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Study of The Potential of City Waste as Fuel for Waste Power Plant in Jambi City

Studi Potensi Limbah Kota Sebagai Bahan Bakar Pembangkit Listrik Tenaga Sampah (PLTSa) di Kota Jambi

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ABSTRACT

Jambi City is the capital city of the province which has a fairly large population density. Waste production in Jambi City is quite large. Garbage is the rest of human activities in their daily lives, so the volume of waste will depend on the population of an area. Therefore, inefficient waste management will become a new problem in urban areas. The waste management applied in Jambi City still adheres to the paradigm (transport-dispose) from the source of waste to the final disposal site (TPA) without special treatment for waste, although in Law No. 18 of 2008 waste management has been regulated as it should be for the realization of improving public health and environmental cleanliness as well as making waste as a natural resource. The daily weight of waste in Jambi City is around 333,610 kg or equal to 333.61 tons/day. The composition of the waste from the total waste is 8% plastic bottles, 28% aqua glass, 3% glass tea bottles, 3% buckets, 9% tubes, 6% cans, and 43% sacks. By using the calculation of the thermal method, the electricity potential generated is 43,008.16 and the Net Power Output (influenced by generator efficiency ±25%) is 10,772,34 kW. By using the method of least cost NPV calculation results of Rp. 60,067,535,702.00 which means, this project is profitable according to the project feasibility criteria NPV > 0 and the payback period for PBP is 12 years (not exceeding the economic life of a generator). The profit-to-cost ratio shown by BCR is 1.61.

Keywords: Study of potential waste, waste into energy, waste power plant (PLTSa)

INTRODUCTION

The increase in population and the rate of economic growth of an urban area has ~~a~~ negative impact. Related to the problem of waste management. The government is aware that the waste problem has become a national problem. Therefore, it is necessary to have a comprehensive and integrated waste management system from upstream to downstream. Comprehensive waste management can be created if waste generation data is available. Garbage generation is waste that appears/arises at the source of the waste. Garbage that arises in urban areas will cause problems for all aspects of urban life. Therefore, waste that arises in urban areas must be managed properly, so that the urban environment can be healthy.

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Based on data from the 2007 Indonesian Environmental Statistics regarding the condition of landfills in Indonesia, most of them are open dumping sites, causing pollution problems in the environment. The data states that 90% of landfills in Indonesia are operated with Open Dumping and only 9% are operated with Controlled Landfill and Sanitary Landfill. Improvement of landfill conditions is very necessary in waste management on a city scale. According to Damanhuri (1995), several problems have arisen related to landfill operations, for instance: 1. Growth of disease vectors. 2. Air pollution Methane gas (CH_4). 3. Unpleasant views and unpleasant odors. 4. Burning smoke. 5. Pollution of leachate or leachate. 6. Noise and, 7. Social impact

The waste problem is an important problem that can damage the balance of the environmental ecosystem. Based on BAPPENAS calculations in the Indonesian infrastructure book in 1995, it was estimated that waste generation in Indonesia was 22.5 million tons and will more than double in 2020 to 53.7 million tons (Mungkasa, 2004). This condition will be a big problem with the limited vacant land in big cities to be used as a final disposal site (TPA). Data from the Ministry of Environment and Forestry of The Republic of Indonesia (2008) states that as many as 47% of TPAs are not equipped with a waste processing system, 42% of TPAs have a waste management system, 10% of TPAs have a waste processing system that does not running properly. The application of reuse, reduce and recycle (3R) of waste is one of the best programs in the context of environmental preservation because it prioritizes waste management from the source. The pattern of on-site waste processing is carried out starting from waste sorting, classifying organic waste into compost and managing inorganic waste which is expected to be further recycled through the recycle bank program or recycling bank. However, it turns out that waste processing with a waste sorting system has not been implemented in an integrated manner. Waste that has been sorted from the household level will not necessarily be handled separately when it arrives at the final disposal site (TPA).

Waste management has been properly regulated for the purpose of improving public health and environmental cleanliness and making waste a resource (Law No. 18 of 2008). Waste management as referred to in the law is a systematic, comprehensive, and sustainable activity that includes waste reduction and handling. However, the simple collection-transport-disposal method is still widely applied in Indonesia. Many final disposal sites (TPA) in Indonesia that should be managed by a sanitary landfill system or controlled landfill, are often operated in an open dumping manner. Although Article 44 of Law no. 18/2008 on Waste Management requires all open dumps to have a closure/remedial plan within one year and the closure or repair of all open dumps to be completed within five years, but this target is still far from expectations, especially in Jambi City.

Population growth has a direct effect on the volume of waste produced by the community, because waste is the result of people's daily activities. The higher the population, the higher the volume of waste generated. Population growth is directly proportional to the increase in the volume of waste generated. Population density causes less land in urban areas. Meanwhile, the volume of waste generated also increases from time to time. This situation poses a big problem in urban areas, because it interferes with comfort and requires proper handling to overcome this environmental problem. On the other hand, waste is one of the potential sources of renewable energy (renewable energy) whose existence is abundant, while its current utilization is not optimal.

