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FINANCING STRATEGY OF REFUSE DERIVED FUEL (RDF) PLANT BASED ON INVESTMENT PROJECT ANALYSIS (CASE STUDY CILACAP RDF PLANT)

STRATEGI PEMBIAYAAN REFUSE DERIVED FUEL (RDF) PLANT BERDASARKAN ANALISIS PROYEK INVESTASI (STUDI KASUS RDF CILACAP)

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ABSTRACT

Refused Derived Fuel (RDF) is a waste processing method that can be used as co-firing in the cement industry. Currently, the Cilacap RDF Plant is one of the RDFs successfully operating in Indonesia, with a machine capacity of up to 200 tons/day. This success has encouraged many local governments to build RDF facilities to handle waste. The research aims to propose alternative funding scenarios for the development of RDF so that it can be applied in other places. Not all regions have the same opportunities as RDF Cilacap, where investment financing includes the construction of RDF facilities and machinery covered by many stakeholders. This study also calculates the potential for reducing CO_2 emissions with the RDF plant and estimates the potential carbon trading value from the reduction in CO_2 emissions. The analysis method in alternative scenario studies uses investment project analysis such as Discounted Cash Flow (DCF), NPV, IRR, Profitability Index, Payback Period, Discounted Payback Period, and IPCC 2006 to calculate CO_2 emission reductions. The potential for reducing CO_2 emissions in this study is calculated by comparing the value of CO_2 produced if waste is disposed of in a landfill (open dumping) and the waste is processed into RDF. The research results show that the third scenario is suitable and feasible for regions planning to build an RDF Factory. It is recommended that the Central Government bear the responsibility for the RDF Factory building infrastructure and the investors or third parties take responsibility for the machinery. The potential for reducing CO2 emissions with the existence of the RDF Plant Cilacap for 20 years is 231,944.86 tons. If multiplied by the average price in the secondary market, IDR 69,600 (USD 4.45), the potential for obtaining funds is IDR 16,143 million, or equivalently, we calculate it in present value to IDR 5,284 million.

Keywords: *Refuse derived fuel, Investment Project Analysis, CO_2 emission reduction*

ABSTRAK

Refused Derived Fuel (RDF) merupakan salah satu metode pengolahan limbah yang dapat digunakan sebagai co-firing pada industri semen. Saat ini Pabrik RDF Cilacap merupakan salah satu RDF yang berhasil beroperasi di Indonesia, dengan kapasitas mesin mencapai 200 ton/hari. Keberhasilan ini mendorong banyak pemerintah daerah membangun fasilitas RDF untuk menangani sampah. Penelitian ini bertujuan untuk mengusulkan skenario pendanaan alternatif untuk pengembangan RDF agar dapat diterapkan di tempat lain. Tidak semua daerah mempunyai peluang yang sama dengan RDF Cilacap, dimana pembiayaan investasi meliputi pembangunan fasilitas dan mesin RDF ditanggung oleh banyak pemangku kepentingan. Kajian ini juga menghitung potensi penurunan emisi CO_2 dengan adanya pabrik RDF dan memperkirakan potensi nilai perdagangan karbon dari pengurangan emisi CO_2. Metode analisis dalam studi skenario alternatif menggunakan analisis proyek investasi seperti Discounted Cash Flow (DCF), NPV, IRR, Profitability Index, Payback Period, Discounted Payback Period, dan IPCC 2026 untuk menghitung penurunan emisi CO_2. Potensi penurunan emisi CO_2 pada penelitian ini dihitung dengan membandingkan nilai CO_2 yang dihasilkan jika sampah dibuang ke TPA (open dumping) dan jika sampah diolah menjadi RDF. Hasil penelitian menunjukkan bahwa skenario ketiga cocok dan layak untuk daerah yang berencana membangun Pabrik RDF. Disarankan agar Pemerintah Pusat memikul tanggung jawab infrastruktur dan mesin untuk pengolahan sampah menjadi RDF untuk dialihkan kepada investor atau pihak ketiga. Potensi penurunan emisi CO_2 dengan keberadaan Pabrik RDF Cilacap selama 20 tahun adalah sebesar 231.944,86 ton. Jika dikalikan dengan rata-rata harga di pasar sekunder Rp 69.600 (USD 4,45), potensi perolehan dana sebesar Rp 16.143 juta atau setara kita hitung dalam nilai sekarang menjadi Rp 5.284 juta.

Kata Kunci: Pengolahan sampah menjadi RDF, Analisis Proyek Investasi, pengurangan emisi CO_2

INTRODUCTION

Indonesia is a developing country with the fourth largest population in the world, with a total of 270,203,917 people. Between 2010 and 2020, Indonesia's average population growth rate was 1.27 percent per year, population growth will go hand in hand with the waste it produces, as seen in the chart below, which will continue to increase to about 70,8 million tons in 2025 if there are no efforts to reduce waste and handle waste properly in the first place (KLHK, 2017). Rapid urbanization, industrialization, and economic development prompted an unprecedented generation of municipal solid waste, which poses severe challenges for waste management authorities.

