Economic analysis of waste power plants based on the economic scale - Case study Merah Putih waste power plant

Hendrik Amrico* and Rinaldy Dalimi

Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, **Indonesia**

*Corresponding Author: hendrik.amrico@ui.ac.id
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Abstract: Jakarta's dense population creates problems with the high daily waste production, which reaches 7,500 tons. On the other hand, the open dumping method in the final waste treatment creates another problem in the form of greenhouse gas emissions. The regional government also issued a policy to reduce greenhouse gas emissions to achieve net zero emission by 2050. The solution that then emerged for the two problems above was to convert waste into electrical energy through incineration technology. This study aims to conduct an economic analysis in the context of implementing incineration technology. The results showed that the minimum capacity for economic feasibility was 8 MW with an LCoE of IDR 2,578.32/kWh, 429 tonnes of waste per day, an IRR of 8.63%, and an NPV of IDR 115,038,835,638.12 at an investment value of IDR 505.877.074.317.

Keywords: PLTS Merah Putih; Economic analysis; Waste to energy; Incineration power plant

1. Introduction

Jakarta, as the capital city of Indonesia, serves as the hub of most economic activities in the country. Spanning an area of approximately 664.01 km2, Jakarta is home to a population of 10,748,230 inhabitants (BPS DKI Jakarta, 2023), making it one of the most densely populated cities in Indonesia. Such population density results in high economic activities, including industries, commerce, government, transportation, and energy. However, these extensive economic activities have a significant impact on the production of waste in Jakarta.

According to data from the Jakarta Provincial Environmental Agency (DLH), the total daily waste entering the Bantargebang Integrated Waste Treatment Facility (TPST) amounts to 7,500 tons. Organic waste, plastic waste, paper, and wood comprise the largest compositions, accounting for 48.87%, 22.95%, 17.24%, and 3.18% (DLH DKI Jakarta, 2023). Unfortunately, not all of this waste can be adequately processed. A substantial portion of it ends up in open dumping areas within the Bantargebang waste management facility owned by the Jakarta Provincial Government. Figure 1 and figure 2 illustrate the waste received at the Bantargebang TPST facility and its composition.

On the contrary, the substantial quantity of readily decomposable waste found in open dumping sites undergoes a process of decomposition, which subsequently leads to the emission of greenhouse gases (GHGs). Greenhouse gas (GHG) emissions from waste decomposition in open dumping sites are a significant contributor to Jakarta's total GHG emissions. In fact, they rank among the top five sources, constituting approximately 5% of the city's overall GHG emissions. These facts emphasize the critical importance of implementing appropriate waste management systems in order to effectively reduce waste accumulation and mitigate GHG emissions. It is crucial to prioritize sustainable waste management practices that minimize the amount of waste sent to open dumping sites, thereby reducing the associated GHG emissions. By implementing proper waste management systems, Jakarta can work towards achieving its environmental goals and contribute to global efforts in mitigating climate change (DLH DKI Jakarta, 2022).

