Characteristic Evaluation of Organic Waste Power Plant in Bantargebang Waste Processing Plant

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Abstract.

Bantargebang landfill located in Bekasi is the place where Jakarta dumps its waste. *Landfill* Gas is a gas produced from biology decomposition reaction process where organic matters are converted into CO2, CH2, ammonia, and hydrogen sulfide. The decomposition will continue aerobically in a short time until the available oxygen lessens. Bantargebang waste processing plant (or TPST in Indonesian) produces an average 6000-7000 tons/day of waste. If the wastes in the waste processing plant are not processed, it could cause undesired environmental pollution. So, with the construction of Waste Power Plant (or PLTSa in indonesian) in Bantargebang waste processing plant could lower the pollution caused by the dumped wastes. Bantargebang's Waste Power Plant have a capacity of 15,6 MW but according to the evaluation result in 2017, the power plant only produces 250 KW electricity. Therefore the purpose of this writing is to evaluate the systems installed in Bantargebang's Waste Power Plant, identify the problem of the decrease in capacity and lowers the level of pollution contained within the area. Based on the evaluation result of attempting to fix the power plant's system using capping and also vertical pipes to collect the landfill gas, it could generates 19,6 MW in the first year and eventually decreased in the following years, until the twentieth year reaches only 0,191 MW. Aside from that, the gas engine itself which was broken needs to be fixed by having its spare part installed and applying a continued maintenance to minimalize future damages

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BACKGROUND

Biomass is an alternative renewable energy that promises to decarbonize environment and to supply electrical energy needs in remote places (e.g. small islands). [1,2] because most power plants rely heavily on imported fossil fuels which are expensive and cause greenhouse gases (GHG). [3,4,5].

Based on the sources of data obtained, in 2015 it was estimated that the waste produced by the people of Jakarta was as much as 6500 tons per day. This waste will then be sent to the Bantargebang Integrated Waste Disposal Site (TPST) which is then processed in various ways, one of which being a source of electricity [6]. Part of the methane generated in landfills can be captured and used as a renewable energy source. In contrast, when methane is allowed to escape to the atmosphere, it has a global warming potential that Intergovernmental Panel on Climate Change (IPCC), estimates to be 23 times greater than that of the same volume of carbon dioxide [7].This has triggered the concern for public and private bodies to engage in processes which have little or no negative impact on the environment. Methane is a Green House Gases (GHGs) which constitutes 50–55% by volume of landfill gas (LFG) and has 21–23 times global warming potential than CO_2 [8].

Methane is produced by anaerobic biodegradation of MSW in landfills and the amount of the gas produced can be estimated from a number of methods [7,9]. The conversion of LFG into resource depends on the management of the management of municipal solid waste (MSW) in landfills. These landfills can be properly managed, by converting them to sanitary and capturing the methane for electricity generation onsite or channeled to industries for same or other purposes. In this way, revenue is generated and the threat to environment due to its emission is mitigated [9]. The world biggest plant of liquefied natural gas (LNG from landfill gas) at Altamont Landfill and Resource recovery Facility in Livermore, California [10], generating roughly 24 000 L of liquefied bio-methane per day. The most suitable process for small-scale liquefaction plants may differ considerably from a large-scale application since these solutions are neither practical nor economical when applied to small plants

With the existence of the Waste Power Plant (PLTSa) project in Bantargebang TPST, it also provides benefits such as absorbing labor, reducing the potential for the spread of dangerous bacteria, reducing bad odors, and reducing carbon emissions. The aim of evaluating PLTSa is to evaluate several things that are obstacles to optimize waste of power plant in Bantargebang. Electricity produced by PLTSa Bantargebang is supplied to the State Electricity Company (PLN) network interconnected with the Java-Madura-Bali system [11].

Bantargebang waste processing (TPST in Indonesian) is one of the only waste institution in Indonesia that can process waste efficiently. In cooperation with *N and G Public Company*, Bantargebang waste processing not only able to produce compost but also able to collect LFG to be processed into electricity which amounts to 10.5 MW. Currently, *N Company* have sold electricity with the price of Rp.820/kW to Government Electric Company. 5% of the total electricity generated are used to operate Bantargebang waste processing, while the rest 95% are sold to National Government Company (PLN) [12].