Figure 1. Projections of waste generation in Indonesia

In practically all regions of Indonesia, due to insufficient segregation, inadequate waste collection, lack of waste treatment facilities, waste management institutions that lack the capacity, and financial issues with the municipal government, a significant fraction of waste eventually goes untreated in landfills or open dumping sites. According to National Waste Management Information System Indonesia's Waste Management Performance was 33,24% unmanaged, 16.49% reduction upstream and 50.27% going to landfills (SIPSN, 2023). IEA Bioenergy state if more waste is landfilled, many valuable resources are wasted (Reza et al., 2013). Apart from having a negative impact on human health, improper waste handling also leads to environmental damage, which will require a large amount of cost to handle. Unmanaged and improperly managed waste decades of economic growth requires urgent action at all levels of stakeholders, and waste handling must be carried out in an integrated manner from upstream to downstream so that all waste can be handled optimally to ensure that the Government of Indonesia has shown immense commitment to waste management, setting a national target of 30% waste reduction and 70% waste management by 2025, including 70% ocean plastic reduction by 2025.

Landfills are a long-term environmental problem because they can contaminate soil and water with leached pollutants and emit greenhouse gases (GHG) like methane (CH_4) and carbon dioxide (CO_2). Furthermore, using landfills represents a significant loss of material and energy resources, as well as land, with potential for other applications (Vaverková, 2019). In 2020, Indonesia reported 1,050,413 Gg CO_2e of GHG emissions, down 43% from the previous year. In 2020, the energy sector accounted for approximately 56% of total emissions, followed by FOLU (16%) and waste (12%). Other sources of emissions included agriculture, industry, and peat fires (Rahmanulloh, 2023). The Indonesian government continues to resolve waste handling issues, encouraging changes in people's behavior to engage in at-source segregation and an integrated waste management process. The government must develop proven advanced technology to process the waste and accelerate those efforts. One of them currently operates in Cilacap Regency is the Refuse Derived Fuel (RDF) method.

Due to rapid population growth in Cilacap, the amount of municipal solid waste has increased significantly with waste composition in Cilacap is mainly composed of food waste (about 58%), Plastic (16%), paper/cardboard (10%), wood (2%) and others (14%) as seen in Figure I.2. In 2018, the existing landfill was predicted to reach maximum capacity, in order that the Cilacap Regency needed a solid solution without an approach other than open landfill. Referencing the hierarchy of waste management, they decided to process municipal waste into RDF.

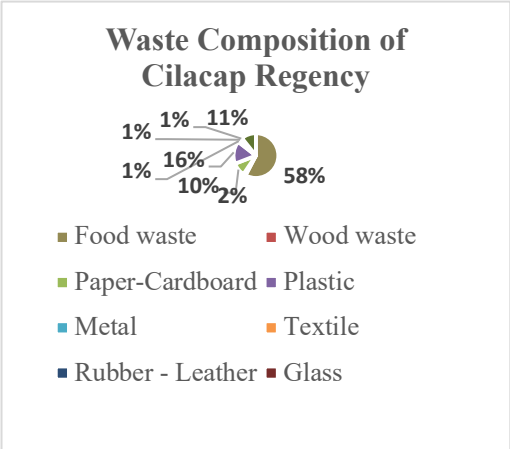

Figure 2. Waste Composition of Cilacap regency (SIPSN, 2022)

The RDF Plant was inaugurated in July 2020 by the Coordinating Minister for Maritime Affairs and Investment, starting operational in 2021. The financing of the RDF project was supported by the Ministry of Environment and Forestry, the Ministry of Public Works and Public Housing, Central Java Province, the Kingdom of Denmark, and PT. Solusi Bangun Indonesia (PT. SBI). Since RDF Cilacap operates until the end of 2023, many parties have contributed to operational costs, while many other regions intend to implement The RDF Plant for their waste management. However, it seems complicated to replicate the Cilacap RDF plan for different areas because not every region gets the opportunity for a high nominal grant for capex expenses; even if it is paid to the central government, it will be challenging to implement owing to budget constraints.

RESEARCH METHODOLOGY

This research assess the RDF project's investment feasibility analysis using the DCF method from RDF offtaker's data then calculate the NPV, IRR, Profitability Index, Payback Period and Discounted Payback of the RDF project. These methodologies are frequently utilized in the valuation of projects to determine whether the project is feasible to operate. To obtain a comprehensive result, the research involves Financial Risk Analysis of the RDF Project and also the potential emission reduction of CO_2 eq by comparing the CO_2 produced when waste is disposed of in the landfill and waste is processed through the RDF. This holistic study will provide a thorough understanding of the project.

RESULT AND DISCUSSION

Analysis

The economic feasibility of the RDF Project will be carried out by using the following financial indicators: NPV, IRR, Profitability Index, Payback Period, and Discounted Payback Period parameters. The calculation starts with the current condition of the existing RDF. In economic terms, the RDF is feasible to operate. However, this will differ if this RDF is replicated in other regions because the central government has limited funds to provide grants for buildings and machines, a significant component of the capex for developing the Cilacap RDF. As a result, this study developed three scenarios to assess the RDF Plant.

The study has three alternative scenarios for the operation of the RDF

Plant based on the RDF Cilacap case. The first scenario applies when the RDF is built with construction costs and machinery without grants implying that all capital expenditures would need to be provided by the investors however, this condition drives up the cost of RDF to the offtaker. The second scenario is when the RDF project receives RDF building construction from the central government (Ministry of Public Works and Housing). Nevertheless, a set of machines would be charged to the investors, in this scenario it is still possible to implement it but further calculations are needed on the RDF price which will be included in scenario three. Subsequently, the study must determine the project's business solution, implementation and plan for RDF.