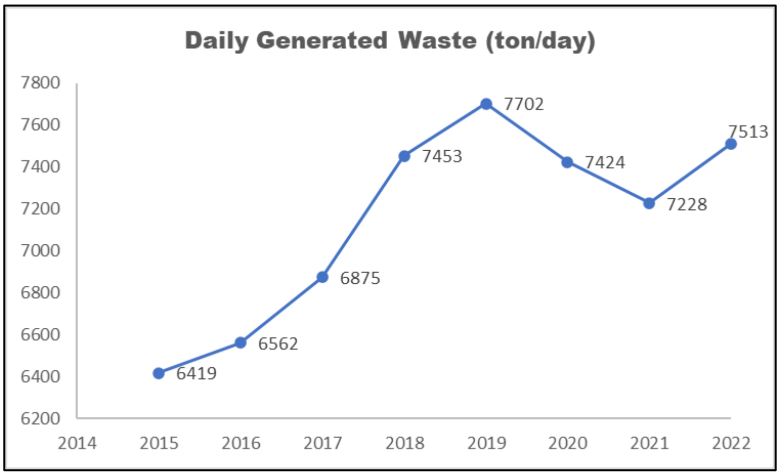

Figure 1. Waste generated in Jakarta

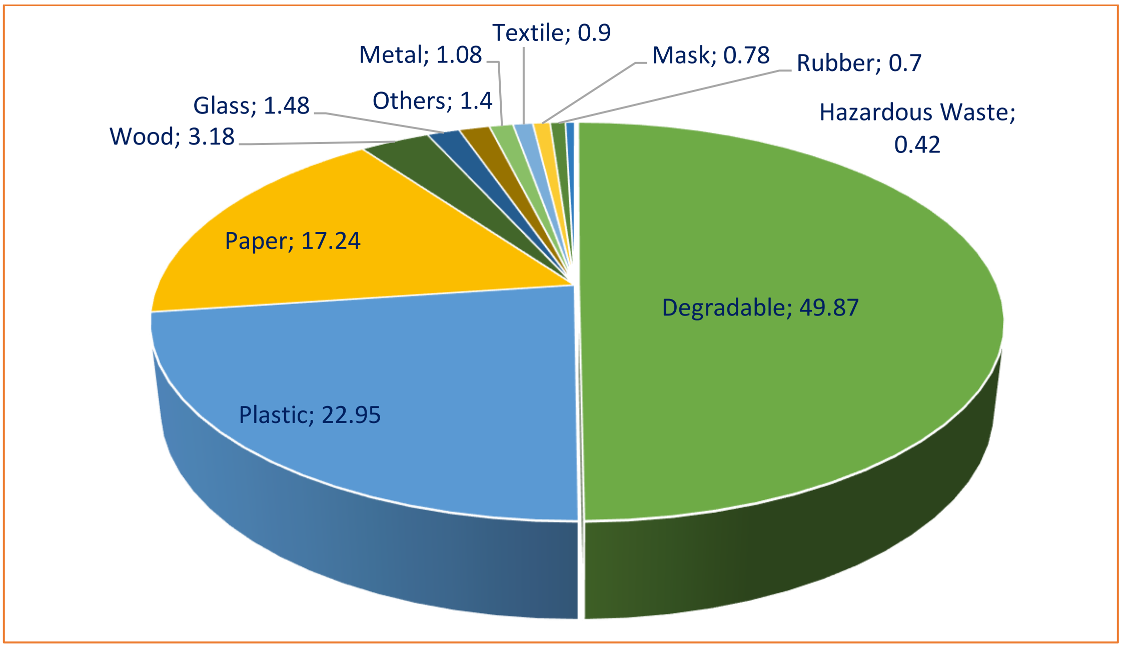

Figure 2. Waste composition of Jakarta MSW

DKI Jakarta is one of 12 cities to accelerate the construction of installations for processing waste into electricity based on environmentally friendly technology, as mandated by Presidential Decree No. 35 of 2018 (Perpres, 2018). In 2019, the Merah Putih waste-to-energy power plant (PLTSa) was constructed in the Bantargebang TPST area and began operations in 2020. The Merah Putih PLTSa project in Bantargebang serves as an excellent role model for waste reduction efforts. According to data from the Jakarta Provincial Environmental Agency (DLH), the waste reduction capability of the Bantargebang PLTSa exceeds 80%. This achievement has a significant impact on the plans of the Jakarta Provincial Government to reduce greenhouse gas emissions and achieve the net zero emission (NZE) target by 2050 (Pergub, 2021).

The Merah Putih waste-to-energy power plant (PLTSa) has a processing capacity of 100 tons of waste per day. Using incineration technology, this waste is converted into electrical energy, generating 750 kW of electricity, as well as producing heat, fly ash, and bottom ash (FABA). The fly ash is further processed into construction materials such as bricks, while the bottom ash is collected and sent to a landfill. Based on quality control tests conducted on the combustion by-products, the results indicate that they fall within safe limits.

Numerous studies have been conducted both domestically and internationally to analyze the economic aspects of waste-to-energy power plants (PLTSa). (Octavianthy & Purwanto, 2019) have studied that the incineration technology has the lowest LCoE than anaerobic technology. One such study conducted (Muhammad Ilham Amba & Dalimi, 2023) examined the feasibility of renewable energy based on parameters such as the levelized cost of electricity (LcoE) and net present value (NPV). Another research conducted by (Cucchiella et al., 2017), demonstrated that waste-to-energy power plants reduce carbon emissions compared to landfills. Additionally, estimating the potential energy from non-degradable waste is also an important aspect. This provides a solution to waste-related issues and supports energy resilience, as stated by (Bangun et al., 2019). However, these studies have not been conducted based on existing conditions but rather on estimated values. Therefore, this study focuses on an economic analysis based on actual data from existing waste-to-energy power plants, taking into account economies of scale. With this approach, it is hoped to provide a clearer understanding of the economic factors involved in the operation of incineration WtE and the potential long-term profitability and investment feasibility.

