Simulation of tipping fee policy to support municipal waste management into alternative fuel in the cement industry: a case study of Tuban landfill Indonesia

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Simulation of tipping fee policy to support municipal waste management into alternative fuel in the cement industry: a case study of Tuban landfill Indonesia

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Abstract. Refused Derived Fuels (RDF) alternative energy materials from municipal waste are alternative materials needed by the cement industry to substitute coal. Apart from the fact that RDF products have high heat, RDF prices are more economical than coal. RDF production is also able to solve municipal solid waste (MSW) problems and reduce CO2 emissions. In Indonesia statute no. 18, 2008, concerning waste management, it has regulated a tipping fee or compensation from the government to process costs per ton of waste. However, not many governments in cities in Indonesia have determined the value of this compensation. The purpose of this study is to simulate a tipping fee policy to support municipal solid waste management as an alternative material for RDF in the cement industry. This research's case study is municipal solid waste management in Tuban, a cement plant in Tuban. Method stages This research was carried out by making a feasibility study model at the RDF Plant in Tuban. Next, a simulation of the number of tipping fees should be spent. The simulation results will be compared with project feasibility indicators such as NPV, IRR, payback period, and BCR. The results showed that tipping fees were needed to support project sustainability. It was suggested that with the maximum investment of 5 billion Rupiah, the minimum tipping fee is 70 thousand Rupiah per ton for processing 120 tons MSW per day. That should be supported by the sale of a by-product of RDF production in the form of fertilizer.

1. Introduction

One of the concepts of waste to energy is processing municipal waste into Refuse Derived Fuel (RDF). RDF is a fuel produced from recycled waste with high heat energy, more flammable, and stable combustion [1]. The MSW management project into RDF can solve the waste problem and save land use for waste storage. It can be a solution as an alternative energy material. Waste management into RDF can be done by processing waste that cannot be decomposed by nature, such as plastic, cloth, used tires, styrofoam, paper, wood, and so on, into an energy source that is environmentally friendly [2] and potentially in CO2 reduction [3]. Waste and biomass have also been widely used as renewable energy, as has been done in Jordan [4].

Semen Indonesia, the largest cement industry in South-East Asia, with a production capacity of 28,272 thousand tons/year, uses coal as the primary fuel in the cement production process. The company's total regional coal consumption in 2016 was 300,769 tonnes, up 6% from 282,718 tonnes in 2015, in line with the increase in clinker production by 6% [5]. According to Indonesia's primary energy target, the company will continue to increase alternative energy sources while addressing environmental problems from biomass of 5% by 2025 [6]. Biomass fuels include rice husks, shells, and coconut husks. However, after laboratory testing, the resulting calorific value was 3,500 per kcal/kg [5]. It has hoped that RDF's production from MSW will also contribute to efforts to reduce coal. Besides, RDF is also more economical than coal and has lower CO2 emissions.

The standard fuel used by PT Semen Indonesia at the Tuban plant is coal with a calorie range of between 2500 - 4800 kcal/kg. RDF has been widely used as an alternative energy material to replace coal in the cement industry [1]. The need for coal in cement production is enormous, namely 50% of cement production. Combustion in the kiln process usually requires 450 grams of coal to produce 900 grams of cement [7]. The need for large coal becomes an opportunity for greater use of RDF in the cement industry. In Indonesia, projects to process municipal waste into energy have been carried out, including at Semarang landfills and Gresik landfills. However, the distance between the RDF plant and the cement plant is quite far (more than 100km), resulting in higher transportation costs and is not proportional to the revenue earned. Currently, the RDF plant that is still operating in Indonesia is the RDF plant in Cilacap, where the RDF plant is also close to the cement plant. The factor of proximity to industrial users is an essential issue for the development of RDF.

Cilacap plant uses mechanical and biological methods by shredding the waste with a shredder until it reaches the desired size, and natural drying using the bio-drying method. This method requires a more efficient investment than other methods, namely the hydrothermal method[8] or processing waste into electricity, which requires a vast capacity[9].

