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Study of Electrical Energy Potential Using Plasma Gasification through Garbage Conversion in Ketapang City

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----------*ABSTRACT*----------
Economic growth and population growth are harmonious in the development of an urban area. In line with this process, problems will arise, including the problem of landfill that continues to increase every year and also as a cause of environmental pollution. One of the New and Renewable Energy technologies (EBT) that can reduce landfill and environmental pollution by using waste as raw material is the Waste Power Plant (PLTSa) with plasma gasification. In this plasma gasification process all types of waste that enter the gasifier reactor will all be destroyed and produce residues that have economic value and synthetic gas that can be used as fuel for electricity generation. This thesis has analyzed the potential of Ketapang City waste that can be converted into electrical energy. The results obtained are that every 1 (one) ton of waste can produce electrical energy of 787.5371 kWh. From the data obtained during 5 years with the amount of waste as much as 37,902.47 tons can produce electrical energy of 298,493.47 MWh with a sale value of Rp. 1,222,596,555. With an interest rate of 12%, the plant production costs are Rp.1,301.04 / kWh. Based on the calculation results of data analysis, PLTSa Waste Power Plant with plasma gasification is one of the effective and environmentally friendly technologies as a solution in dealing with the problem of waste compared to open landfill and landfilled waste.
KEYWORDS;*Electric Energy, Plasma Gasification, Waste, Synthetic Gas.*

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I. INTRODUCTION

Ketapang Regency is the largest regency among 14 (fourteen) Regencies / Cities in West Kalimantan Province with an area of 31,588 km2 with a population of currently around 485,118 people with a population growth rate of 2.15 percent per year. The population density is Ketapang in Delta Pawan District, which is around 1,147 people per km2 with the population in Delta Pawan District in 2016 around 84,868 people. With a large population, it can produce waste amounting to 43,950 m3 / year. The final landfill (TPA) owned by Ketapang City is in the Awan River area of Muara Pawan District, which has an area of around 10 ha.

Handling the waste problem in Ketapang City is still very simple. There are some garbage bins that still use human labor to clean and transport them, others also use automatic bins that can be directly transported by garbage trucks placed around community settlements which are temporary dumpsites (TPS). Garbage is mounting in almost all TPS locations and scattered outside the garbage bin. Sometimes the amount of garbage that is not accommodated, the amount is more than the amount of garbage that is in the trash. Not to mention the behavior of the people who often throw garbage in any place. Waste that has a lot of economic value by changing waste into raw materials that can produce energy. Referring to the amount of garbage in the city of Ketapang that has not been utilized so that it has no economic value, pollutes the environment and is only piled up in a landfill. In a long time this garbage will continue to grow. Therefore waste needs to be utilized by conducting research to find out how much the potential waste in Ketapang city can be converted into electrical energy with plasma gasification technology.

To limit the discussion to fit the problem identification, the scope of the study includes:

The type of waste or urban waste that will be used as an energy source is garbage in Ketapang City.

1. Data on the amount of waste collected is sourced from the Department of Housing and the Environment in Ketapang Regency.
2. The waste processing technology used as a source of electrical energy is plasma gasification.
3. The result of plasma gasification that will be used as a source of power generation for waste is synthetic gas.
4. The calculation of the price of electricity sales based on the Minister of Energy and Mineral Resources Regulation No. 27 of 2014 concerning the purchase of electricity for biomass Rp. 1,150,- / kWh x F, with F equal to 1.30 for the Kalimantan region.
5. Type of plasma gasification technology used with a capacity of 120 m3 per day.

The exchange rate of the rupiah against the dollar in this study uses the assumption of Rp. 15,000 per dollar.

The method used in this study is to calculate the potential of waste that can be converted into electrical energy with plasma gasification, so it is known the potential contribution of electrical energy produced. In the economic analysis of electricity this leads to the calculation of investment costs for electricity generation, operational costs, maintenance costs and the value of sales of electricity produced during the year. To find out the cost of electricity production per kWh, generating income and investment it is necessary to analyze the economic and financing aspects.