MANAGEMENT OF MUNICIPAL SOLID WASTE (MSW) AND REGULATED LANDFILLS

The management of solid waste continues to be a major challenge in urban areas throughout the world, particularly in the rapidly growing cities and towns of the developing countries. The increase in population causes increase in human activities and this in turn leads to increase in waste generation [13].

In October 1988, the US Environmental Protection Agency (USEPA) reported to the Congress that municipal solid wastes were landfilled in nearly 6,500 landfills. Although these landfills used a wide variety of environmental controls, they posed significant threats to groundwater and surface water resources, as well as health effects due a threat to air and water. To address these concerns, and standardize the technical requirements for MSW landfills, USEPA promulgated revised minimum federal criteria for MSWLFs on October 9, 1991 [14]. As a result of these more stringent regulations, many of the smaller landfills were closed and at the present time there are only 1767 landfills EPA [15]. Large landfill operations have taken advantage of economies of scale by serving large geographic areas and accepting other types of wastes, such as commercial solid waste, non-hazardous sludge, and industrial non-hazardous solid wastes. In 2000, an estimated 75% of the US municipal solid waste was deposited in 500 large landfills [16].

Within the European strategy for sustainable development, a long-term objective is to limit climate change, firstly by meeting the commitments of the Kyoto Protocol and then by reducing greenhouse gas emissions by an average of 1% per year over 1990 levels up to 2020 [17.19]. In 1998, the CH4 emissions inventory for the UK totalled some 2.6 million tones, of which approximately 29% was derived from landfills [18]. LFG is therefore a major source of UK CH4 emissions and a long-term strategy in order to minimize LFG emissions is thus required.

Landfill Gas

Landfill Gas (LFG) is a gas produced from fermentation or anaerobic processes from organic materials. Such as, animal waste, human waste, domestic waste (household), agricultural waste, plantation waste, etc. The main content (LFG) is methane (CH_4) and carbon dioxide (CO_2). Here are the gases produced from landfills with anaerobic processes can be seen in table 1[20].

TABLE 1. Gas Composition in Landfill

Component	Composition %
Methane (CH_4)	45-60
Carbon Dioxide	35-40
Nitrogen	10-25
Oxygen	0.1-1
Ammonia	0.1-1.1
Hydrogen	0-0.2
Carbon Monoxide	0-0.2

Source: Sarifudin; 2012; 22

Potential Landfill Gas

In Indonesia, organic waste decomposition are mainly acquired from methane gas produced from agriculture and transport activities which amounts to an estimate of 50% of total methane gas emission [21]. The potential of LFG is very promising where methane gas contained in LFG is very large, which is around 50%. The calculation of the potential landfill gas produced in a sanitary landfill is calculated using the U.S model of the Environmental Protection Agency (EPA) used in various sanitary landfill scenarios in the United States which also applies to Indonesia because of its relevance. The calculation of the potential landfill gas produced can be seen as follows [20]:

$$Q_t = 2 * lo * m_o * (e^{k*ta} - 1) * e^{-k*t}$$

Where:

Qt	=	the amount of gas produced in the year to year in m^3/year
l_o	=	potential methane value produced in m^3/year
m_o	=	Solid amount received in tons/year
t	=	Age of landfill in year
k	=	Constanta average of Methane every year

Calculation of the value of k is based on 30% of the waste decomposes quickly (food scraps, etc.), and 60% for the waste decomposes slowly, (plants, etc.), and the value of 1% is to decompose slowly (plastic, etc.). The k weight value for organic is 0.4, the decay medium is 0.8, selow decay is 0.02, for further explanation in the following table 2 [20,22]:

TABLE 2. EPA Model k value calculation

Characteristic	amount	weight	k value
Organic Waste (i.e. waste food)	0.3	0.4	0.12
Medium decay (i.e. plants)	0.6	0.08	0.048
Slow decay (i.e. plastics)	0.1	0.02	0.002
Total			0.17