Current Condition of RDF Plant Cilacap

The RDF Cilacap has been operating in its 4th year; in the first year, RDF processed 45,600 tons of waste/year, then in the second year 47,900/year, and in the third year, it reached 44,566 per year. In this research, a projection of the operations of RDF Cilacap has been developed until 2040, in the calculation of this study makes assumptions for every item, as seen in Table 1.

Table 1. Assumptions in calculating RDF projections until 2040

Item	Unit	Assumption
Input		
Waste Input	Ton	Increase of 1.5% every year based on Cilacap's population rate
Output		
RDF	Ton	Obtained data from the previous three years (2021-2023), where the RDF results are 51% of the waste input
Unit Price RDF (Revenue)		
RDF Sales	IDR/ton waste	Based on an agreement between RDF off-taker and the government over the past three years, the price of RDF products has been IDR 300,000 per ton, however in this research, with an additional 5% every five years
Tipping Fee from Pemda	IDR/ton waste	150,000 per ton (benchmarking to other places in Indonesia and consideration of Government capabilities) in this study with an additional 5% every five years
Grant from PT X	IDR/ton RDF	According to the agreement 100,000 per ton RDF for 5 years, in this research with an additional 5% every five years

After the Cilacap RDF forecast is carried out until 2040, calculate the projected cash flow from the operational of the RDF plant for 20 years, the values are shown in Table 2.

Table 2. Cash Flow Statement Current Condition of RDF Cilacap (in .000 IDR)

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Disc. Cash Flow
2020	-	(83.419.081)	83.419.081	-	-
2021	204.000	(204.000)	-	(0,094)	(0,083)
2022	876.526	(569.039)	-	307.487	239.532
2023	734.049	(532.847)	-	201.202	138.336
2024	5.446.524	-	-	5.446.524	3.305.145
2025	5.474.791	-	-	5.474.791	2.932.287
2026	(2.232.699)	-	-	(2.232.699)	(1.055.448)
2027	5.578.279	-	-	5.578.279	2.327.420
2028	5.605.429	-	-	5.605.429	2.064.197
2029	(1.790.713)	-	-	(1.790.713)	(582.018)
2030	6.418.679	-	-	6.418.679	1.841.296
2031	6.455.160	-	-	6.455.160	1.634.379
2032	(2.036.969)	-	-	(2.036.969)	(455.196)
2033	6.580.075	-	-	6.580.075	1.297.813
3034	7.406.525	-	-	7.406.525	1.289.328
2035	(1.501.268)	-	-	(1.501.268)	(230.661)
2036	7.555.698	-	-	7.555.698	1.024.611
2037	7.602.101	-	-	7.602.101	909.884
2038	(1.754.217)	-	-	(1.754.217)	(185.312)
2039	8.647.156	-	-	8.647.156	806.234
2040	8.726.150	-	-	8.726.150	718.089
Total	**73.995.274**	**(84.724.966)**	**83.419.081**	**72.689.389**	**18.019.918**

Based on calculations, the cash flow in the current conditions for 20 years is positive. After calculating the WACC, the discounted cash flow is also

positive. WACC will evaluate the feasibility of investing in the RDF project based on its capital structure in this project. All capital expenditure in the current condition is a grant from stakeholders. NPV is used to evaluate the investment project by considering the time value of the cash flow generated. RDF has a positive NPV from this current condition, which implies the RDF is feasible, as shown in Table 3.

Table 3. Financial feasibility of the current RDF Project

Weighted Cost of Capital (WACC)	13.30%
Net Present Value (NPV)	IDR 18,019,917,764

DCF Calculation Result

Discounted Cash Flow (DCF) to determine a company's financial worth. DCF refers to a valuation method that estimates the value of an investment using its expected future cash flows. This method is commonly used in finance to determine the intrinsic value of a company. And the following calculations are based on the current Cilacap RDF.

Weighted Average Cost of Capital (WACC)

WACC is a weighted average of the costs of the components of debt, preferred stock and common equity (Brigham and Houston, 2018). WACC (Weighted Average Cost of Capital) is calculated by combining the cost of equity and the cost of debt, each weighted by their respective proportions in the company's capital structure. The equity weight is determined by dividing the market value of equity by the total capital, while the debt weight is obtained by dividing the book value of debt by the total capital. Once these weights are determined, then multiply the cost of equity by its equity weight and add it to the cost of debt multiplied by its debt weight to calculate WACC.

Cost of Equity

The objective of this research is to value RDF Project' equity, therefore the study used the calculation of cost of equity or expected return as a method in determining its discount rate. According to Heinle and Smith (2017) have defined the cost of capital as "the discount that is applied to price relative to expected cash flows". According to Aswath Damodaran (2010), the CAPM formula for calculating the cost of equity, there are three variable that is required to determine expected returns, which Risk-Free rate, Indonesia risk premium and the company's beta. The formula is below:

Expected Return = Risk-free rate + Beta * Risk Premium

The risk-free rate and risk premium of Indonesia can be found on the trading economy's website. To calculate the beta of the RDF Project, the study compared it to Aswath Damodaran website and took for Environmental & Waste Services in January 2023.