The population of Jambi Province in 2020 was 3,548.2 thousand people, while in 2010 there were 3,092.3 thousand people, during this period there was an annual growth of 1.38 percent (Central Bureau of Statistics Jambi Province, 2020). This increase in population results in an increase in the amount of waste disposed of. The production of waste in Jambi City, which comes from markets, households, businesses, and industry, amounts to 1,000 cubic meters per day. The production of waste in Jambi City is quite high, due to the relatively rapid population growth. Five years ago, the waste generated by the residents of Jambi City was around 600 cubic meters per day, while now it has increased by 60 percent to 1,000 cubic meters. Not all of the municipal waste produced by the community can be transported to the TPA. Thus, 400 cubic meters of waste in Jambi must be queued for transportation so that garbage accumulation is often seen on the side of the road or in temporary dumps (Jambi City Waste Information Baseline, 2017).

Waste management that is mostly done by the community so far is through open dumping. This method is quite easy and economical, only by dumping the waste in a final disposal site (TPA) and no other treatment is needed. However, as the population increases, there will be more waste accumulation, so that the TPA provided is not expected to be able to accommodate the waste produced by the community. This will trigger the emergence of new problems such as the rapidly increasing demand for landfill land, various environmental and health problems, conventional reduction techniques by burning directly have a negative impact on the atmosphere in the form of greenhouse gas pollution and other toxic gases.

In addition, in general, the supply of electrical energy in Indonesia is supplied by power plants that use fossil fuels. The availability of fossil fuels that are continuously decreasing due to their non-renewable nature threatens the sustainability of human activities. To overcome the constraints of sustainability and aspects of continuity, it is necessary to develop new and renewable energy as a supplier of electrical energy in the energy mix. New and renewable energy has several advantages, namely, energy sources that are always available, high aspects of sustainability, environmental friendliness and low emissions.

Waste processing is one of the activities that are considered efficient at this time by utilizing it as fuel for PLTSa. In the past, waste was leftovers that had no use anymore, so that waste management was always considered a cost center, so there was an assumption that the more waste that was managed, the more costs would have to be incurred to manage it, this mindset would change after the implementation of PLTSa in the area. Waste disposal and will increase public awareness of the environment.

METHODOLOGY

A waste power plant is a power plant with a generation mechanism that can be done in two ways, namely by a thermal conversion process and a biological conversion process. The thermal conversion process basically has the same working principle as PLTU in general. However, due to differences in fuel, this plant has an additional component in the form of its own fuel processing plant before utilizing incineration, pyrolysis, and gasification technologies. While the biological conversion process is by Anaerobic Digestion and Landfill gasification. In determining the generation process, one must choose the most appropriate technology to be used as a solution to the waste problem depending on the conditions of each region. The concept of Waste to Energy Processing (Waste to Energy) or commonly called PLTSa (Waste Power Plant) uses three technologies, namely, waste processing with Thermal Converter Incinerator technology, Gasification and Fermentation.

Thermochemical Conversion Method

The characteristics of the fuel converted into electrical energy can be analyzed through the composition of the waste. Biomass from organic solid waste can be divided into two types of processes, namely thermochemical and biochemical conversion processes. To calculate the energy potential, a test is carried out as shown in the equation. At the time of observing the composition of the waste, observations were also made on the density of the waste. The density of the waste that goes to the landfill on average is 216 kg/m^3 of waste.

Table 1 Test Results Average waste condition

Parameter	Average Test Results
Total Moisture	64.73% ar
Proximate Analysis:	
Moisture in Analysis	21.47% adb
Voltatile Analysis	54.36% adb
Fixed Carbon	11.02% adb
Gross Calorific Value	5728.63 kcal/kg adb
Gross Calorific Value	2672.48 kcal/kg ar
Ultimate Analysis:	
Carbon (C)	32.07% adb
Hydrogen (H)	6.21% adb
Nitrogen (N)	1.75% adb
Oxygen (O)	47.36% adb

The test results in research at Bantar gate can be seen in Table 1. The value listed is considered to have the same value as the waste in the city of Jambi because the categories of waste in Indonesia tend to be the same. According to Syamsarief (2017) the results of the average waste condition test are as shown in Table 1.

Table 1 shown that ar (as received) is the condition of the state of the waste when it was just taken (original state), adb (air dried) is the condition of the state of the waste losing its free water (technically, the analysis test is carried out using test samples that have been dried in air). open). Gross Calorific Value (adb): for this condition the value tends not to show the exact calorific value because free moisture is not included. Gross Calorific Value (ar): analysis for calories in this condition includes the total water content. To calculate the potential electricity from waste we will use the NCV (Net Calorific Value) and GCV (Gas Calorific Value) calorific values using the lab test data in the table above.