Source: Sarifudin; 2012; 67

To overcome the uncertainties surrounding the efficiency of collection, EPA (United States Environmental Protection Agency) has published estimates of reasonable collection efficiency for U.S. landfills whom meet U.S. design standards and which has a "comprehensive" gas collection system. The EPA defines a "comprehensive" LFG collection system as a vertical well system that provides 100 percent collection system coverage of all areas with waste within one year after the waste is deposited. According to EPA, the efficiency of collection in these landfills usually ranges from 60 to 95%, with an average of 75% most often assumed. Estimates of collection efficiency for sites with operating gas collection and control systems are usually based on information about current conditions. Calculations looking for efficient gas collection to capture LFG produced by waste can be seen as follows: [20]

$$Production\ Gas\ (\frac{m^3}{year})\ =\ 75\%\ x\ Qt$$

The content in the gas still consists of several other gases, such as CO2 carbon dioxide, Methane (CH_4), carbon monoxide (CO), ammonia (NH_3), Nitrogen (N_2), Hydrogen Sulfide (H_2S), and Oxygen (O_2) . From the amount of methane gas with a percentage of 45-60% in landfill the amount of methane gas uses 50% as the average recommended by EPA [20]

$$Methane\ Gas\ (\frac{m^3}{year})\ =\ 50\%\ x\ Recoverable$$

To calculate the amount of electricity produced from the gas engine, use the following calculation: [20]

$$Amount\ of\ Electricity\ =\ Methane\ Gas\ x\ 9.39\ kWh\ x\ engine\ efficiency$$

Where, the energy conversion of methane gas into electrical energy based on the heat potential possessed by 1 Kg of methane gas is equivalent to 6.13 x 107 J, and 1 kWh of electricity is equivalent to 3.6 x 106 J, 1 m3 of methane is equivalent to 9, 39 kWh so that it can be seen in table 3 below:

TABLE 3. Energy Conversion Data

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

Source: Sarifudin; 2012; 58

PLTSa Biological Conversion Process

PLTSa or *Waste Power Plant* is a plant that uses gas from landfills as a result of garbage decomposition or called LFG (landfill gas), which will then be used as methane gas contained in it as a gas engine fuel which will then generate electricity. The following is a special layout image of the LFG system into electricity [23] in the Figure 1

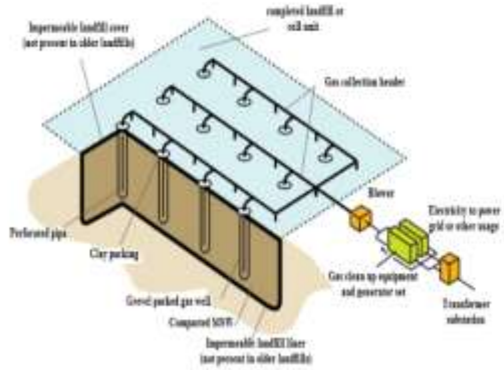

FIGURE 1. Special layout of the LFG system into electricity

One of the major environmental challenges associated with landfills is the generation of landfill gas (LFG); the main components of which are methane (CH_4) and carbon dioxide (CO_2), both produced by the anaerobic decomposition of the organic waste fraction [24,25,26]. CH_4 and CO_2 are greenhouse gases (GHGs) with a high potential to cause adverse effects on global climate change. Several researchers have determined typical gas generation rates at MSW landfills using comprehensive field monitoring programs at US landfill sites [25, 27, 28, and 29]

Landfill gas could be utilized in power plants if the methane composition is around 38% - 65%. Usually landfill gases (LFG) project utilizes spark ignition engine (small scale) or turbine gas (large scale) to generate electricity around 1 – 5 MW by burning methanes. [30,31]

Waste data of Bantargebang Waste Processing

From the observed data, the amount of domestic waste entering the Bantargebang TPST is 2,251,987.41 in 2016. TPST Bantargebang operates 24 hours a day.