Table 4. Cost of Equity Calculation

Variable	Value
Risk-Free Rate source: Indonesia 20Y gov Bond	6.88%
Risk Premium Source: Damodaran	7.38%
RDF Project's Beta	0.87
Estimated Cost of Equity	13.30%

Cost of Debt

The cost of debt refers to the complete interest payment obligation on a debt. It represents the effective interest rate or the overall interest amount that a company is liable to pay on any obligations, including bonds and loans. The cost of debt is zero.

WACC Calculation

Table 5. WACC Calculation

Variable	Value
Cost of equity	13.30%
Risk free rate	7.38%
Beta	0.87
Equity Risk Premium	6.88%
WACC	13.30%

Net Present Value (NPV)

The criteria for determining the economic viability of the RDF Plant state that if the NPV is greater than zero, the plant or technology is economically viable. As shown , the NPV of IDR 18,019,917,764 for a 20-year period indicates that the RDF will be financially viable.

$$\text{NPV of Project} = \sum_{t=1}^{t=N} \frac{\text{CFt}}{(1+r)^{t}} - \text{Initial Investment}$$

Below is the analysis obtained after the study calculated the current condition of RDF Cilacap with the capex were funded by multistakeholder, the result of the NPV is positif however the financial scheme for RDF Cilacap will be challenging to implement in other regions to earn building and machinery grants, for that reason the study examines with three alternatives scenarios so that the RDF project can be declared eligible for implementation in other cities.

Proposed alternative scenarios for implementing RDF Plant

The scenario analysis is used to provide for investors and other local governments considering implementing RDF Plants for their waste management. Scenario analysis is conducted, to analyze the impacts of possible future events on the RDF operation by taking into several alternative outcomes, and to present different options for the future development of the RDF Plant. Scenario analysis is the process of forecasting the expected value of a performance indicator, given a period, and the occurrence of different situations. Scenario analysis can be used to estimate the costs that will be incurred and the potential feasibility of the RDF business for investors.

Scenario I, RDF Project without a building and machine grant

In the planning, scenario 1 applies with the RDF project that would be built without a building and a machine grant, it implies that the capex is fully funded by the investor. Then, calculate cash flow and discounted cash flow for scenario 1 with projections until 2040, which are attached in the Table 6. The scenario calculation assumes that the investor pays the capital for machines and buildings. The input waste data, RDF output, all revenue from RDF sales to off-takers, tipping fees from the region, and grants from third parties are assumed to be the same as the current condition of the existing RDF.

Table 6. Cash Flow Statement Scenario I Without Building and Machine Grant (in .ooo IDR)

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Disc. Cash Flow
2020	-	(83.419.081)	-	(83.419.081)	(83.419.081)
2021	204.000	(204.000)	-	(0,094)	(0,083)
2022	876.526	(569.039)	-	307.487	239.532
2023	734.049	(532.847)	-	201.202	138.336
2024	5.446.524	-	-	5.446.524	3.305.145
2025	5.474.791	-	-	5.474.791	2.932.287
2026	(2.232.699)	-	-	(2.232.699)	(1.055.448)
2027	5.578.279	-	-	5.578.279	2.327.420
2028	5.605.429	-	-	5.605.429	2.064.197

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Disc. Cash Flow
2029	(1.790.713)	-	-	(1.790.713)	(582.018)
2030	6.418.679	-	-	6.418.679	1.841.296
2031	6.455.160	-	-	6.455.160	1.634.379
2032	(2.036.969)	-	-	(2.036.969)	(455.196)
2033	6.580.075	-	-	6.580.075	1.297.813
3034	7.406.525	-	-	7.406.525	1.289.328
2035	(1.501.268)	-	-	(1.501.268)	(230.661)
2036	7.555.698	-	-	7.555.698	1.024.611
2037	7.602.101	-	-	7.602.101	909.884
2038	(1.754.217)	-	-	(1.754.217)	(185.312)
2039	8.647.156	-	-	8.647.156	806.234
2040	8.726.150	-	-	8.726.150	718.089
Total	**73.995.274**	**(84.724.966)**	**-**	**(10.729.692)**	**(65.399.163)**

Based on calculations, the cash flow in scenario I for 20 years is negative, and this figure also coincides with the negative discounted cash flow value. The current condition of RDF Cilacap is that it has a positive cash flow and positive NPV, this is because the cost of building and the machine is granted from several stakeholders; when all the capex is charged to the inventor, the NPV becomes negative, as seen in Table 7.

Table 7. Project Feasibility Indicator of Scenario I

Weighted Cost of Capital (WACC)	13.30%
Net Present Value (NPV)	(Rp65,399,162,736)

This scenario is not feasible to be implemented. RDF seems very unattractive from an economic standpoint.

Scenario II, RDF Project with a Building Grant

Scenario II is proposed with a building grant through the Ministry of Public Works and Public Housing (PUPR) to build RDF facilities that provide building infrastructure to support assets in the RDF Project while the investor would charge the machine. In this condition, regional governments implementing the RDF Plant can submit a proposal for the construction of the RDF Plant to the PUPR. On that condition, the regional government provides clear and clean land. After the RDF is ready, PUPR will offer the facility to the local government. Once accepted, the local government handed it over to the private sector as the operator of the RDF facility. The selection of private parties is carried out through a tender scheme or direct appointment. DCF calculations were also carried out for scenario II, as seen in Table 8. Funding for the building grants from PUPR and machines from investors. For the input waste data, RDF output, all revenue from RDF sales to off-takers, tipping fees from the region, and grants from third parties are assumed to be the same as the current condition of the existing RDF.