2. Methods

This study focuses on the economic analysis of a waste-to-energy power plant using incineration technology, based on primary data collected through interviews and site visits to both the Merah Putih waste power plant (and the DKI Jakarta Environmental Agency (DLH). Table 1 presents the investment costs, operational costs, and technical data of the Merah Putih waste power plant. Figure 3. Shows the simulation process of the plant.

Table 1. Data parameters of Merah Putih WtE Plant

Parameters	Value
Investment Cost	RP 118.000.000.000
Construction Cost	Rp 98.000.000.000
Pre-treatment construction cost	Rp 20.000.000.000
O&M Costs	Rp 20.964.672.664
WtE operational and maintenance	
Pre-treatment operational and maintenance	
Steam Turbine Generator capacity (kW)	750
Maximum capacity (kW)	1000
Project Lifetime (years)	25
Power self-use (kW)	350
Waste capacity (ton per day)	100
Operational days a year	250

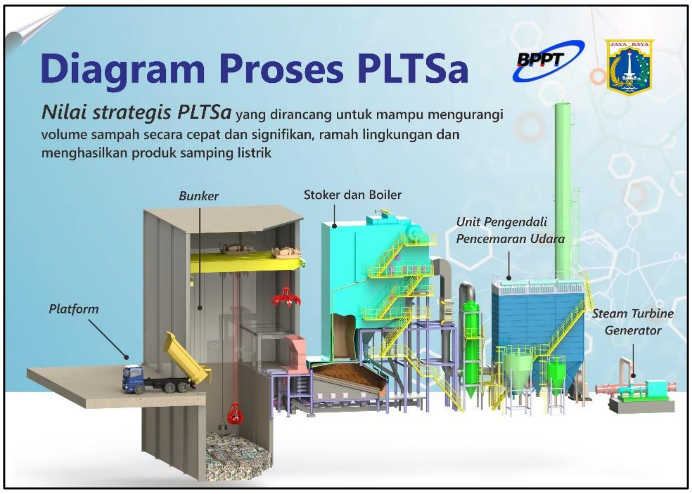

Figure 3. Merah Putih WtE diagram process

The capacity factor falls below 70% due to the presence of large-sized and non-combustible waste, necessitating operational interruptions for maintenance purposes. The current operational plan includes a 30-day period of operation followed by 7 days allocated for maintenance activities. The initial (existing) data calculations are based on the maximum power capacity of 1000 kW. The concept of economies of scale will also be taken into account when determining the associated costs of capacity enhancements. Equation (1) is utilized to perform these calculations (DJEBTKE-KESDM, 2021).

$$\frac{C1}{C2} = \left(\frac{Q1}{Q2}\right)^{\alpha} \tag{1}$$

where c denotes costs), Q denotes increase of capacity, and α denotes coefficient. This equation will be assumed to be used either for increasing of investment and O&M cost or waste capacity.

Calculate the LcoE

The Levelized Cost of Electricity (LcoE) represents the average cost of electricity production per unit of energy throughout the project's duration. It is obtained by dividing the total expenses, encompassing both initial investment costs and operational expenditures, by the total energy output during the project's lifespan. Equations (2) and (3) are utilized to calculate the LcoE, with equation (3) determining the total operational costs based on annual maintenance and fuel expenses multiplied by the project's duration.

$$\text{LCC} = I_0 + \sum_{t=1}^{n} M_t \tag{2}$$

$$LCOE = \frac{LCC}{E_t} \tag{3}$$

Where,

LCOE = cost of energy (Rp/kWh)
LCC = Life cycle cost
I_0 = total investment cost
M_t = O&M cost at period t
n = project lifetime (25)
E_t = total energy produce lifetime project (kWh)

Calculate the NPV

Net Present Value (NPV) is an economic analysis technique used to determine the present value of all cash flows generated by a project. NPV is a crucial parameter in assessing a project's economic viability. To calculate NPV, the net cash flow for each period, the initial investment cost, and the interest rate are considered. Equation (5) is used to calculate NPV, with NCF_n representing the net cash flow in period n, I_0 denoting the investment cost, and I representing the interest rate.