1. Electric Energy Prices

The price of electricity for each power plant is different which is calculated based on the following parameters:

a. Cost of generation per kWh
b. Operating costs per kWh
c. Maintenance costs per kWh
d. Interest rate
e. Depreciation
f. Operating age
g. Power generated

2. Capital Cost

Capital costs are all expenditures needed during the project, from pre-survey to the completion of the project. The cost of capital is influenced by interest rates and the economic life of a plant. Capital costs include:

a. Survey work costs
b. Civil works costs
c. Costs of mechanical and electrical work
d. Distribution network work costs
e. Indirect costs (unexpected costs)

Capital costs (CC) are formulated in the following equation:

$$\text{Capital Costs} = (\text{Construction Costs x CRF})/E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

$$\text{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

Where:
Construction costs = construction cost (Rp)
E = energy produced (kWh)
CRF = Capital Recovery Factor
i = interest rate in 2017
n = year

3. Operational and Maintenance Costs

Operational and maintenance costs are all costs used during the operation of the plant. Operational and maintenance costs include fixed costs, i.e. costs that are not related to the amount of electricity generated by the plant and variable costs, which are costs associated with expenditures for equipment and maintenance used in short periods and are dependent on the amount of electricity produced.

4. Fuel Costs

In this generator uses fuel from waste. Therefore, this plant does not incur fuel costs. However, fuel costs are the operational transportation of waste from the TPS location to the Generation site.

5. Total Cost

Total costs are the sum of capital costs, operational costs and fuel costs in a year. The total cost can be formulated as follows:

$$\text{Tot Cost} = \text{Cp Cost} + \text{Op Cost} + \text{F Cost} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

Where:
Tot Cost = Total Cost
Cp Cost = Capital Cost
Op Cost = Operational Costs
F Cost = Fuel Cost

6. Revenue per Year (Cash in Flow)

Income per year is formulated in the following equation:
Revenue = (H x P) - (BTotal x E) …… (2.7)
Where:
H = Selling price (Rp / kWh)
P = Power sold (kWh)
BTotal = total generation cost (Rp / kWh)
E = Energy generated (kWh)

II. RESULTS AND DISCUSSIONS

The types and characteristics of waste in the Sungai Awan landfill consist of several types as in Table 4.1
Types and Characteristics of Waste in the City of Ketapang

No	Waste Type	Percentage (%)
1.	Paper	Other 0.5
2.	Glass	0.5
3.	Plastic	77.0
4.	Metal	0.5
5.	Wood	0.5
6.	Rubber	0.5
7.	Organic	20.0
8.	Other	0.5
Total		100

Amount of Waste Production in Ketapang City

No	Type	Units	Year				
			2013	2014	2015	2016	2017
1	Total population	Souls	78.438	80.612	83.268	84.868	88.180
2	Amount of Waste Production	M^3/th	42.944.805	44.135.070	45.589.230	46.465.230	48.278.550
3	Amount of Waste Volume transported to landfill	M^3/th	14.314.935	17.645.028	21.274.974	24.781.456	28.967.130
4	Amount of Waste Production	Ton/Day	196.095	201.530	208.170	212.170	220.450
5	Amount of Waste Volume transported to landfill	Ton/Day	65.365	80.571	97.146	113.157	132.270
6	Percentage of Trash transported	%	33	40	46	53	60

Waste management in the Sungai Awan landfill is carried out with an open dumping system or with an open pile where rubbish is only piled up at the landfill site so that later the location used will be increasingly reduced and of course the additional landfill site needs to be added. This open dumping system has the potential to pollute the surrounding environment, such as air pollution by odors and gases produced, water pollution due to leachate (liquid waste) that arises as well as poor environmental aesthetics due to dirty scenes.