Table 8. Cash Flow Statement Scenario II With Building Grant (in .000 IDR)

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Disc. Cash Flow
2020	-	(83.419.081)	38.460.000	(44.959.081)	(44.959.081)
2021	204.000	(204.000)	-	(0,094)	(0,083)
2022	876.526	(569.039)	-	307.487	239.532
2023	734.049	(532.847)	-	201.202	138.336
2024	5.446.524	-	-	5.446.524	3.305.145
2025	5.474.791	-	-	5.474.791	2.932.287
2026	(2.232.699)	-	-	(2.232.699)	(1.055.448)
2027	5.578.279	-	-	5.578.279	2.327.420
2028	5.605.429	-	-	5.605.429	2.064.197
2029	(1.790.713)	-	-	(1.790.713)	(582.018)
2030	6.418.679	-	-	6.418.679	1.841.296
2031	6.455.160	-	-	6.455.160	1.634.379
2032	(2.036.969)	-	-	(2.036.969)	(455.196)
2033	6.580.075	-	-	6.580.075	1.297.813
3034	7.406.525	-	-	7.406.525	1.289.328
2035	(1.501.268)	-	-	(1.501.268)	(230.661)
2036	7.555.698	-	-	7.555.698	1.024.611
2037	7.602.101	-	-	7.602.101	909.884
2038	(1.754.217)	-	-	(1.754.217)	(185.312)
2039	8.647.156	-	-	8.647.156	806.234
2040	8.726.150	-	-	8.726.150	718.089

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Disc. Cash Flow
Total	73.995.274	(84.724.966)	38.460.000	27.730.308	(26.939.163)

Year	Net Cash Provided by Operating	Net Cash Provided by Investing	Net Cash Provided by Financing	Net Cash Flow	Acc. Net Cash Flow	Disc. Cash Flow	Acc. Disc. Cash Flow
2020		- (83.419.081)	38.460.000	44.959.081)	(44.959.081)	(44.959.081)	(44.959.081)
2021	204.000	(204.000)	-	(0,094)	(44.959.081)	(0,083)	(44.959.081)
2022	876.526	(569.039)	-	307.487	(44.651.593)	239.532	(44.719.549)
2023	734.049	(532.847)	-	201.202	(44.450.391)	138.336	(44.581.213)
2024	10.709.905	-	-	10.709.905	(33.740.486)	6.499.153	(38.082.059)
2025	10.817.123	-	-	10.817.123	(22.923.363)	5.793.630	(32.288.430)
2026	3.189.768	-	-	3.189.768	(19.733.595)	1.507.877	(30.780.553)
2027	11.082.083	-	-	11.082.083	(8.651.512)	4.623.767	(26.156.786)
2028	11.191.790	-	-	11.191.790	2.540.277	4.121.372	(22.035.414)
2029	4.162.951	-	-	4.162.951	6.703.229	1.353.042	(20.682.371)
2030	12.461.648	-	-	12.461.648	19.164.877	3.574.814	(17.107.558)
2031	12.588.774	-	-	12.588.774	31.753.651	3.187.345	(13.920.213)
2032	4.188.649	-	-	4.188.649	35.942.300	936.025	(12.984.188)
2033	12.899.078	-	-	12.899.078	48.841.377	2.544.134	(10.440.054)
3034	14.141.001	-	-	14.141.001	62.982.378	2.461.667	(7.978.387)
2035	5.334.226	-	-	5.334.226	68.316.605	819.574	(7.158.813)
2036	14.493.724	-	-	14.493.724	82.810.329	1.965.462	(5.193.351)
2037	14.644.197	-	-	14.644.197	97.454.526	1.752.742	(3.440.609)
2038	5.393.511	-	-	5.393.511	102.848.037	569.760	(2.870.849)
2039	16.264.847	-	-	16.264.847	119.112.884	1.516.485	(1.354.365)
2040	16.458.106	-	-	16.458.106	135.570.990	1.354.365	0,001
Total	181.835.956	(84.724.966)	38.460.000	135.570.990		0,001	

In Scenario II, the cash flow is already positive. However, the discounted cash flow estimate for this project is negative. In the DCF, calculation considers the time value of money. The NPV calculation was carried out as seen in Table IV.9, and the results were negative, this shows that investment in this project is not considered profitable. In order to make this project feasible to operate, scenario III will be carried out, where the RDF price is changed to become higher to increase income in this business so that the NPV would be positive.

Table 9. Project Feasibility Indicator of Scenario II

Weighted Cost of Capital (WACC)	13.30%
Net Present Value (NPV)	(Rp26,939,162,736)

Scenario III, RDF Project with a building grant

Financing in scenario III is the same as in scenario II, where physical development will come from the central government, and investors will bear machinery. Nonetheless, there are changes in the RDF buying and selling transactions to make the project feasible and attractive to investors. When the price of RDF is added to IDR 522,979, the Cash flow and Discounted cash flow from the project are positive as seen in Table 10.