Thermochemical conversion process with incineration, gasification, and pyrolysis technology where heat from the combustion process is used to convert water into hot steam which is then used to drive a steam turbine generator to generate electricity, while gasification technology is obtained through partial combustion of biomass with a low oxygen environment and produces electricity. syngas in the form of CO, CO_2, H_2O, char, tar, and hydrogen (H).
There are several variables that will be calculated in the Thermochemical conversion process based on predetermined equations. In calculations using equations such as:
Finding the value of H ar is calculated by the formula described below

$$\mathrm{H_{ar}} = [\mathrm{H\ ad} - 0.1119\ \mathrm{CX\ M\ adb}) x \left\{\frac{(100 - \mathrm{M\ ar})}{(100 - \mathrm{M\ adb})}\right\} + 0.1119\ x\ \mathrm{M\ ar}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
H ar = Hydrogen as received (%)
M ad = Moisture air dried (%)
M ar = Total Moisture as received (%)
M adb = Moisture in Analysis (%)

Next look for the value of the Thermochemical NCV with the described formula in chapter two by entering the parameter value of the test results and the value of GCV is:

Thermochemical NCV = GCV – ((5.72 X (9 X H ar))……………………………….(2)

where:

NCV = *Net Caloric Value* (kcal/kg)
GCV = *Gross caloric Value* (%)
H ar = *hidrogen as received* (%)

The thermochemical conversion process using the total weight of the waste is obtained can be calculated by the following calculation formula:

W_C = W_{gross} x % waste……………………………………………(3)

where:

W_{gross} = total weight of waste components (Tons/day)
W_C = net weight of each waste (tons/day)

After obtaining the weight of each component of the waste then calculated using the following equation:

$W = W_g \mathrm{x} W_c$.......................……....………………………...….....…....................(4)

where:

W = Total Waste Quantity (Ton/hari)
W_{gross} = Total Waste Generation (m^3/day);
W_C = Waste Composition (%)

NCV Termokimia = GCV gross ar – ((5.72* (9* H ar)).......................................(5)

where:

NCV Termokimia = Net Calorific Value as received (Kcal/kg).
GCV ar = Gross Calorific Value as received (Kcal/kg),
H ar = Hydrogen as received (%)

ERP = NCV_{Gross} x W x 1000 / 860 ....(6)

where:

ERP = Energi Recovery Potential (kWh)
NCV = Net Calorific Value (kcal/kg)
W = Total Waste Quantity (Ton)
1000 = kg of waste / TONS
860 = Unit Conversion (1 kWh = 860 kkal)

P = ERP/24 ....(7)

where:

P = Power Generation Potential (kW)
ERP = Energi Recovery Potential (kWh)
24 = Unit of use 1 day (24 Hours)

Waste Power Plant (PLTSa)

A waste power plant is a power plant with a generation mechanism that can be done in two ways, namely by a thermal conversion process and a biological conversion process. The thermal conversion process basically has the same working principle as PLTU in general. However, due to differences in fuel, this plant has an additional component in the form of its own fuel processing plant before utilizing incineration, pyrolysis, and gasification technologies. While the biological conversion process is by Anaerobic Digestion and Landfill gasification. In determining the generation process, you must choose the most appropriate technology to be a solution to the waste problem depending on the conditions of each region.

Incineration

Incineration is the general term given to the direct thermal conversion of waste through combustion with high oxygen content, at temperatures above 850 °C. waste is converted to heat, which is used to heat water in a boiler to produce steam. The steam can be distributed for sale (usually to industrial/chemical manufacturers) or it can be converted to electricity via steam turbines. The efficiency for generating electricity is in the range of 18% - 27% for power plants with a size of 25,000 to 600,000 tons per year. The technology also produces waste residues in the form of ash, boiler ash, fly ash, and scrubber residue from flue gas cleaning operations. Incineration with a moving bed/conveyor belt is a technology that has proven its reliability for incineration of waste so that this technology is more appropriate to be applied.

In Indonesia, the technology itself is quite simple, with the main problems in optimizing heat and energy recovery and minimizing emissions from incineration. Garbage that has not been sorted can be put directly into the incinerator without having to be sorted first. Although the high moisture content in Indonesian waste will reduce thermal efficiency when compared to what is achieved in Europe, incinerator operation must be maintained at critical operating temperatures. If the temperature is lower, volatile organic toxic compounds (VOC) which are harmful to human health and the environment do not decompose completely, and the emission of gas from the generator will violate national safety standards. To achieve and maintain a minimum safe operating temperature, where the volume of the waste stream may be low and/or have a high moisture content, additional fuel is required. This can cause the waste treatment method that should be cheap to be very expensive, and for the incinerator flue gas still requires treatment with gas cooling systems and scrubbers to remove harmful carcinogenic dioxins. This exhaust gas treatment system is quite expensive and requires careful operation and maintenance.

Gasification

Gasification technology is a form of increasing the use of energy contained in biomass materials through the conversion of solid materials into gases, organic materials at high temperatures in incomplete combustion (Antonio et al, 2016). This process takes place in a device called a reactor / gasifier; biomass fuel is fed into the reactor to be burned imperfectly. In other words, the gasification process is a partial combustion process of solid fuel, involving the reaction between oxygen and solid fuel (Rauch et al, 2014). The results of combustion in the form of water vapor and carbon dioxide are reduced to flammable gas, the gas resulting from the gasification process is called producer gas. Generally, the content of producer gas is carbon monoxide (CO), hydrogen (H_2) and methane (CH_4), these gases can be used as a substitute for fuel oil for various purposes such as driving propulsion engines (diesel and gasoline), which in turn can used to generate electricity, drive pumps, and others (Basu, 2010). In general, the gasification process goes through four process stages, namely drying, pyrolysis, oxidation, and reduction.