Analysis of Potential Electric Energy from Waste in Ketapang City
To calculate the potential electrical energy from waste in Ketapang City, the steps are as follows:
a. Determine the amount of weight of waste to be calculated;
b. Determine the amount of waste calorie value based on the assumption of raw material sources (calorie value of municipal waste = 2200 kcal / kg);
c. Determine the amount of energy output to heat input (1 kcal = 0.001163 kWh);
d. Determine the amount of energy produced through the plasma gasification process (assuming the energy produced in the reactor gasifier has 80% efficiency in covering waste energy into synthetic gas and has 10% losses from the gasification process) [12];
e. Determine the amount of electrical energy generated from the process of generating electricity by the electric energy generation system (assuming the generating system uses IGGC technology that has an efficiency of 45%) [17];
f. Determine the amount of electrical energy that can be used in the electricity system in Ketapang City (assuming the energy used for this process (self-use) is 5% of the total energy generated) [20].
The amount of electrical energy that can be generated from 1ton of waste is as follows:
- The amount of garbage calories value = garbage weight (kg) x garbage calorie value (kcal / kg)
= 1000 x 2200= 2,200,000 kcal
- Energy to heat input = 2,200,000 kcal x 0,001163 kWh / kcal
= 2,558.6 kWh
- Energy produced through the plasma gasification process
= 80% x 90% x 2,558.6 kWh
= 1,842,192 kWh

- Electricity generated by the IGGC system
= 1,842,192 kWh x 45%
= 828,9864 kWh
- Total electrical energy generated after reducing the power used alone.
= 828.9864 - (828.9864 x 5%)
= 787,5371 kWh.

So that for 1 ton of waste can be converted into electrical energy of 787.5371 kWh.

1. Electrical Energy Potential Analysis in 2013

The amount of waste produced by the City of Ketapang in 2013 was 196.095 tons / day, so the total potential of electric energy produced is as follows:

- Production of electricity generated per day = 196,095 tons / day x 787,5371 kWh
= 154432.09 kWh
= 154.43 MWh
- Power that can be generated = 154.43 / 24 = 6.43 MW

2. Analysis of Electric Energy Potential in 2014

The amount of waste produced by the City of Ketapang in 2013 was 201.53 tons / day, so the total potential of electricity generated is as follows:

- The production of electricity generated per day = 201.53 tons / day x 787.5371 kWh
= 158712.35 kWh
= 158.71 MWh
- Power that can be generated = 158.71 / 24 = 6.61 MW

3. Analysis of Electric Energy Potential in 2015

The amount of waste produced by the City of Ketapang in 2015 was 110.9 tons / day, so the total potential of the electric energy produced is as follows:

- The production of electricity generated per day = 208.17 tons / day x 787.5371 kWh
= 163941.60 kWh
= 163.94 MWh
- Power that can be generated = 163.94 / 24 = 6.83 MW

4 Analysis of Electric Energy Potential in 2016

The amount of waste produced by the City of Ketapang in 2016 amounted to 212.17 tons / day, so the total potential of electricity generated is as follows:

- The production of electricity generated per day = 212.17 tons / day x 787.5371 kWh
= 167091.75 kWh
= 167.09 MWh
- Power that can be generated = 167.09 / 24 = 6.96 MW

5 Analysis of Electric Energy Potential in 2017

The amount of waste produced by Ketapang City in 2017 is 220.45 tons / day, so the total potential of electricity produced is as follows:

- The production of electricity generated per day = 220.45 tons / day x 787.5371 kWh
= 173612.55 kWh
= 173.61 MWh
- Power that can be generated = 173.61 / 24 = 7.23 MW

From the results of calculations, the total amount of electrical energy that can be generated during the period of 2013 to 2017 is as in Table 4.2. the following:

Table 4.2. Total Potential of Electric Energy from the City of Ketapang Waste

No	Year	Waste Year (Ton / Year)	Waste (Ton / Day)	Annual Electrical Energy (MWh)	Per day Electrical Energy (MWh)	Electric Power (MW)
1	2013	71.574,675	196,095	56.367,71	154,43	6,43
2	2014	73.558,45	201,53	57.930,01	158,71	6,61
3	2015	75.982,05	208,17	59.838,68	163,94	6,83
4	2016	77.442,05	212,17	60.988,49	167,09	6,96
5	2017	80.464,25	220,45	63.368,58	173,61	7,23
Total		379.021,47		298.493,47		