Table 10. Cash Flow Statement Scenario III With Building Grant (NPV +) (in .000 IDR)

After calculating cash flow and discounted cash flow, proceed with calculating the Investment Project Analysis as in the table: NPV, IRR, Profitability Index, Payback Period, and Discounted Payback Period with a WACC of 13.30% for Scenario 3 RDF.

Table 11. Project Feasibility Indicator of Scenario III

Weighted Cost of Capital (WACC)	13.30%
Net Present Value (NPV)	IDR1,00
Internal Rate of Return (IRR)	13.30%
Profitability Index (PI)	1.00
Payback Period, year	7.8
Disc Payback Period, year	20.0

Risk Analysis

From Scenario III which has just been proposed as an RDF model to be implemented in other places, a method is needed for risk management to predict the likelihood of different outcomes when there is uncertainty in project variables among the methods used to address this problem are sensitivity analysis and Monte Carlo risk analysis.

Sensitivity Analysis

Sensitivity analysis, or determining the most pertinent input parameters, is a crucial step in examining the relationship between input and output behavior in a performance evaluation. Sensitivity

analysis (SA) studies how much the uncertainty of a model output depends upon its inputs. Though it is generally agreed in existing guidelines that uncertainty and sensitivity analyses are both crucial for the validation or verification of a model (Saltelli, Andrea 2021). This RDF project's intrinsic value is determined by considering critical variables like waste input, the selling price of RDF, and COGS. It's crucial to understand that these factors are subject to change. The study tested several variables that could potentially swing to increase or decrease. These variables include waste input, selling price of RDF, COGS and Maintenance of NPV. These variables were adjusted to both increase and decrease by 20 percent of their original values. For visual representation, the widely used tornado chart was used to illustrate the sensitivity analysis, and the chart is presented below:

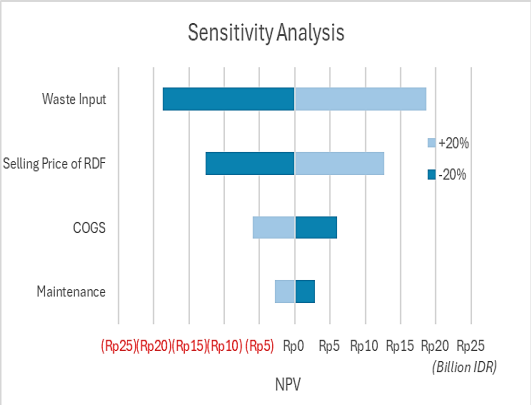

Figure 3. Sensitivity analysis

According to the sensitivity analysis conducted by the study, the most sensitive variable in the category is the waste input followed by selling price of the RDF to the offtaker, then COGS and the Maintenance as they demonstrate a significant increase when the swing changes from 80% to 120%, indicating its substantial responsiveness to fluctuations. As an example, changes in waste input directly affect the NPV of the project. The Waste input is a key driver of financial performance as it directly influences a company's ability to generate profits. As the number grows, there is an opportunity for the company to achieve economies of scale, thereby enhancing its equity value. The three variables were considered unsensitive as the +20% swing and -20% swing only affecting less than 20% changes.

Monte Carlo Simulation

Monte Carlo simulation is a model that makes decisions with repeated evaluation,with the input being a set of random numbers. Such a method is often used for complicated evaluation, nonlinear or more than two uncertain parameters. For representativeness, a model can contain a simulation that is evaluated more 10,000 times (Sun et al., 2022). In this simulation, the study developed Monte Carlo Simulation that uses three different variables such the waste input, selling price of RDF, COGS to generate a thousand outcomes. The simulation was conducted to explore various potential outcomes for the NPV of RDF Project . Moreover, the simulation generated a distribution of possible outcomes, and these outcomes were presented visually through a histogram graph.

Table 13. Monte Carlo Simulation of the possibilities of NPV

Variables	Min	Max	Max-Min
Waste input (tons)	46,355	73,000	26,645
Selling price of RDF (IDR)	300,000	586,163	286,163
COGS (IDR)	5,912,138,044	6,207,744,946	295,606,902

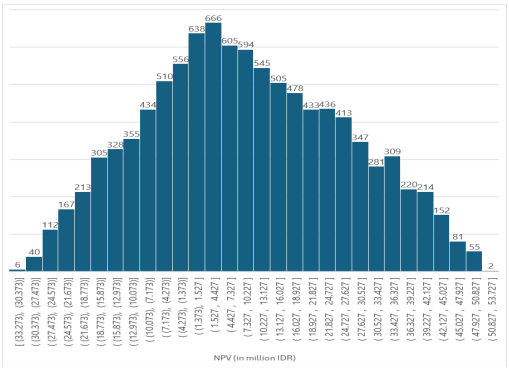

Figure 4. Descriptive Statistics

According to the simulation, the possibilities of outcomes of NPV of RDF Project were generated and shown as a histogram graph above. The 10,000 outcomes generates that the results were 66.75% percent consistently NPV positive.