For each of these processes as follows:

1. Drying :
   Drying is the initial stage of the gasification process, which takes place at temperatures above 100 ^{o}C. When solid fuel enters the reactor, water in the form of moisture on the surface of the fuel will evaporate, while what is inside will flow out through the pores of

the solid fuel and evaporate. This process continues until it reaches a temperature of about 200 ^oC and is endothermic.

2. Pyrolysis/Devolatilization:
   Pyrolysis is the thermal decomposition of a solid fuel. Pyrolysis products generally consist of three types, namely light gas, char and charcoal. The main components of the mixture of these gases are H_2, CO, CO_2, H_2O, CH_4 and other hydrocarbons. The tar fraction includes heavy organic compounds which are gases when released during pyrolysis or as liquid drops, charcoal (char) is composed mainly of carbon and the presence of mineral matter in solid fuels (Basu, 2010). The pyrolysis process occurs at a temperature of 150 to 800 ^oC. 3. Oxidation: Oxidation or burning of charcoal is the most important reaction that occurs in the gasifier, occurring at a temperature of 800 ^oC to 1000 ^oC (Basu, 2010). This process provides all the heat energy needed for an endothermic reaction. Power Plant with gasification type

Pyrolysis

Pyrolysis uses waste thermal degradation in the absence of oxygen. Like gasification, waste treatment with pyrolysis technology may require some form of pretreatment to produce consistent raw materials i.e. separation of glass, metal, debris etc., however, gasification of commercial waste processing on a global scale is currently limited. The pyrolysis installation requires an external heat source and the combustion temperature must be maintained at 400°-850° Celsius. This technology produces syngas, pyrolysis oil for fuel, solid residue or charcoal, and ash/metal residue. Pyrolysis syngas from waste is estimated to have a Net Calorific Value/NCV of 10-20 MJ/Nm^3.

Technology used in Waste Power Plants

This PLTSa system uses three methods where the first method uses Incinerator technology, namely the combustion process. In addition to using the PLTSa Incinerator technology, you can also use LFG consisting of a collection system and fermentation of waste into methane gas, as well as processing waste into electricity using Gassification technology. Based on the technology that has been developed processing waste into energy, including the following.

RESULTS AND DISCUSSION

Garbage Composition

This waste composition analysis aims to determine the components that make up the waste to be processed so that by knowing the composition of the waste generated by the community, to calculate the volume of each component of the waste to make it easier for us to calculate the calorific value of the waste as shown in Figure 1.

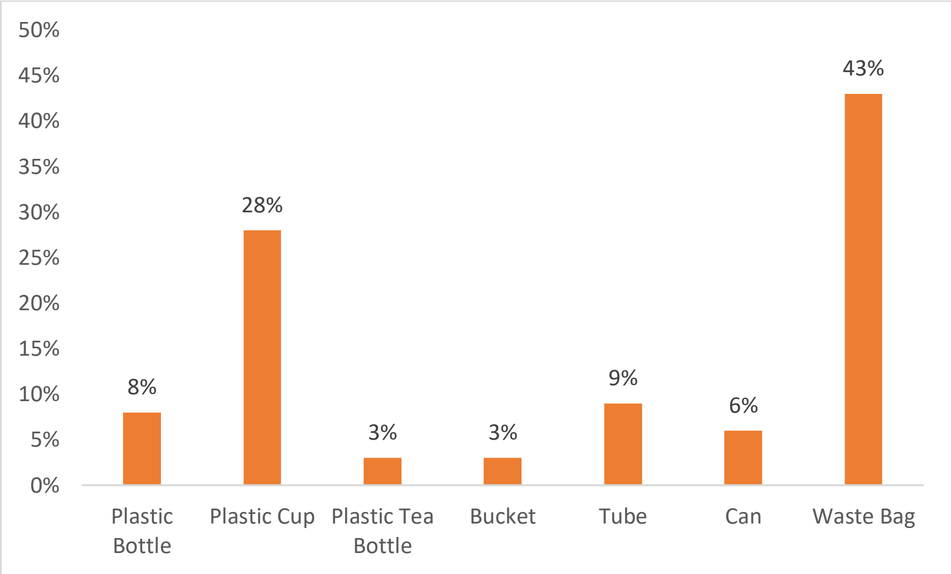

Figure 1 Percentage of each waste composition (Jambi City Environmental Service, 2021)

Based on Figure 1, the waste composition data obtained from the Jambi City Environmental Service is a type of inorganic waste consisting of plastic waste and cloth waste. This is because the sorting has not been done perfectly and the waste obtained is homogeneous waste which is organic waste and inorganic waste mixed in one place. According to Faruq (2016), the type of waste that is better used as a source of PLTSa is organic waste because organic waste is combustible waste and waste that cannot be reprocessed. Inorganic waste is rarely used as a source for PLTSa because organic waste is often recycled. However, it is possible that organic waste can be used as a source of PLTSa.