$$NPV = \sum_{1}^{n} \frac{NCF_n}{(1+i)^n} - I_0 \tag{4}$$

Calculate the IRR

The last parameter needed in the economic analysis of this research is IRR. IRR is a method that uses the rate of return to assess the feasibility of a project investment. Equation (5) below shows how to find the IRR value.

$$IRR = r_a + \frac{NPV_a}{NPV_a - NPV_b}(r_b - r_a) \tag{5}$$

where,

r_a = the lowest discount rate
r_b = the highest discount rate
NPV_a = NPV at required rate r_a
NPV_b = NPV at required rate r_b

In conducting a more comprehensive research, sensitivity analysis is performed on the tipping fee and power plant capacity to assess the project's feasibility under various scenarios. This analysis helps to evaluate the project's robustness and identify the range of values for the tipping fee and capacity that still yield acceptable project feasibility. By varying these parameters and observing the resulting changes in the project's financial indicators such as NPV, IRR, and LCOE, researchers can gain insights into the project's sensitivity to different factors and make informed decisions regarding its viability.

3. Results and discussion

In this research, every economic analysis is based on the BI rate of 6%, the selling price of electricity from the waste-to-energy power plant (PLTSa) at Rp 2,002.5/kWh, as stated in Presidential Decree No. 35 of 2018, with an exchange rate assumption of $1 = Rp 15,000. A coefficient of 0.7 is used for economic calculations, as per DJEBTKE-KESDM (2021). The operational period is assumed to be 310 days (0.85% capacity factor). Additionally, maintenance and operational costs (O&M) are assumed to increase by 1% annually. These assumptions provide the basis for the economic analysis conducted in the research.

Table 2. Economic analysis on existing plant

Parameter	Value
Tipping fee	Rp 500.000
LcoE (Rp/kWh)	Rp 7.547
NPV	Rp 305.936.051.430,76
IRR	-

Economic analysis based on economies of scale

Economies of scale, as described by Equation (1), will be used to assess the increase in power plant capacity, investment costs, and daily waste processing capacity. There are four capacity schemes considered for the expansion: 4 MW, 8 MW, 10 MW, and 20 MW. For each capacity calculation, tipping fee values of Rp 300,000, Rp 400,000, and Rp 500,000 are used. The economic parameters for each capacity are presented in Table 3 as follows.

Table 3. Economic parameters analysis

Capacity	4 MW	8 MW	10 MW	20 MW
Capital Cost	Rp311.403.866.942	Rp505.877.074.317	Rp591.400.935.680	Rp960.733.654.427
O&M Cost	Rp56.909.512.346	Rp92.449.775.557	Rp108.079.386.364	Rp175.575.481.141
Waste Capacity	264 tpd	429 tpd	501 tpd	814 tpd
LCoE	Rp 3.353,22	Rp2.578,32	Rp2.375,85	Rp1.855,68
Tipping Fee Rp 300.000				
NPV	Rp209.854.889.626,40	Rp54.851.851.829,90	Rp59.196.855.844,05	Rp811.311.631.388,00
IRR	-	-	7,23%	14,73%
Available PP (yr)			19 years	9 years
Tipping Fee Rp 400.000				
NPV	Rp 105.274.904.248,61	Rp 115.038.835.638,12	Rp257.809.358.036,53	Rp1.133.958.593.092,29
IRR	-	8,63%	10,77%	17,76%
Available PP (yr)		16 years	12 tahun	7 tahun
Tipping Fee Rp 500.000				
NPV	Rp694.918.870,82	Rp284.929.523.106,13	Rp456.421.860.229,00	Rp1.456.605.554.796,58
IRR	-	11,95%	13,93%	20,73%
Available PP (yr)	-	11 tahun	9 tahun	6 tahun

The comparison of IRR values with respect to tipping fee and power plant capacity is illustrated in Figure 3.