Calculation Results of Analysis of Potential Electric Energy from Ketapang municipal wasteFrom the calculation results of the analysis of the electrical energy potential of the municipal waste in Ketapang can be described in graphical form as in Figure 4.1 below:

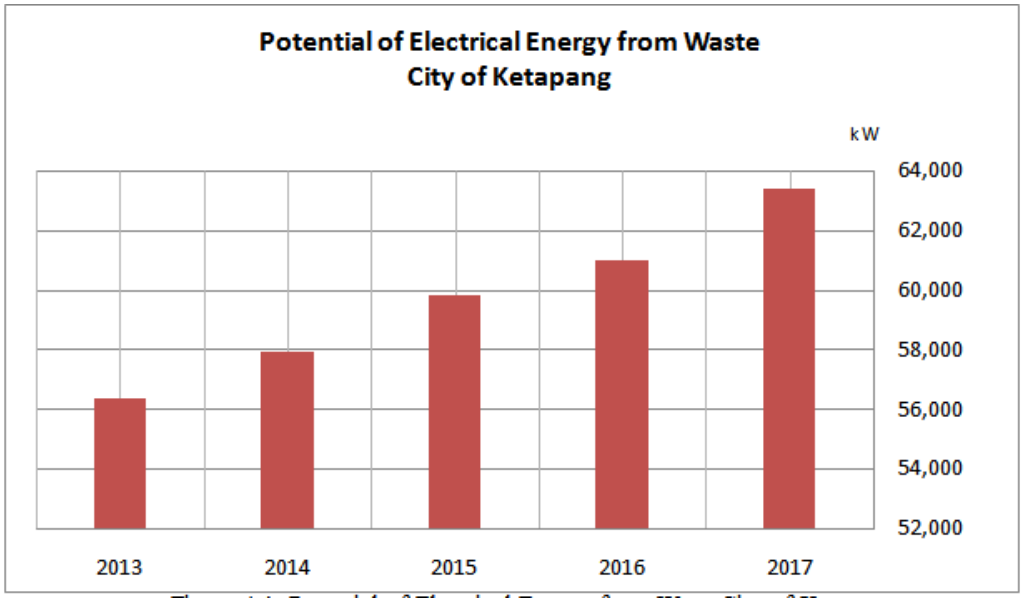

Figure 4.1. Potential of Electrical Energy from WasteCity of Ketapang

From Table 4.1 it can be seen that the potential for electricity increases from year to year in line with the increase in the amount of waste produced by the City of Ketapang.

Based on the results of calculations that with plasma gasification technology, the waste produced by the City of Ketapang can be used as an energy source for electricity generation. From the average power generated during the last five years a power plant with a capacity of 8 MW can be built. But to make it easier in the matter of maintenance of the power plant and the reliability of the electrical system, 2 power plants with a capacity of 2 x 2 MW can be built. In this case, with the construction of two power plants that have each capacity of 2 x 2 MW, it is expected that economic scheduling can be carried out alternately to serve the load and maintenance of the power plant.

a. Potential Analysis of Electric Energy Sales

Based on the Minister of Energy and Mineral Resources Regulation No. 27 of 2016 concerning the purchase of electricity for biomass Rp. 1.150, - / kWh x F if interconnected at medium voltage by PT. PLN (Persero) with the magnitude for the Kalimantan region, F = 1.30, the annual revenue f
rom the sale of electricity from waste can be seen in Table 4.3

Table 4.3. The Economic Value of Converting Waste into Electrical Energy

No	Year	Electricity Sales Value (Rp)
1	2013	230.875.971
2	2014	237.274.966
3	2015	245.092.689
4	2016	249.802.161
5	2017	259.550.768
Total		1.222.596.555