Table 14. Generated outcomes from Monte Carlo Simulation

Variables	Value
Percentage of NPV (-)	33.25%
Percentage of NPV (+)	66.75%
NPV Minimum	(IDR 33,273,397,956)
NPV Maximum	IDR 51,576,659,461
NPV Mean	IDR 8,788,617,069

Essentially, the Monte Carlo simulation provided insights into the range of possible scenarios for NPV Value, with a breakdown of how many times it fell into undervaluation, intrinsic value, or overvaluation categories. The simulation does not predict the future price of NPV. However, it illustrates the potential future outcomes that NPV might experience based on its anticipated numerical tolerances. This information can be valuable for investors to assess the risk and uncertainty associated with the company's share valuation.

The potential of emission reduction and potential carbon credit RDF Cilacap

In this study, we calculated the potential reduction in CO_2 emissions from the Cilacap RDF Project compared to waste going to landfills (open dumping). The emission reduction calculation was taken from the IPCC Guideline for National Greenhouse Gas Inventories for the Waste sector. The composition and amount of waste make the difference in calculating CO_2 emission reduction. The composition and amount of waste make a difference in calculating CO_2 emission reduction between landfill and the RDF Plant. Table 15 shows an example calculation for CO_2 produced from waste in the landfill. The data was calculated for 2021. It is assumed that 100% of the waste is thrown in the landfill without any reduction efforts or initial treatment, whereas organic waste produces CH_4 gas. The waste composition in the table is taken from Cilacap Waste Composition data in 2020.

Table 15. CH_4 Emission Calculation to Landfill in 2021

Waste composition	% Wi	DOCi			DOCf	MCF	F	16/12	R	OX	CH_4 Emission
		W (Gg/year)		DOC (GgC/ Gg Waste)							(Gg CH_4 /year)
Food waste	58%	25,70	15%	0,087	0,5	0,5	0,5	1,333	0	0,1	0,33349
Wood	2%	0,76	43%	0,007	0,5	0,5	0,5	1,333	0	0,1	0,00084
Paper / Cardboard	10%	4,33	40%	0,039	0,5	0,5	0,5	1,333	0	0,1	0,02521
Plastic	16%	7,22	-	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Metal	1%	0,59	-	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Textile	1%	0,56	24%	0,003	0,5	0,5	0,5	1,333	0	0,1	0,00025
Rubber - Leather		0,00	39%	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Glass	1%	0,52	-	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Others	11%	4,79	-	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
TOTAL	**100%**	**44,57**									**0,35979**

The CO_2 value calculation in this research was taken from converting Menthane Gas (CH_4) to CO_2. As in Table 15, the total CH_4 produced in 2021 is 0.35979 Gg CH_4 /year, or the equivalent of 10,074.26 tonnes of CO_2 eq/year. The CH4 to CO_2 conversion factor is 28. Calculations for CO_2 produced from waste processed into RDF can be seen in Table 16. It is assumed that the waste that will produce CO_2 from RDF is only metal, textile, and glass because other waste such as food waste, paper, and plastic has been processed into RDF products in the form of fluff, pellets, so it does not produce a lot of CH_4 compared to waste, goes to landfills without any processing efforts. The waste

composition in the table is taken from Cilacap Waste Composition data in 2020.

Table 16. CH_4 Emission Calculation to RDF in 2021

Waste composition	% W_i	W (Gg/year)	DOC_i	DOC (GgC/ GgWaste)	DOC_F	MCF	F	16/12	R	OX	CH_4 Emission (Gg CH_4/year)
Food waste	58%	0,00	15%	0,087	0,5	0,5	0,5	1,333	0	0,1	0,00000
Wood	2%	0,00	43%	0,007	0,5	0,5	0,5	1,333	0	0,1	0,00000
Paper / Cardboard	10%	0,00	40%	0,039	0,5	0,5	0,5	1,333	0	0,1	0,00000
Plastic	16%	0,00		0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Metal	1%	0,59		0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Textile	1%	0,56	24%	0,003	0,5	0,5	0,5	1,333	0	0,1	0,00025
Rubber - Leather		0,00	39%	0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Glass	1%	0,52		0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
Others	11%	4,79		0,000	0,5	0,5	0,5	1,333	0	0,1	0,00000
TOTAL	**100%**	**6,46**									**0,00025**

The CO_2 value calculation in this research was taken from converting Menthane Gas (CH_4) to CO_2. As in Table 16, the total CH_4 produced in 2021 is 0.00025 Gg CH_4 /year, equivalent to 7 tonnes of CO_2 eq/year. The CH_4 to CO_2 conversion factor is 28. In this research, it is known, for example, that in 2021, CO_2 from landfills is 10,074.26 tonnes of CO_2 eq/year, while CO_2 from RDF is 7 tonnes of CO_2 eq/year. The difference in CO_2 is 10,067.24 tonnes of CO_2 eq/year, so this value is the potential for reducing CO_2 emissions from the RDF Plant. With the potential to reduce CO_2 emissions, it is possible to be registered as a carbon credit and traded in the market. However, this process requires a valid calculation using an internationally recognized method and following Indonesia's system processes for carbon trading. Still, this research only examines and carries out simple calculations regarding the potential for CO_2 reduction multiplied by the price. The current carbon in Indonesia is IDR 69,600 (USD 4.45) (International Carbon Action Partnership, 2024), and the potential carbon value obtained will reach IDR 700,679,904 in 2021. Table 17 shows the potential carbon value if RDF operates until 2040.