Government cooperation and support is required to help the sustainability of the project. The government provides compensation for every tonne of waste management [10]. In Thailand, a support tipping fee is also required up to an 8% discount rate so that municipal waste management projects to become RDF become feasible [11]. However, in Indonesia, the tipping fee amount is still not done thoroughly in every local government. There have been many studies that discuss the RDF plant, namely the RDF plant in Gresik [2], [12],[13],[3], or the plant in Cilacap [14]. However, no research discusses the tipping fee policy that supports the city waste processing project as an alternative material for RDF to be sustainable. Waste processing costs are calculated per tonnes, excluding costs for collection, transportation, and final processing.

The purpose of this research is to simulate a tipping fee policy to support municipal solid waste management as an alternative material for RDF in the cement industry. This research's case study is municipal solid waste management in Tuban Regency, where the Tuban landfills are located close to the Indonesian cement plant.

The method used starts from making a feasibility study model on municipal processing waste into RDF, with a case study of Tuban's city. Furthermore, a simulation of the government's tipping fee is carried out so that the project is feasible. The simulation results will be compared with project feasibility indicators such as NPV, IRR, PB, and BCR. The result of the research is the number of tipping fees to support the feasibility of RDF production.

2. Method

A case study for the construction of the RDF plant in Tuban was carried out to model project feasibility and see the tipping fee policy's effect on project success. First, a Focus Group Discussing that invited parties from the cement industry and the environmental agency was conducted to identify the opportunities and challenges faced by the city of Tuban regarding the management of municipal waste into energy, as well as the possible use of alternative energy from this waste in the cement industry.

Data from the Department of Alternative Fuels in a cement industry includes opportunities for using alternative energy in the cement industry and its characteristics. Thus, data from the environmental agency Tuban shows the amount of waste from the city of Tuba, its characteristics, and how the city waste is currently managed.

Furthermore, benchmarking was carried out at the RDF plant in Cilacap. Production process data and identification of investment costs are carried out at the RDF plant. The benchmarking results are the basis for calculating the RDF plant investment costs, with adjustments if the RDF plant location is in

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Tuban. The process and cost adjustments were consulted in-depth interviews with the cement industry's engineering design department.

The calculation of the RDF plant's feasibility in Tuban was analyzed by comparing the NPV, IRR, and payback period parameters. The tipping fee simulation is carried out to determine how much tipping fee is needed so that the RDF plant can operate sustainably.

In the NPV calculation, several things must be prepared, including the initial investment value, the period for conducting the analysis, the estimated cash inflows and outflows for each period, and the appropriate interest rate. The next step is to add up the project cash flow minus the initial project investment. If the NPV value has been obtained, the analysis can be carried out[15]. If formulated, the NPV formula [16] are as follows:

$$NPV = -\sum_{t=0}^{d-1} \frac{C_t}{(1+i)^t} + \sum_{t=d}^{n} \frac{B_t}{(1+i)^t} \tag{1}$$

When:
C_t: cost at period t
B_t: benefit at period t
d: duration of studies
t: *time*

Analysis of the NPV value. When the NPV is more than zero, it can be said that the investment made provides benefits to the company so that the project is feasible to run. Also, the parameter used in the feasibility study analysis is the Payback period, which is the period the project's net revenue can cover all investment costs. The payback period is worth it if it is less than the investment period. Next is the Benefit-Cost Ratio (BCR). BCR is a tool used to calculate whether a project is feasible or not to run. Usually, BCR is used for government projects intended as public facilities and does not take profit into account. The calculation of BCR can be formulated as follows:

$$BCR = \frac{B}{I+C} \tag{2}$$

When:
B: Profits that are obtained after the project is held during its economic life
I: Project Investment
C: Operation & Maintenance Cost

The project will be feasible if the BCR value is more than 1.

3. Results and Discussions

3.1. The Potential of Waste from Tuban City for the Cement Industry

The amount of daily waste entering Tuban landfills is currently around 50 tonnes per day, increasing every year. Waste components, as in Table 1, generally still have a high selling value if there is an RDF production process facility. Municipal waste from food waste and garden waste with a total percentage of 76.69% can still be processed into raw material for petrochemical fertilizers. Tuban City also has a fertilizer company.