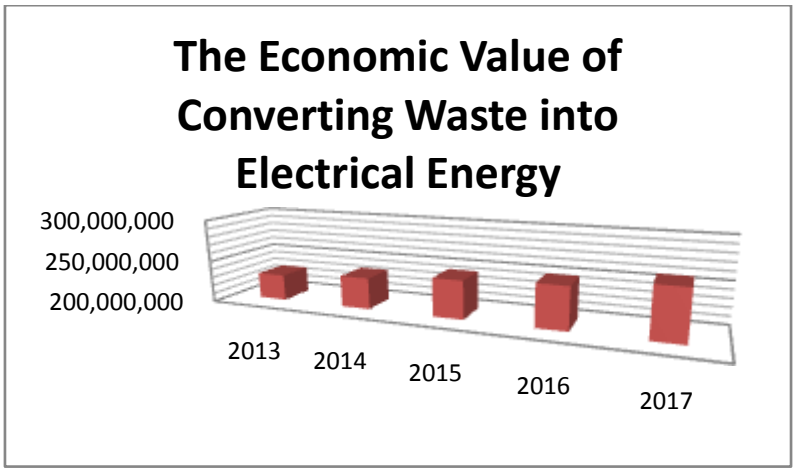

Figure 4.2. Graph of Economic Value of Converting Waste into Electrical Energy

From Table 4.3 we can see the results of electricity sales for 5 (five) years amounting to Rp 1,222,596,555 from the waste produced by the City of Ketapang. In addition, other economic value results are the residual results of the plasma gasification process in the form of slag which can be sold for use as construction materials.

Economic Analysis

Economic analysis is needed to determine the cost of producing electricity per kWh. In determining these costs required data such as investment costs for the construction of a power plant, operational costs, maintenance costs and fuel costs. The costs mentioned above using technical economic analysis will be calculated the costs that will be incurred for a year (annual cost).

a. Capital Cost Calculation (BCapital)

To build a PLTSa with the assumption that the capacity to be used is an average of 200 tons per day using plasma gasification technology. Based on reference [22] the capital cost required to build a PLTSa with a capacity of 1000 tons per day is US $ 150,000,000.00. Assuming a currency value of 1 US Dollar equals Rp. 15,000.00, and an increase factor [23] of 1.1, an investment cost of generating a 200 ton per day capacity of Rp. 495,000,000,000.00. With a loan interest rate of 6%, 9%, and 12% and the economic life of the plant is 25 years, it can be calculated for the following capital costs:

1. Calculation of Capital Costs (Revenue per Year):

For interest rates (i) = 6%, CRF = 0.078
For interest rates (i) = 9%, CRF = 0.10
For interest rates (i) = 12%, CRF = 0.127

2. Calculation of Capital Costs:

- For interest rates (i) = 6%

Capital = = IDR 495,000,000,000.00 x 0,078) / (200 x 365 x 787,5371 kWh)= Rp. 671.59 / kWh

- For interest rates (i) = 9%

Capital = = Rp. 495,000,000,000.00 x 0,10) / (200 x 365 x 787,5371 kWh)= Rp. 861.02 / kWh

- For interest rates (i) = 12%

BCapital = (Rp. 495,000,000,000.00 x 0,127) / (200 x 365 x 787,5371 kWh)= IDR 1093.49 / kWh

b. Calculation of Operating and Maintenance Costs (BOperational).

The operational and maintenance costs for PLTSa with plasma gasification are assumed to be 5 percent of the investment costs. The operational and maintenance costs for this plasma gasification technology plant are assumed to be twice the operational and maintenance costs of conventional PLTSa (incineration technology). So that the annual operational and maintenance costs are Rp. 24,750,000,000.00.

Operational and maintenance costs per k wh can be calculated as follows:

BOperational = (Rp. 24,750,000,000.00) / (365 x 200 x 787,5371 kWh) = Rp. 430.50 / kWh

c. Fuel Cost Calculation (Fuel Fuel)

For PLTSa with plasma gasification technology, no fuel costs are needed. However, the cost required is to transport waste from TPS located in Ketapang City to Sungai Awan Landfill (100 Liters / Vehicle / Day) with a total of two vehicles. The amount of the fee is Rp.547,500,000.00 per year.