Table 17. The potential carbon value with the development of RDF

Year	W	TPA / Landfill	RDF	CO_2 (TPA - RDF)	CO_2 Price	PV CO_2						Price
							CH_4 Emission	$CO_{2\ eq}$	CH_4 Emission	$CO_{2\ eq}$		
		(ton/year)	(Gg CH_4 /year)	ton CO_2 eq /year	(Gg CH_4 /year)	on CO_2 eq /year	ton CO_2 eq/year	.000 IDR	.000 IDR
2020	0							-	-
2021	44.566	0,3598	10.074,26	0,00025	7,019	10.067,24	700.680	618.425
2022	47.900	0,3867	10.827,92	0,00027	7,544	10.820,37	753.098	586.661
2023	45.600	0,3681	10.308,00	0,00026	7,182	10.300,81	716.937	492.929
2024	46.284	0,3737	10.462,62	0,00026	7,290	10.455,33	727.691	441.589
2025	46.978	0,3793	10.619,56	0,00026	7,399	10.612,16	738.606	395.596
2026	47.683	0,3850	10.778,85	0,00027	7,510	10.771,34	749.685	354.393
2027	48.398	0,3907	10.940,53	0,00027	7,623	10.932,91	760.930	317.482
2028	49.124	0,3966	11.104,64	0,00028	7,737	11.096,90	772.344	284.416
2029	49.861	0,4025	11.271,21	0,00028	7,853	11.263,36	783.930	254.793
2030	50.609	0,4086	11.440,28	0,00028	7,971	11.432,31	795.688	228.255
2031	51.368	0,4147	11.611,88	0,00029	8,090	11.603,79	807.624	204.482
2032	52.139	0,4209	11.786,06	0,00029	8,212	11.777,85	819.738	183.184
2033	52.921	0,4272	11.962,85	0,00030	8,335	11.954,52	832.034	164.105
2034	53.714	0,4337	12.142,29	0,00030	8,460	12.133,83	844.515	147.013
2035	54.520	0,4402	12.324,43	0,00031	8,587	12.315,84	857.182	131.701
2036	55.338	0,4468	12.509,29	0,00031	8,716	12.500,58	870.040	117.984
2037	56.168	0,4535	12.696,93	0,00032	8,846	12.688,09	883.091	105.696
2038	57.011	0,4603	12.887,39	0,00032	8,979	12.878,41	896.337	94.687
2039	57.866	0,4672	13.080,70	0,00033	9,114	13.071,58	909.782	84.825
2040	58.734	0,4742	13.276,91	0,00033	9,251	13.267,66	923.429	75.991
Total	**1.026.782**	**8,2895**	**232.106,58**	**0,00578**	**161,718**	**231.944,86**	**16.143.362**	**5.284.208**

Proposed RDF Project

In this research, after analyzing and calculating the three scenarios carried out, the third scenario is the relevant scenario that other regions can carry out to implement the RDF project. In this third scenario, RDF Infrastructure Financing will be presented to the central government (PUPR), with the Investor covering the machine financing. Local governments are required to provide clear and clean land when applying to PUPR. The RDF Price of RDF would be IDR 522,979 per ton, and it will increase by 5% every five years.

CONCLUSION

Waste is an unavoidable by-product of human activities. Currently, solid waste management is one of the most critical and challenging environmental problems in urban settings, including regions in Indonesia,

therefore efforts are needed for integrated waste management and also to accelerate waste processing through proven technology, one of which is RDF as a strategy to solve this problem. RDF Cilacap is the first RDF Plant in Indonesia that has been successfully operating since 2020, From the calculations, it is obtained that the current condition of the Cilacap has a Net Present Value IDR 18,019,917,764 for 20 years with the assumption that the amount of waste input is 120 tons/day and will increase by 1.5% per year, the RDF produced is 51% of the amount of waste entered. The RDF price starts at IDR 300,000 per ton, the tipping fee from the local government is 150,000 per ton, and the third party (PT X) grant is 100,000 per ton of RDF. For RDF prices, tipping fees and grants will increase by 5% every five years.

Many regions intend to apply RDF in their areas. However, this will be very different when RDF is implemented in other regions; as previously explained, not all areas can have the opportunity to receive grants even if the central government bears everything; it will be difficult due to the limitations of the APBN; thus, from this research, an option was created funding scenario for RDF development. A third scenario that is relevant and feasible to implement is where the central government provides the financing for the physical development of the RDF Plant, and investors or third parties bear the cost of the machinery. In this scenario, the price of RDF changes to 522,979 per ton, which will increase by 5% every five years.

The sensitivity analysis and Monte Carlo simulation reinforce the NPV valuation. The four variables indicate minimal sensitivity, with swings of +20% and -20% causing less than 20% changes. The Monte Carlo simulations constantly indicate a positive NPV of 66.75, indicating the feasibility of the RDF Project. The potential for reducing CO2 emissions with the existence of the RDF Plant Cilacap for 20 years reaches 231,944.86 tons and, if multiplied by the average price in the secondary market IDR 69,600 (USD 4.45) from transactions involving Emission Reduction Certificates (SPE, Indonesian Emission Reduction Certificates in Indonesia), the potential for obtaining funds is IDR 16,143 Million or equal we calculate in present value it reached to IDR 5,284 Million.

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