Table 1. Composition of the Municipal Solid Waste in Tuban District

No	Waste Component	Waste Component (%)
1	Food waste	55,58
2	Garden/plant waste	19,11
3	Plastic	9,68
4	Paper	5,02
5	Wood	0,06
6	Textil	1,55
7	Steel	0,08
8	Glass	3,61
9	Diapers	5,30

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Inorganic waste currently carried out is only limited to recycling materials that are possible to be recycled and have economic value, for example, such as thermoset and metal category plastics. Plastics and metals that may be recycled will be taken by scavengers where the plastic waste is processed into other plastic items. However, not all inorganic waste from Tuban landfills can be collected and sold like plastic packaging. There are other materials, such as plastic food packaging, which is very small. Many other types of waste do not have sale value, styrofoam, sandal waste, used tires, and other rubber types. The amount of waste increases every day if it is not treated correctly. Refuse Derived Fuel (RDF) is an alternative for handling inorganic waste that has no selling value. The results of RDF production can be used as fuel, especially in cement production companies. The cooperation scheme in the construction of the RDF plant can be described in figure 1.

Figure 1. Illustration of the Tuban city TPA RDF cooperation scheme

From Figure 1, the RDF plant has beneficial cooperation, both with the government and cement factories, as users of RDF as an alternative to coal. Besides, it has advantages to the fertilizer industry because of the by-product of RDF products as fertilizer. Tuban municipal waste has a calorific value of 2051 kcal/kg. This value is close to the minimum calorific value of fuel material or energy sources for the kiln, 2500 kcal/kg. The calorific value of municipal solid waste in the Tuban landfill can still be increased if a sorting process is carried out to remove materials that can reduce the heating value, such as organic and metal waste. Municipal waste has a generally low ash content. The water content of municipal solid waste varies widely and can change significantly due to processing, handling, and storage. With the drying method using decomposing bacteria for 15 (fifteen) days, the water content of municipal solid waste in Tuban landfills reaches 18-22%. [17]. Furthermore, the project scheme can also be developed into a PPP(Public-Private Partnership) [18], as in the PPP scheme from waste management in West Java[19].

3.2. Potential of RDF for Alternative Fuels to Substitute Coal in the Cement Industry

In general, coal is the primary fuel in the cement industry because of its low price. However, coal is a non-renewable source of fossil energy. Based on data from the Ministry of Energy and Human Resources in 2019, Indonesia's total coal reserves are 26.2 billion tons, assuming that coal energy can be used for the next 56 years without discovering new reserves. For an energy source to be used in the kiln combustion process, several requirements must be met, as mentioned in table 2. RDF from MSW then needs to be tested for characterization to meet the cement industry's specifications.

Table 2. Fuel Specifications for Kiln Combustion in A Cement Industry

	Engineering Metric	Specification
1.	Calorific Value	≥2500 Kcal/kg
2.	Moisture Content	≤20%
3.	Chlorine	≤1%
4.	Size	3-5 cm
5.	Ash Content	-
6.	Particulate	80 mg/Nm^3
7.	Sulfur Dioxide	800 mg/Nm^3

3.3. RDF Production Process

The RDF production process discussed in this study results from observations at the RDF plant in Cilacap. The RDF plant is built on the landfill covering 4.9 Ha of old landfills and 1.4 Ha of the new landfill. The processing facility is capable of managing 120 tons of fresh waste per day.

The RDF processing process starts when a garbage truck enters the RDF Plant area. Each garbage truck will be weighed to determine the total waste that enters the RDF Plant before processing. The weighed waste is then unloaded in the demolition area, and scavengers are manually sorted out to sort the trash with a sale value. The sorted waste is then chopped using a Shredder machine. The chopped waste is then put into a biological drying box or what is commonly called bio-drying. The drying process used in RDF Cilacap is carried out aerobically by utilizing the bacteria present in the waste itself.

The dry waste produced from the drying process is then sorted using a separator. This sorting process is carried out to separate RDF from other materials such as inert materials (soil, rock, and compost) and products that do not meet RDF specifications (a size too large). The Cilacap RDF production process diagram, as shown in Figure 2.