The cost of fuel per kWh can be calculated as follows:

Fuel Fuel = (Rp. 547,500,000.00) / (365 x 200 x 787,5371 kWh) = Rp. 9.52 / kWh

d. Calculation of Total Generating Costs per year.

Estimated calculations for capital costs, operational costs, maintenance costs and fuel costs assuming loan rates of 6%, 9% and 12% and the economic life of PLTSa for 25 years can be seen in the following table.

Table 4.4. Total Cost of PLTSa Plasma Gasification Plant per kWh.

Loan	6% Interest Rates (Rp / kWh)	9%Loan Interest Rates (Rp / kWh)	12% Loan Interest Rate (Rp / kWh)
Capital Costs	671,59	861,02	1093,49
Operational and Maintenance Costs	430,5	430,5	430,5
Fuel Cost	9,52	9,52	9,52
Total	1111,61	1301,04	1533,51

e. Annual Revenue (CIF)

Assuming the sale price of electricity used for 2017, the annual opinion (CIF) can be calculated as follows:

- For interest rates (i) = 6%

CIF = 259,550,768 - (1111.61 x 63368.58 x 1000) = Rp. 70,181,596,446

- For interest rates (i) = 9%

CIF = 259,550,768 - (1301.04 x 63368.58 x 1000) = Rp. 82,185,506,555

- For interest rates (i) = 12%

CIF = 259,550,768 - (1533.51 x 63368.58 x 1000) = Rp. 96,916,800,348

Table 4.5. Annual income

Income	6% interest rates (Rp / kWh)	9% Loan interest rates (Rp / kWh)	12% Loan Interest Rate (Rp / kWh)
Income per year	70.181.596.446	82.185.506.555	96.916.800.348

III. CONCLUSIONS

Based on the results of the research that has been done, several conclusions can be drawn, including:

1. Plasma gasification is a New Renewable Energy technology that is effective in creating a Ketapang city that is clean from waste. Calculation results obtained for 1 ton of waste produce electrical energy of 787.5371 kWh. With the amount of waste that can reach 220.45 tons / day in 2017 in the city of Ketapang, power can be generated by 7.23 MW, and the electricity generated by 63.368.58 MWh / year.
2. From the results of calculations for the last 5 (five) years, from 2013 to 2017 379,021.47 tons of Ketapang municipal waste can produce electricity.
3. amounting to 298,493.47 MWh. So that the estimated electricity sales will reach Rp. 1,222,596,555. This potential is very large considering that at present the waste does not have economic value and requires a significant amount of cost in its management.
4. From the calculation results obtained generator costs per kWh for a loan interest rate of 6% is Rp. 1,111.61 / kWh, for a 9% loan interest rate is Rp. 1,301.04 / kWh and for a 12% loan interest rate is Rp. 1,533.51 kWh assuming an economic age is 25 years. While the annual income with the assumption as the basis of calculation is for 2017 and for the amount of value sold is fixed and the total cost is fixed, it is obtained for an interest rate of 6% of annual income of Rp. 70,181,596,446, for an interest rate of 9% annual income of Rp. 82,185,506,555 and for an interest rate of 12% annual income of Rp. 96,916,800,348

5.2. Suggestion

Suggestions that can be given to various parties are as follows:

1. For academics this research can be developed in terms of the analysis of techno-economic aspects.
2. As input for the Ketapang District Government that based on the results of calculations with an average electric energy capacity that can be generated at 7.23 MW. For this reason, it is recommended that if the Regional Government is interested in investing, it is recommended to build 2 units of 2 x 2 MW plasma gasification PLTSa.
3. For the Regional Government of Ketapang Regency, it can study more deeply in planning and building this PLTSa by collaborating with investors so that the PLTSa can be realized.
4. For the Regional Government of Ketapang Regency, it can also socialize waste management starting from the starting point of the house waste to the end point, namely the final killing location.
5. For the Regional Government of Ketapang Regency, it can add temporary landfills and add waste transportation equipment from the TPS to the TPA.

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