TABLE 4. Waste Technical Data

Month	Tonnage
Jan-16	193.776,58
Feb-16	185.695,86
Mar-16	204.386,02
Apr-16	175.585,43
May-16	121.136,68
Jun-16	190.514,53
Jul-16	173.755,71
Aug-16	205.843,83
Sep-16	203.099,22
Oct-16	189.698,89
Nov-16	193.522,58
Dec-16	214.972,08
TOTAL	**2.251.987,41**
Average per day	6.169,83

Source : TPST Bantargebang

Based on the results of research conducted by the DKI Jakarta Provincial Sanitation Office, the source of waste and the composition of domestic waste in DKI Jakarta can be seen in table 5 below: [23, 32]

ANALYSIS AND DISCUSSION

Waste Analysis at Bantargebang Waste Processing

From the waste processing (or TPST) area in Bantargebang, the area is 120.8 hectares with land from 5 waste disposal zones which, when combined, reach 81.91 hectares can accommodate an average waste volume of 6,169.83 tons / day and an average of 187,665.62 tons / day month. DKI Jakarta domestic waste comes from several different sources such as settlements of 52.97%, industry 8.97%, markets 4%, schools 5.32%, offices 27.32%, others 1.4% tend to be more organic waste of 55.57% with inorganic amounts to 44.63%.

Environmental Impact Analysis at Bantargebang Waste Processing

Along with the system used in Bantargebang Waste Power Plant (PLTSa) with a sanitary landfill system, the volume of waste is very large from the capital city of Jakarta and currently the system used is without using capping. This will cause some environmental problems like other garbage dumps. Common problems that usually exist are bad smell, contamination of ground water by the remnants of leachate which is not channeled to leachate treatment, release of methane gas that is not utilized so that it is released into the air and can cause greenhouse gas effects in the earth's atmosphere which are actually more dangerous compared to CO_2 carbon gas. The system used to reduce problems such as methane gas which evaporates and is not utilized and can cause fires can be minimized by adding existing systems using capping as a cover to minimize methane gas that is not utilized out. With this capping, methane gas produced from a pile of garbage can be fully concentrated to be channeled to the use of electricity.

Environmental Impact Analysis at Bantargebang Waste Processing

One of the factors that influence the production of LFG is the amount of waste and the composition of waste in landfills. This composition will affect how much LFG will be produced each year. The composition in Bantargebang is based on the data obtained, the organic composition (food waste) is far more than the composition of inorganic waste. This is because, the amount of disposal of organic waste such as food scraps, vegetables, fruit, etc. more than inorganic rubbish thrown into Bantargebang TPST. The following is a calculation of the k value of the Bantargebang TPST waste composition which can be seen in the table 6 as follows: [33, 34]

TABLE 6. Calculation of k value in the EPA model in Indonesia

Characteristic	amount	weight	k value
Organic Waste (i.e. waste food)	0.55	0.4	0.22
Medium decay (i.e. plants)	0.22	0.08	0.017
Slow decay (i.e. plastics)	0.23	0.02	0.004
Total			0.24

Table 6 above shows the k value produced by Bantargebang TPST in the composition of the waste (55%) decomposes rapidly, (22%) decomposes slowly, (23%) decomposes slowly.

From a study result of Sei Beringin waste processing in Riau, Indonesia, the methane potential value is calculated from anaerobic process considering the density, pH, temperature, water composition, and type of waste in which acquires a L_o Value of 68 m^3/years [20] Here is the calculation of the potential amount of gas stocked up to 1 year at Bantargebang TPST Methane (L_o) gas produced is assumed to be 68 m^3 / year, based on the characteristic assumption for the tropical region almost the same.

$$Qt = 2 * 68 * 2.251.987,41 * (e^{0,24} * 1 - 1) * e^{-0,24*1} = 65.349.546,39\ m^3/year$$

For the next calculation, using the same equation is only different in the increasing year. The following figure 2 describes the results of the overall calculation from the first year to the twentieth year:

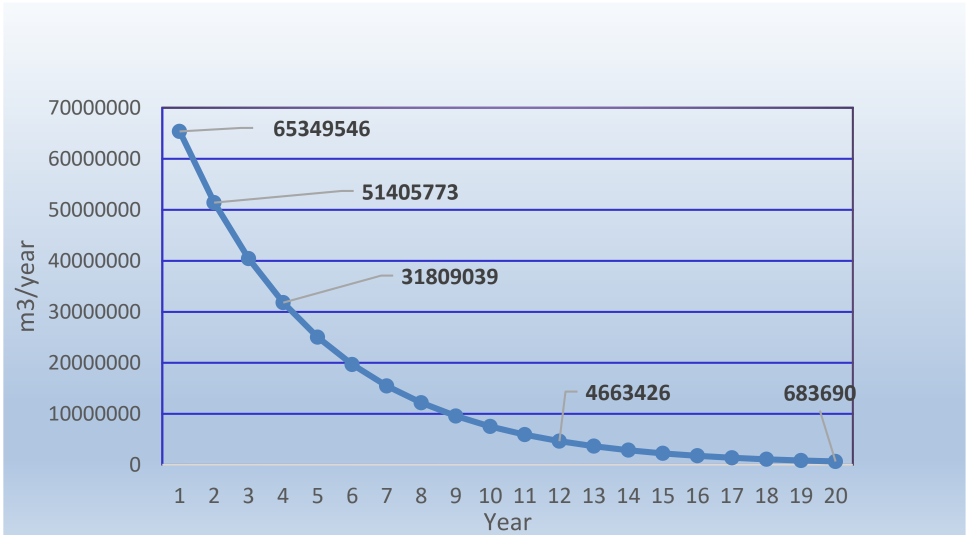

FIGURE 2. Potential amount of Gas in m^3/year

As seen in the figure 2 above, in the first year, 65.349.546,39 m^3 of methane gas are produced in Bantargebang Integrated Waste Disposal Facility (TPST) and then in the 20^{th} year, the production of methane gas are significantly dropped by 683.690 m^3.

System Evaluation Analysis on Bantargebang Waste Power Plant

Based on the calculation of the potential utilization of waste used in PLTSa Bantargebang the potential is very large, the utilization of the potential of waste or landfill gas is not maximized by PLTSa Bantargebang so that the electricity power that can be produced in 2017 is only 250 KW. Some of the factors in the small efficiency of PLTSa Bantargebang are that the landfill gas collection system is very inefficient, this is caused by the use of landfill gas collection without capping so that a lot of untapped landfill gas potential evaporates into the air. In addition, the use of landfill gas suction pipe extraction wells that only use a horizontal system that has considerable losses, when compared with the vertical installation of gas-sucking landfill pipe extraction wells.

Analysis of the Use of Vertical Piping Systems to increase Bantargebang Power Plant Landfill Gas Production

The piping system at PLTSa Bantargebang currently only uses horizontal piping installations. The background of horizontal pipe use in PLTSa Bantargebang is irregular waste disposal, if applied with vertical pipes it will be easily damaged or buried by the garbage piled up in Bantagebang TPST. In the use of a vertical pipe system, geomembrane or capping is used to cover the rubbish mound so that the maximum landfill gas is produced, so that if it is forced to use a vertical piping system, Bantargebang TPST officers must maintain extracted wells to utilize landfill gas in the waste. There is no activity done in a special area of collection of gas landfills. If the purpose of the Bantargebang TPST system is to produce electricity, the Bantargebang TPST must use a vertical piping system with capping to increase the effectiveness of gas landfill utilization and also to increase the potential of the electrical energy produced later.

Analysis of the Use of Capping on Bantargebang Waste Power Plant Gas Collection

Collection efficiency is very dependent on the design and maintenance of the collection system as well as the materials used to cover the landfill. Here evaluates by using geomembrane-based capping with a collection efficiency typical of 90% to 99% of gas not coming out into the air. In addition, with landfill conditions that not only produce gas, but also produce leachate, mud, etc. Therefore, the pipes that suck gas from the landfill will not completely suck the gas, but will also suck up the other contents. With the difference in value between 60% to 95%, Optimization of the use of PLTSa is to use geomembrane capping and vertical pipe use in collecting existing landfill gas. The production of electricity produced by landfill gas and methane gas is as follows:

$$The\ amount\ of\ gas\ produced\ (m^3/year) = 60\%\ x\ 65.349.546,39 = 39.209.727{,}6\ m^3/year$$

The Landfill Gas Efficiency Value is taken at least 60%, from the value of Gas Landfill efficiency 60% to 90% For the calculation of the following year using the same equation is only different in Qt = the amount of potential landfill gas in each year. Figure 3 below shows the calculation of Recoverable Gas from The amount of Gas Production