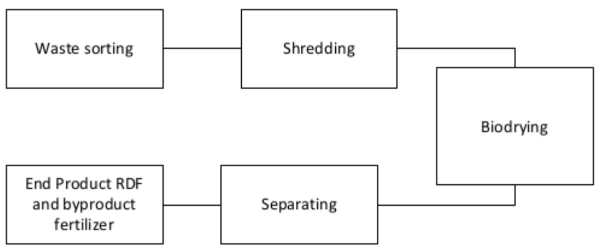

Figure 2. RDF Production process diagram in Cilacap

3.4. Financial Analysis.

The financial calculation identifies investment costs, operational costs, and revenue generated from the RDF plant's construction. The investment costs needed in the construction of the RDF plant are divided into equipment such as Screen, Conveyor, Hopper, Separator, Shredder, Dryer, Rotary Screen, Magnetic Separator, and Ballistic Separator, dump trucks, buildings, work tools, permits, electricity, and land. At the Cilacap RDF plant with 120 tons per day, the total investment cost is Rp. 85 billion. In Cilacap, the investment value is the result of cooperation with many parties, including the Danish government (44 Billion), the Indonesian government through the PUPR ministry (27 Billion), the Central Java provincial government (9 Billion), the Cilacap Regency Government (3 Billion). Based on the Focus Group Discussion with the Tuban Regency Government, the amount of investment prepared is 5 billion, where the rest will use the Cooperation scheme.

Furthermore, per year's operational costs consist of labor costs, electricity costs, maintenance costs, and transportation costs. Operational costs are shown in the table where the appropriate data obtained from the Cilacap RDF Plant with some adjustments shows that the total operating costs are 3.9 billion per year.

The revenue obtained for the RDF plant project consists of selling RDF products, selling by-products in the form of compost, and tipping fees. The price of RDF products by RDF products in Cilacap is IDR 300,000 / ton. The price must comply with the criteria that humidity is less than 20%. If the humidity value is more than the specified price, the selling price of RDF will decrease. From the production capacity of 120 tons per day of municipal solid waste, the RDF output will be 36 tons per day (30% of the total raw material input). In 300 production days per year, RDF production reaches 10,800 tons per day. Besides, the by-product in the form of compost can also generate income. The fertilizer production generates 35% of the waste input. If the waste is processed 120 tons per day, the fertilizer produced is 42 tons per day of compost. The selling price of compost is assumed to be IDR 100,000 / ton. The overall income and opportunity cost of RDF management can be seen in Table 3.

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Table 3. Total Revenue of RDF Plant in Tuban

Output product	Unit		Price (Rp)	Total revenue (Billion Rp per Year)
a. **RDF**	10,800	TPY	300,000	3.240
b. **Fertilizer**	12,600	TPY	100,000	1.260
Total Revenue				4.5

Apart from revenue in the form of product sales, RDF production will also generate Opportunity costs. That is the opportunity cost that can be obtained from waste management, including a tipping fee. With the volume of MSW processed of 120 tons per day, 300 days per year, 36,000 tons of processed waste will be obtained per day, which is entitled to a tipping fee as compensation for each ton of waste management. In Cilacap, the proposed tipping fee is Rp. 100,000 -. Per tonne of waste management.
Apart from that, the opportunity cost can also come from saving costs for spending on additional land. It is assumed:

Design embankment height = 10 m
Volume per hectare = 10,000 m^2 x 10 m = 100,000 m^3.
With the density of waste = 0.5 ton/m^3
The amount of waste that can be accommodated per hectare = 50,000 tons.

If 50 TPD per day of garbage entering the Tuban landfills, the landfills will be full in 1000 days, or the equivalent of 2.7 years. Or every five years, it is necessary to add 2 hectares of land, which is equivalent to 0.4 hectares per year.

To calculate the savings from coal and RDF substitutes, an economical price comparison is made between RDF and coal, as shown in Table 4.

Table 4. Comparison of Economic Prices for RDF and Coa

Item	RDF	Coal
Economic Price (Rp/kal)	0.1	0.15
Calori	3000	3000
Price(Rp/ton)	300,000	450,000

From the calculation of coal substitution savings with RDF, the savings obtained are Rp. 150,000 per tonne of coal substitution. The overall opportunity cost from municipal solid waste management to RDF is shown in table 5.

Tabel 5. Opportunity Cost from RDF Production

	Opportunity Cost				
a.	**Tipping fee per ton**	10800	TPY	100,000	1,080,000,000
b.	**Landfil)**	0.4	Ha	2.500,000,000	1,000,000,000
c.	**Saving Cost for Coal**	10800	TPY	150,000	1,620,000,000
	Total Opportunity Cost				3,700,000,000

This opportunity is still added to reduce CO_2 emissions. From processing 1 ton, MSW can prevent methane gas released into the environment by 50 Nm^3 methane. If the processed waste is 120 tons per day, the potential for methane gas is 6000 Nm^3. The processing waste in 365 days means 2,190,000 Nm^3 can be a potential carbon tax reward. Although a carbon tax policy has not been implemented in Indonesia, this can show the contribution of RDF processing to emission reduction.