Garbage Capacity

This calculation aims to calculate the daily capacity of waste transported by garbage trucks in Jambi City, data on the daily capacity of transported waste is used to calculate waste heat. Daily waste transport fleets in the form of Fleet, Arm Roll and Patrol and others operating in the southern Jambi sub-districts, Kota Baru, Jambi Market, Telanaipura, Jelutung, East Jambi with a carrying capacity of 333,610 kg (Jambi City Environmental Service, 2021). The average amount of waste every day comes from residential, commercial, market, offices, public facilities, industrial areas, road sweeps, canals, and others. In Table 4.1, is the data of daily waste transport cars in Jambi City. It can be concluded that, in one sub-district more than 1 car can be transported. Garbage that is transported in the morning, will be transported back in the afternoon and evening. This indicates that people in Jambi City produce quite a lot of waste per day. The more waste produced, the more potential the use of waste as a source of PLTSa will be.

Calculation of Potential Energy (Thermochemical NCV)

Inorganic waste is waste that can be reprocessed and has a lower water content than organic waste. Inorganic waste can be used as a source of PLTSa by using thermochemical conversion. The thermochemical conversion of biomass requires fuels with high heating value and low water content. The thermochemical conversion process with incineration technology is also known as "mass combustion" where the heat from the combustion process is used to convert water into hot steam which is then used to drive a steam turbine generator to generate electricity (Jain et al., 2014).

In 2021, on September 1, to be exact, Jambi City's daily waste capacity will reach 333,610 kg. To calculate the energy potential of the waste data that has been obtained, the NCV (Net Calorific Value) calorific value is used.
By using equation 1 in chapter Methodology, it is obtained:

$$\mathrm{H\ ar} = \left[\mathrm{H\ ad} - (0.1119 \times \mathrm{M\ adb})\left\{\frac{(100-\mathrm{M\ ar})}{(100-\mathrm{M\ adb})}\right\} + (0.1119 \times \mathrm{M\ ar})\right]$$

$$\mathrm{H\ ar} = 6.21\% - (0.1119 \times 21.47\%)\ \left\{\frac{(100-64.73\%)}{(100-21.47\%)}\right\} + (0.1119 \times 64.73\%)$$

$$\mathrm{H\ ar} = 12.37\%$$

Next, look for the thermochemical NCV value. with the formula described in chapter 2 by entering the parameter value of the test results and the GCV value in table 1 into equation 2 then we get:

$$\mathrm{NCV\ Termokimia} = \mathrm{GCV} - ((5.72\ (9 \times \mathrm{H\ ar}))$$

$$\mathrm{NCV\ Termokimia} = 2672.48\ \mathrm{kcal/kg} - ((5.72\ (9 \times 12.37\%))$$

$$\mathrm{NCV\ Termokimia} = 2666.11\ \mathrm{kcal/kg}$$

This NCV value is needed to calculate ERP in the next calculation in the thermochemical process.

Calculation of Wnet (Net Weight), ERP, and P of Waste Composition

Based on data from the Jambi City Environment Agency on September 1, 2021, the daily waste capacity is 333,610 kg or equal to 333.61 tons/day. By using equation 3 using the calculation value of the net weight of the waste composition above is as follows:

Table 2 Calculation of Net Waste Weight Based on Composition

No.	Waste Composition	Wc (% of waste)	Wgross (kg)	Wnet (kg)
1.	Plastic Bottle	8%	333,610	26.688,8
2.	Plastic Cup	28%	333,610	93.410,8
3.	Plastic Tea Bottle	3%	333,610	10.008,3
4.	Bucket	4%	333,610	10.008,3
5.	Tube	9%	333,610	30.024,9
6.	Can	6%	333,610	20.016,6
7.	Waste Bag	43%	333,610	143.452,3
	Total	**100%**		**336.610**

After obtaining the Wnet results which can be seen in table 2 then using equation 4 using the value of the waste weight calculation above to calculate the ERP (Energy Recovery Potential) is as follows:

Table 3 Energy Recovery Potential (ERP) Calculation Results

No.	Waste Composition	Wnet (kg)	NCV (kcal/kg)	ERP (kWh)
1.	Plastic Bottle	26.688,8	2666,11	82.738,69
2.	Plastic Cup	93.410,8	2666,11	289.585,42

3.	Plastic Tea Bottle	10.008,3	2666,11	30.968,82
4.	Bucket	13.344,4	2666,11	30.968,82
5.	Tube	30.024,9	2666,11	93.081,03
6.	Can	20.016,6	2666,11	62.054,02
7.	Waste Bag	143.452,3	2666,11	444.720,47
	Total			**1.034.117,2**

The total amount of energy potential (ERP) from table 4 above, will be converted to obtain the power potential (P) of generation for 24 hours using equation 7 in chapter Methodology

Table 4 Calculation Results of Power Generation Potential (P) for 24 Hours

No.	Waste Composition	ERP (kWh)	Hour/day	P (kW)
1.	Plastic Bottle	82.738,69	24	3.447,44
2.	Plastic Cup	289.585,42	24	12.066,05
3.	Plastic Tea Bottle	30.968,82	24	1.290,36
4.	Bucket	41.369,34	24	1.290,36
5.	Tube	93.081,03	24	3.878,37
6.	Can	62.054,02	24	2.585,58
7.	Waste Bag	444.720,47	24	18.530
	Total			**43.008,16**

From the results obtained above, it can be seen that there is an efficiency in using PLTSa components of 10,772,34 kW. These results are obtained because it is known that each PLTSa component has an efficiency that affects the results of the performance of these components. The efficiency of PLTSa is in the range of 25-30%. Then the efficiency obtained is from Efficiency = P x 25% = 43,088,16 kW x 25% = 10,772,34 kW.