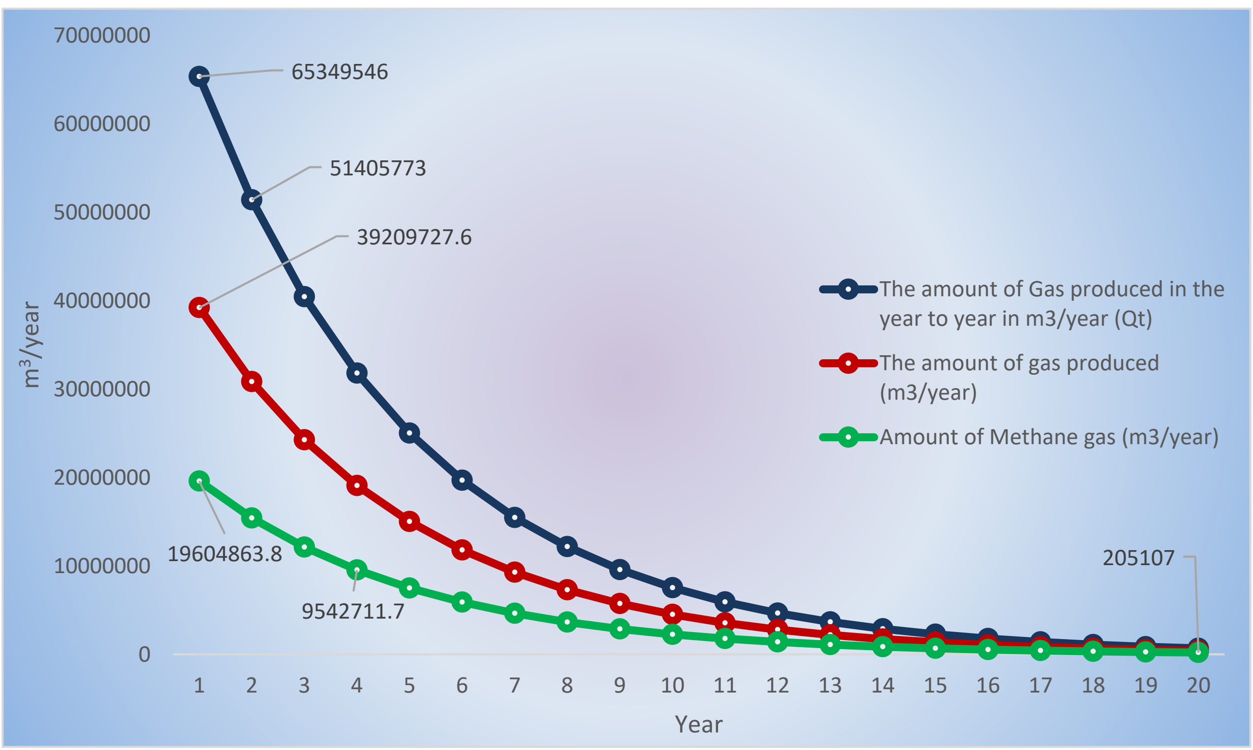

FIGURE 3. Recoverable Methane Gas

From the amount of LFG produced after being calculated with the efficiency of using *capping*, however, the content in the gas still consists of several other gases, such as CO_2 carbon dioxide, methane gas (CH_4), carbon monoxide (CO), ammonia (NH_3), nitrogen (N_2) , hydrogen sulfide (H_2S), and oxygen (O_2). In determining the methane gas contained in landfill gas from the PLTSa Bantargebang system using capping (cover) can be seen as follows:

$$Amount\ of\ Methane\ gas\ (m3/(year\ ))\ =\ 50\%\ x\ 39.209.727{,}6\ \ =\ 19.604.863{,}8\ m3/year$$

From potential methane gas produced by Bantargebang Integrated Waste Disposal with a *capping* increase on the gas collection system, then the generated electrical potential could also be determined. Electrical potential calculation generated by Bandargebang Integrated Waste Disposal as follows:

$$Amount\ of\ electricity\ energy\ =\ 19.604.863{,}8\ x\ 9{,}39\ KWh\ x\ 86{,}2\%\ \ =\ 158.317.117.1\ kWh/year$$

