (Reduce Re-use and Recycle) which utilize the waste for renewable energy development. Thus, the waste management incorporates composting method and their remaining wastes are distributed into the final waste disposal. Subsequently, this model was developed by cluster system which is consisting of 12 cluster location.

The type of digester used in all 3 TPS-3R locations is fixed dome type using fiberglass material with a capacity of 17 m^3 for Taruna and Ceremai and 11 m3 for Dharmais. While the type of raw materials used in the waste processing are vegetable and fruit wastes with an amount of 85 kg per day for Taruna and Ceremai, and 55 kg for Dharmais. In biogas processing, the raw materials are mixed into water with a ratio of 1:2. At starting condition, the required period of organic waste processing that is being mixed with water is 40 days.

The objective of the development of TPS 3R in the city of Bogor is to assess and evaluate the utilization of waste materials for renewable energy in this case processing waste into biogas and compost, and the residue regarding of their C/N ratio and electrical energy generated by biogas power plants in three different TPS 3R. Hence, this study is important in order to provide feedback to the local government in Bogor, to optimize the waste management in the future.

The benefit of TPS 3R are as follows:

a. To reduce the volume of waste that distributed, both in various locations and the final disposal of landfill in Bogor
b. To utilize the waste for productive use, such as, renewable energy generation and compost

III. Analysis and Discussion

Biogas Potential in Mulyaharja's TPS 3R Taruna

In this TPS, the waste comes mostly from vegetable waste and fruit waste from household. The number of organic waste that are converted into biogas is 85 kg per day. 20% is assumed to be produced from the waste which is roughly 0.50 m³. To calculate the total TS using the equation (2.2) and the gas that can be produced from biogas processing on each day and month, equation (2.3) is used.

TS Total = TS (%) x Number of Raw Materials

= 20% x 85 kg

= 17 kg

The number of Gas produced per day

= TS Total (kg) x Produced Gas (m³)

= 17 kg x 0,50m³

= 8,5m³

The number of Gas produced per month

= Daily gas production x 1 month

= 8,5m³ x 30

= 255 m³

The gas that can be produced daily and monthly from the biogas processing is 8.5 m³ and 255 m³ respectively.

In the table 2.3, the value of biogas energy of 1 m³ is equal with an electrical energy of 6.1 kWh, then electrical energy can be generated using the equation (2.4)

Electrical Energy = Produced Gas (m³) × Biogas energy value proportional with Electric Energy (kWh)

= 8,5m³ x 6,1 kWh

= 51,85 kWh

Electrical Energy per Month = Daily electrical energy × 1 Month

= 51,85 kWh x 30

= 1.555,5 kWh

In result, the electricity generated daily and monthly respectively are 51,85 kWh and 1.555,5 kWh.

To calculate the ratio of carbon (C), equation (2.1) is used. For ratio of Nitrogen, equation (2.2) is used and for the C/N ratio, equation (2.3) is used.

Ratio of C = Amount of Raw Organic Waste× % C (Dry)

= 85 kg x 24%

= 20,4 kg

Ratio of N = Amount of Raw Organic Waste×%N (Dry)

= 85 kg x 1,5%

= 1,275 kg

C/N Ratio = C / N

= 20,4/1,275

= 16

Thus the amount of C/N Ratio is 16 and compatible to be used in biogas processing in a digester.

The amount of Electrical Energy generated on each day from the biogas processing is 51,85 kWh. While the 5 kW biogas generator capacity is used, then we can calculate how long the electrical energy can be used for the generator

W = P x T

T = W/P

T = 51,85 kWh/5 kW

T = 10,37 Hour

Using the same calculation method, the potential of the other 2 TPS locations can be calculated namely Cipaku's TPS 3R Ceremai and Kencana's TPS 3R Dharmais.

In Cipaku TPS 3R Ceremai Kelurahan,the amount of gas produced per day and per monthis 8,7975 m³ dan 263,925 m³ respectively, considerably bigger than the one in TPS 3R Taruna. Even though the amount of organic waste per day and the digester capacity are the same. That is because the organic wastes processed in TPS 3R Ceremai are consisted of plant waste, and animal waste. Meanwhile in TPS 3R Dharmais is smaller because the amount of raw organic waste being processed into biogas and the digester capacity is smaller.

The C/N Ratio in TPS 3R Taruna and TPS 3R Dharmais are the same that is 16 because of the same type of organic waste, vegetable and fruit waste. TPS 3R Ceremai has the bigger ratio because of the mixed organic waste of both plant and animal waste.

The daily and monthly electrical energy generated in TPS 3R Ceremai are 53,6645 kWh and 1.609,9425 kWh, bigger than the other two TPS 3R, TPS 3R Taruna and TPS 3R Dharmais because of the bigger amount of gas produced. TPS 3R Ceremai also takes 10,73 hour longer in the biogas generator usage than the other two TPS 3R.

IV. SUMMARY

From the analysis of the 3 TPS 3R locations, to produce an amount of biogas is heavily determined from the mixture of waste regardless having the same amount of organic waste and digester's capacity. This case will affect the comparison of C/N Ratio value in TPS 3R.

The amount of electrical energy generated per day and per month in Cipaku's TPS 3R Ceremai are 53,66475 and 1.609,9425 kWh is bigger than TPS 3R Taruna and TPS Dharmais, because of the higher amount of produced gas in daily and months' time.

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