Based on the calculations that have been described, it can be concluded that the largest potential type of inorganic waste as PLTSa using the thermochemical method is sack waste, which is 18,530 or 43%. The potential for inorganic waste to become PLTSa in the city of Jambi using the thermochemical method is 43.008,16 kW. It is likely that the potential for waste to become a source of PLTSa will be greater if it uses the type of organic waste that has a higher water content than the type of inorganic waste. The physical nature of waste in Indonesia is wet because Indonesia is in a tropical wet climate zone. This wet waste condition can also be caused by the absence of an adequate upstream to downstream waste management system. People are not aware of the importance of sorting waste in their respective homes. Garbage that is still mixed between organic waste (high water content) and inorganic (low water content) causes waste segregation at the TPA to be ineffective (Widyawidura and Pongoh, 2016).

The data on the incoming waste at the Talang Gulo TPA is in the form of the total capacity of incoming waste from the City of Jambi. The data found that the capacity of the incoming waste in Jambi City to the Talang Gulo TPA reached 418.91 tons/day. With a population in 2020 of around 3,548,228 million people spread across 11 regencies and cities (Source: Population Census, 2020), have the potential for waste generation to reach 1,746 tons per day. The amount of incoming waste capacity is of course included in the large category because it has passed the maximum limit of 500 tons/day. The source of the Jambi City waste pile comes from household waste; market; industry; garden; public facility; and others. Based on data on the capacity of the waste entering the Jambi Province TPA which is increasing every time, if this is left alone it will also harm the land around the Talang Gulo TPA because it will continue to expand to no limit. In Table 5 below, it can be seen the results of measuring the capacity of incoming waste at the Talang Gulo TPA.

Table 5 Data on the period of Jambi city waste entering the Talang Gulo TPA

Year	Month	Mass (ton)
2021	Juny	9,920,070
	July	10,556,760
	August	10,963,920
	September	11,328,320

In Table 5 above, it can be seen that the largest capacity for waste entering the Talang Gulo TPA in September 2021 is 11,328,320 tons, equivalent to 377.6 tons/day, in the city of Jambi. The incoming waste capacity seems to be increasing from June to September 2021. This is directly proportional to the increase in the number of residents in Jambi City. Based on data, the capacity of waste entering the Talang Gulo TPA is increasing every month. If this is left unchecked, it will also harm the land around the Talang Gulo TPA which currently covers an area of 5.2 ha, because it will continue to be expanded until there is no limit.

Through the construction of a Waste Power Plant (PLTSa), it is one solution to reduce the increasing volume of waste. PLTSa is a type of new renewable energy (EBT) in the field of waste to energy (WtE). WtE utilizes the rest of human activities (in the form of waste) to be processed and utilized its heat energy to generate a boiler engine which is connected by a turbine and generator. Electromagnetic waves will be generated by a rotating generator so that it is able 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 a right decision, so that the use of WtE technology that is selected is in accordance with the characteristics of Jambi City's waste. The steps taken in selecting the technology using the GA method must be in accordance with the rules that have been determined.

In choosing PLTSa technology at the Talang Gulo TPA, the first step can be to compose a table as can be seen in Table 6 by filling in the actual values for each factor choice. Next is to give an assessment ranging from 1 to 5 (poor to excellent) or the highest value of excellent in each column. Table 3 which shows the consideration of the assessment of the norm factor on each of the factors of consideration. The value of the consideration factor may vary according to the actual value of each factor.

Table 6 Consideration ff Actual Assessment of Each Factor

Factor Technology Choice		Incoming Garbage (tons)	Landfill Area (ha)	Process Efficiency	Waste Volume Reduction
Thermal	**Incinerator**	377,6	5,2	Very fast	>100 ton/day
	Pyrolysis/gasification	377,6	5,2	Medium	21-30 ton/day
	Hydrothermal	377,6	5,2	Very Fast	50-100 ton/day
Biochemistry	**Anerobic digestion**	377,6	5,2	Very slow	<10 ton/day
	Landfill	377,6	5,2	Slow	10-20 ton/day

Table 7 Considerations For Assessing The Norms of Each Factor

Factor Technology Choice		Factor Technology Choice	Landfill Area (ha)	Process Efficiency	Waste Volume Reduction
Thermal	**Incinerator**	5	5	5	5
	Pyrolysis/gasification	5	5	3	3
	Hydrothermal	5	5	5	4
Biochemistry	**Anerobic digestion**	5	5	1	1
	Landfill	5	5	2	2

Table 8 Assessment of Weighting Factor

Factor	Incoming Garbage (tons)	Landfill Area (ha)	Process Efficiency	Waste Volume Reduction
Weighting Factor	5	5	3	5

Table 9 Calculation of Multiple Between the Norma And Weighting Factor

Factor Technology Choice		Incoming Garbage (tons)	Landfill Area (ha)	Process Efficiency	Waste Volume Reduction
Thermal	**Incinerator**	25	25	15	25
	Pyrolysis/gasification	25	25	9	15
	Hydrothermal	25	25	15	20
Biochemistry	**Anerobic digestion**	25	25	3	5
	Landfill	25	25	6	10

The last step is making the right technology decision at the Talang Gulo TPA based on the results of the multiplication calculation between the norm factor and the weighting factor. The results of the values in Table 9 are then added up for the value of each type of technology. Incinerator technology scored 90; pyrolysis/gasification 74; hydrothermal 85; anaerobic digestion 58; and landfill 66. Based on the calculation of the sum of the values of each technology, the appropriate technology for the Piyungan landfill is incinerator technology.