For the calculation of the following year using the same equation, only different methane gas is produced each year. And the conversion of KWh to KW uses the formula below:

$$Power\ Calculation = 158.317.117.1: 12\ :\ 30\ :\ 24\ =\ 18.323{,}74\ \ kW\ \ =\ 18{,}3\ MW$$

The potential of PLTSa electricity can be seen in the following table:

TABLE 7. Potential Electricity produced

Year	Methane Gas Amount (m^3)	Energy (kWh/year)	Power (kW/hour)	MW
1	39.209.727,6	19.604.863,8	18.323,74	18,3
2	30.843.463,8	15421731.9	14.413.96	14,4
3	24.262.328,4	12131164.2	11.338.43	11,3
4	19.085.423,4	9542711.7	8.919.122	8,9
5	15.013.125,6	7506562.8	7.016.03	7,0
6	11.809.743	5904871.5	5.519.005	5,5
7	9.289.873,2	4644936.6	4.341.403	4,3
8	7.307.673	3653836.5	3.415.068	3,4
9	5.748.418,8	2874209.4	2.686.388	2,6
10	4.521.866,4	2260933.2	2.113.187	2,1
11	3.557.026,2	1778513.1	1.662.292	1,7
12	2.798.055,6	1399027.8	1.307.605	1,3
13	2.201.028,6	1100514.3	1.028.599	1,02
14	1.731.390,6	865695.3	8.09.1245	0,80
15	1.361.959,8	680979.9	6.36.4798	0,63
16	1.071.355,8	535677.9	500.6728	0,50
17	842.758,2	421379.1	393.8431	0,39
18	662.937	331468.5	309.808	0,30
19	521.484,6	260742.3	243.7035	0,24
20	410.214	205107	191.7038	0,19

Waste Management in PLTS Bandar Gebang

PLTSa Bantargebang which has been running for almost 8 years, but electricity generation is still far below the target. The installed capacity of PLTSa in Bantargebang TPST is 15.6 MVA. Some of the constraints of PLTSa Bandar gebang management are:

a. From the 10 gas engine units that haven’t been repaired, some needs to be overhauled, it is very important to restore optimal gas engine performance. The gas engine must be checked carefully and if damage is found to the component engine, it will be replaced immediately. Periodic checks in the future must be carried out so that damage can be detected early.

b. PLTSa Bandargebang's breaking down the acquisition of methane gas is less optimal due to the condition of the waste not being in a closed space which makes some of the gases leaking out.

c. The absence of a legal that specifically regulates the problem of PLTSa. PLTSa is only sheltered by ESDM Minister Regulation No 19/2013 concerning Electricity Purchases by PT PLN from City Waste Based Power Plants.

d. Investment in the relatively expensive PLTSa sector requires security guarantees from the government. This means that there must be a risk of costs that will be subsidized by the government

. CONCLUSION

Based on the results of the evaluation study of the Bantargebang garbage power plant (PLTSa) and the calculations that have been made, conclusions can be taken as follows:

1. Based on the analysis of Waste in Bantargebang TPST, the volume of waste with an average of 6,169.83 tons / day or reached 2,251,987.41 tons / year with a percentage of 55.37% organic waste is very possible to maximize the potential of PLTSa in Bantargebang.
2. Utilizing the potential of landfill gas with the use of capping and vertical pipes in Bantargebang TPST based on the amount of waste in the first year reaching 65,349,546.39 m3 / year with gas that can be utilized reaching 39.209.727,6 m3/year and methane gas 19.604.863,8 m3/year and Power Electric Production PLTSa = 18,3 MW
3. From the potential calculation of methane gas, it can be seen that the electricity potential in the first year reaches 18,3 MW and decreases in the following years to twenty years by 0.19 MW. This situation becomes direr with electricity generation in 2017 which only generates 250 KW of power.
4. Out of the 10 damaged PLTSa Bantargebang gas engines, the next step is to overhaul the gas engine for a very careful inspection to find out the damaged components to repair and replace damaged components. Furthermore, there is a need to apply preventive actions to prevent future damages. If the 10 gas engines are active, then the power plant will be able to produce 15.6 MVA.
5. In order to improve Bantargebang power plant in the future, the management system needs to be changed and emphasize the use of landfill gas recovery to minimalize methane gases' negative impact on the environment.

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