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3.5. Tipping Fee Simulation

After knowing the amount of investment, operational, and revenue costs, the cash flow projection for ten years and a 6% interest can be made. It can be analyzed based on indicator parameters, as shown in Table 6.

Table 6. Indicator of Feasibility RDF Plant in Tuban

	Result	**Feasibility**
I.R.R.	2.3%	IRR < WACC (Not Feasible)
WACC	9.0%	
Payback (tahun)	9	< 10 tahun (Feasible)
N.P.V. (billion, Rp.)	Rp. (2.735)	< 0 (Not Feasible)
BCR	1.52	> 0 (Feasible)

BCR (Benefit Cost Ratio) is a comparison between all benefits and the investment issued. With an investment value of 5 B (converted to an annual value, with an interest rate of 6%, equivalent to Rp. 679,339,791) and operational value of 3.9 B per year compared to the benefits generated by 8.2 B per year, the BCR value of this project is still feasible because of the 1.52 indicators > 0. The PDF project is feasible because more benefits are generated, from reducing the need for landfill purchases and the opportunity to reduce coal and CO_2 emissions. Although other indicators indicate this project is not feasible, it is indicated by IRR <WACC, and the NPV is negative. The tipping fee simulation is carried out to determine how influential the tipping fee is on the NPV, BCR, and Payback Period values. The tipping fee in 2019 for each city in Indonesia is different, as depicted in Figure 3.

Figure 3. Tipping fee in cities in Indonesia

From the cash flow calculation, the revenue component tipping fee is then added. The simulation of the tipping fee is carried out so that the project is worthy of value. The simulation results with various scenarios are presented in table 7.

Table 7. Result of Feasibility Calculation with Tipping Fee Simulation

	Baseline	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Investment (in Billion Rp.)	5	5	5	5	2.5
RDF Production (ton per days)	120	120	120	140	140
Fertilizer Sales	Yes	Yes	-	-	-
Tipping Fee (in Thousand Rp)	-	50	100	100	70
Feasibility Indicator					
NPV (Rp in Billion)	-2.360	0.297	-3.693	-0.529	0.111
IRR	2.30%	17.40%	-16.50%	-4.50%	16.0%
Payback Period	9	5	55	17	5
BCR	1.52	1.64	0.77	1.07	1.56
	Not Feasible	Feasible	Not Feasible	Not Feasible	Feasible

Table 7 shows that the project will be worth it if, with an investment value of 5 billion, and a production capacity of 120 tons per day, there are additional sales of fertilizers and a tipping fee of Rp. 50 thousand. If the investment value is reduced to Rp. 2.5 Billion, then the production capacity needs to be increased to 140 tons per day, and there is a tipping fee of Rp. 70 thousand. In the case study of the RDF plant in Tuban, tipping fees are needed to support its sustainability. Additional sales of product variations, such as fertilizers, are also an essential factor to increase revenue. A larger capacity will provide better economic performance, although with a more considerable investment[20].

4. Conclusions

The simulation of the tipping fee for the RDF plant in Tuban, Indonesia, has been investigated. Municipal Solid Waste in Tuban has a tremendous potency for alternative fuels as coal substitution in cement plants. The investment required for the construction of the RDF plant is 85 billion. With an annual income of 4.5 billion and operations of 3.9 billion. So the feasibility indicator for this project is not feasible because the IRR value is 2.3% <WACC 9%, NPV <0 even though the Benefit-Cost Analysis shows an indicator of 1.52 and a payback period of 9 years.

Based on the feasibility scenario simulation, the project becomes feasible, provided there is an income from the fertilizer by-product. We also need a minimum support tipping fee of Rp. 50,000. If there is no additional compost by-product, then the eligibility requirements are a maximum investment value of 2.5 billion, increase production capacity by 140 tons per day, and increase Rp's minimum tipping fee. 70,000. Collaboration with various parties is crucial in realizing the RDF plant as a waste to energy solution, primarily to support coal substitution in the cement industry.

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