Incinerator technology is a PLTSa technology with a working process based on the thermochemical method. The working process of PLTSa with incinerator technology begins with the waste that enters the Talang Gulo TPA and is left for approximately 3 days to reduce the water content of the waste by an average of 60%. The water content after 3 days will shrink to about 20% for the minimum limit for waste ready to enter the reactor. The residue from burning waste is in the form of top ash and bottom ash.

The waste that is ready to be burned in the reactor passes through the conveyor to be put into the chopping machine so that the waste is decomposed into smaller sizes. The conveyor machine continues to move to send the crushed waste into the boiler. The waste in the boiler will be burned at temperatures above 10000 C. The high temperature causes the dioxi in the waste to be released into the air, and the dioxin is captured by a small material capture system (electrostatic precipitator). The heat from the boiler is then used to evaporate the water vapor that drives the turbine. The turbine connected to the generator drives the generator to produce electricity. The electricity generated is then distributed to the PLN electricity network. Based on energy conversion calculations from the Ministry of Energy and Mineral Resources, the Directorate General of New, Renewable Energy and Energy Conversion (EBTKE) that 100 tons of waste is capable of generating 5 MW of electricity. Based on the conversion calculation, the potential mass of Jambi City's waste is able to generate 18.5 MW of electricity.

Economic Analysis

The potential costs of waste energy are capital and operational costs. One of the main drawbacks to setting up a waste energy facility is the high capital cost. According to the lead research organization at Waste too Energy in the United States (Waste-To-Energy Research and Technology Council 2012), the cost of capital ranges from $150,000 to $200,000 per tonne, daily Capacity in the European Union and the United States. Before a project is implemented, it is necessary to analyze the investment so that the feasibility of a project will be known from the economic side of the investment. There are several methods of assessing investment projects, namely:

a) Initial Investment

The investment cost of the power plant is obtained from the cost of building a power plant with almost the same capacity so that the accuracy of the data used is not too different from the reality in the field. The investment costs can be seen in table 10

Table 10 Investment Costs for PLTSa Development

No.	Description	Price (Rp)
1	Generator and Turbine Package	12,811,543,053.00
2	Control System and Supporting Facilities	200,152,510.00
3	Gathering Land	1,506,594,081.00
4	Construction Materials and Labor	3,518,270,741.00
5	Project Management and Construction	2,500,962,445.00
6	Engineering Fee	2,500,962,445.00
7	Unforeseen expenses	3,000,000,000.00
8	Total Before Tax	26,038,485,275.00
9	10% tax	2,603,848,528.00
	Total Investment	**54,680,819,078.00**

b) Admission Fee

The purchase price of PLN electricity from PLTSa according to the Minister of Energy and Mineral Resources No. 44 of 2015 has been fixed. Sanitary landfill: IDR 1,650 – IDR 2,160/kWh; incinerator type Rp/kWh 1,870 (T. Medium – T. High) and Rp. 2,240/kWh (T. Low).

Power generated/hour	= 10,772.04 kW
Power raised in 1 day	= 10,772.04 kW x 24 hours
	= 258,528.96 kWh
Energy generated in 1 month	= 7,755,868.8 kWh/month
Energy generated in 1 year	= 93,070,425.6 kWh/year
Which can be sold to PLN	= 93,070,425.6 kWh/year
Then receipts/year	= 93,070,425.6 kWh/year x 1.870
	= Rp. 174.041.695.872,-

c) Operational and Maintenance Costs

Table 11 Operational and Maintenance Cost

No.	Details of O and M . Costs	Amount	Description
1	Fuel Collection	-	PEMKO Subsidy

2	Fuel Processing	-	PEMKO Subsidy
3	Generators and Turbines	2,866,729,795.00	
	Total	**2,866,729,795.00**	

d) Depreciation/Depreciation Cost

The estimated economic life of the power plant is around 2 years and at the end of the plant's life there is still a residual value of about 10% of its service life.