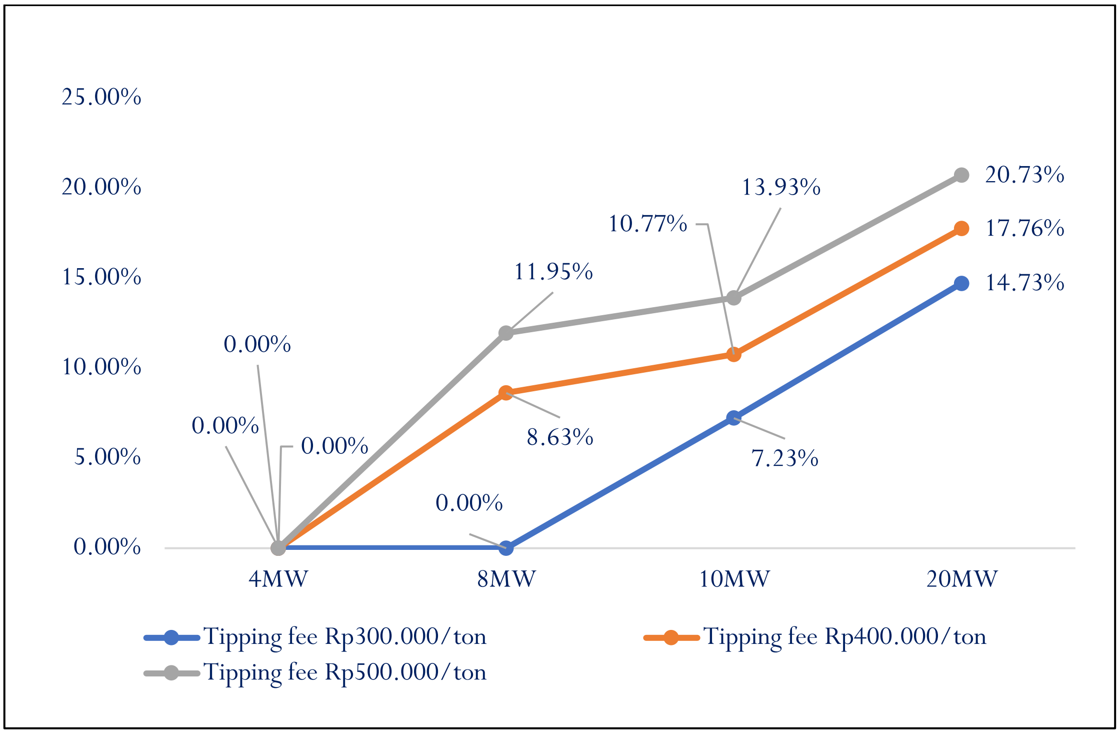

Figure 3. IRR Value based on tipping fee and power plant capacity

The research findings indicate different IRR results for each power plant capacity scheme. At a tipping fee rate of Rp 300,000, the power plant capacities of 10 MW and 20 MW demonstrate economic feasibility (positive NPV). Both power plant capacities yield an LCoE of Rp 2,375.85 and Rp 1,855.68, with NPVs of Rp 59,196,855,844.05 and Rp 811,311,631,388.00 respectively. At a tipping fee rate of Rp 400,000, the economically feasible capacities are 8 MW, 10 MW, and 20 MW. The calculations show that the corresponding NPV values are Rp 115,038,835,638.12, Rp 257,809,358,036.53, and Rp 1,133,958,593,092.29, respectively. The IRR values for these capacities are 8.63%, 10.77%, and 17.76%, respectively. Similarly, for a tipping fee of Rp 500,000, the NPVs are Rp 284,929,523,106.13, Rp 456,421,860,229.00, and Rp 1,456,605,554,796.58, while the IRR values are 11.95%, 13.93%, and 20.73%, respectively. These results indicate the economic viability of different power plant capacities based on the tipping fee rates, with varying levels of NPV and IRR. According to Table 3, the tipping fee does not affect the LCoE value but has an impact on the NPV value. It can be observed that the LCoE value remains constant for each tipping fee value entered. The LCoE value is directly influenced by the power plant capacity, which increases proportionally with the waste processing capacity. This finding is consistent with previous (Alkishriwi, 2021) regarding the economic feasibility of waste-to-energy power plants.

4. Conclusion

Based on the data analysis and calculation results in this study, it can be concluded that the existing power plant does not meet the economic feasibility criteria, as it has a negative NPV value. The research indicates that the economically feasible capacity for the waste-to-energy power plant is 8 MW, with an IRR of 8.63%. However, the feasibility level is considered medium due to the payback period of 16 years. Considering that tipping fees can be a burden for the local government, based on this research, a capacity of 20 MW is recommended with the lowest tipping fee and a payback period of 9 years. In terms of economic scale, at this capacity level, the LCoE value is Rp1,855.68. Another finding from this study is that the higher the daily waste processing capacity, the higher the NPV and IRR values obtained, and the lower the LCoE value. This research is expected to provide valuable insights for investors in the implementation of waste-to-energy power plants, and future studies can explore alternative methods to assess the feasibility of such projects.

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