- Residue
  Initial investment = Rp. 54,680,819,078.00
  Residual value (10%) = Rp. 5,468,081,908.00
- Depreciation

$$\text{Depresiasi} = \frac{\text{Investment}-\text{Residue}}{\text{t}}$$

$$\text{Depresiasi} = \frac{\text{Rp.}54.680.819.078{,}00 - \text{Rp.}5.468.081.908{,}00}{20}$$

$$\text{Depresiasi} = \text{Rp.}\,2.460.636.858{,}5$$

e) Preparation of Cash Flow

The preparation of cash flow uses several assumptions including:

- Discount rate = 15%
- Discount factor = 25%
- Economic life of the generator = 20 years
- Load factor = 0,65

The preparation of cash flow can be done using the Least cost method, where from the investment cost of 54,680,819,078.00 (million), with a benefit of 3,515,842,471,680.00 and a net benefit of 88,548,382,660.00, PV Costs 487,876,558,506.00, PV then the benefit is 547,944,094,208.17.

f) Economic Evaluation

- **NPV (Net Present Value)**

  NPV is the present value of the entire Discounted Cash Flow or an overview of the total cost or total revenue of the project in terms of the present value (the value at the beginning of the project). Mathematically the NPV value can be expressed as an equation:

$$NPV = -CoF + \frac{C1}{(1+i)^1} + \frac{C2}{(1+i)^2} + \cdots \ldots + \frac{Cn}{(1+i)^n}$$

Where:

I = *Discount rate used*
COF = *Cash out flow* or Investment
C = *Cash in flow in period n*
N = The last period of expected cash flow
NPV $= \text{Entrance fee} - \text{Expenses}$
NPV $= \text{Rp } 547{,}944{,}094{,}208.00 - \text{Rp } 487{,}876{,}558{,}506.00$

$$\text{NPV} = \text{Rp.}\,60{,}067{,}535{,}702.00$$

- **Payback Periode (PP)**

  By using the equation

  $$\text{PBP} = \frac{\text{Investmen Cost}}{\text{Annual CIF}}$$

  $$\text{PBB} = \frac{\text{Rp. }54{,}680{,}819{,}078.00}{\text{Rp.}4{,}427{,}419{,}133.00}$$

  $$\text{PBB} = 12{,}3 \text{ year}$$
  $$\text{PBP} = 12 \text{ year } 3 \text{ month}$$

- **Benefit Cost Ratio (BCR)**

  By using equation (3) the BCR value can be calculated as follows:

  $$\text{BCR} = \frac{\sum_1^n \text{CIF}_1}{\text{Investment cost}}$$

  $$\text{BCR} = \frac{88{,}548{,}382{,}660.00}{54{,}680{,}819{,}078.00}$$

  $$\text{BCR} = 1{,}61$$

S-W-O-T ANALYSIS

Internal factors

Internal is something that can be controlled by the Jambi City Government, in this case the Sanitation Department. These are things that have been owned by the Jambi City Government which are strengths that have a positive value for the success of waste management planning by building mini PLTSa. On the other hand, the lack or absence of things that should exist becomes a negative value and will reduce the success of planning.

a) Strength
   1. Facilities and infrastructure
   2. Waste retribution
   3. Provincial Government Commitment
   4. Legislation
   5. Technology for PLTSa planning

b) Weakness
   1. Availability of unrealized land
   2. Garbage retribution has not been determined
   3. Waste that is managed a lot
   4. The waste to be managed must be selected
   5. Waste transport process
   6. Quality of technology for PLTSa planning
   7. Need to be managed by institutions
   8. Capital and rupiah fluctuation

External Factors

External factors are those that are beyond the control of the Jambi City Government. This will directly affect the government's performance in management planning activities in Jambi City. This influence can contribute positively so that it can provide opportunities (opportunity) to accelerate the implementation of activities. However, there are also threats (threats) in the implementation of activities.

a) Opportunity
   1. Many choices of waste utilization
   2. Jambi City as the center of government in Jambi Province
   3. Utilization of the 3R concept in processing waste
   4. Increased community participation in waste management
   5. Create job opportunities for the community
   6. Get a by-product in the form of electricity

b) Threat
   1. Too much trash
   2. People still think of garbage as a negative thing
   3. Lack of public awareness about waste selection
   4. Degradation of soil quality around the site
   5. The impact of HCl, NO2, CO, dioxins, heavy metals, fly-ash must be managed by competent institutions
   6. There is traffic jam around the location

CONCLUSION

1. Based on the data collected and processed, the total mass of waste entering the City of Jambi to the Talang Gulo TPA was obtained at 377.6 tons/day or equivalent to an average of 11,328 tons/month. The area of the Talang Gulo TPA is 5.2 ha, so the right technology for this condition is incinerator technology. Incinerator technology can be used as PLTSa
2. By using the calculation of the thermal method, the electricity potential generated is 43,008.16 and the Net Power Output (influenced by generator efficiency ±25%) is 10,772,34 kW.
3. By using the least cost method, the result of NPV calculation is Rp. 60,067,535,702.00 which means that this situation is favorable according to the project feasibility criteria NPV > 0 and the payback period for PBP is 12 years (not exceeding the economic life of a generator). The profit-to-cost ratio shown by BCR is a positive number, 1.61, which is greater than 0.

SUGGESTION

1. In this study, the calculation used is only one of the thermochemical methods, so for the continuation of this research, several thermochemical methods, gasification, pyrolysis, etc. can be used. And compare the results in order to get better results for the application of the type of PLTSa.
2. The selection of PLTSa locations needs to be carefully considered in order to obtain PLTSa operational efficiency.
3. Waste management in Jambi City must be improved as a whole to facilitate waste processing in PLTSa, so that the success of PLTSa requires coordination and synergy between the government, community and developers.
4. Exhaust gas processing needs to be taken into account to assess the feasibility from environmental aspects and the processing costs.

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