DEVELOPMENT OF A LIFE CYCLE CARBON NEUTRAL WASTE-TO-STEAM PROJECT USING HEAT FROM MUNICIPAL WASTE INCINERATION IN BANTEN PROVINCE

THESIS

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Jakarta, 16 October 2026

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NON-PLAGIARISM DECLARATION FORM

This Thesis is a presentation of our original research work. Wherever contribution of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

Also, this work is being submitted in partial fulfillment of the requirements for the Master of Business Administration degree and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Jakarta, 16 October 2026



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ABSTRACT

Banten Province is one of Indonesia's key industrial and logistics hubs, and its rapid economic and population growth has increased municipal solid waste (MSW) generation, placing growing pressure on a waste management system that still relies mainly on landfills. At the same time, industries in the Serang–Cilegon corridor depend heavily on fossil fuels, particularly coal, to produce process steam. A Waste-to-Steam (WtS) project that recovers heat from municipal waste incineration offers a potential solution to both challenges. Although a Pre-Feasibility Study (Pre-FS) has established the project's technical foundation, this basis has not yet been translated into a structured business model, financing strategy, or investment-ready case.

This study develops the business, financial, and strategic framework needed to advance a WtS project in Banten Province, including an assessment of its Life Cycle Carbon Neutral (LCCN) potential. It employs an applied, mixed-method research design based primarily on secondary data from the Pre-FS, government reports, and industry sources. The strategic assessment applies PESTEL, VRIO, Porter's Five Forces, SWOT, and TOWS analyses. The financial assessment uses a capital budgeting model incorporating Net Present Value (NPV), Internal Rate of Return (IRR), Debt Service Coverage Ratio (DSCR), and free cash flow analysis. A scenario-based sensitivity analysis evaluates the financial implications of pessimistic, moderate (base), and optimistic engineering assumptions, complemented by regulatory, market, and Public–Private Partnership (PPP) assessments.

The results indicate that the proposed 600-tonnes-per-day plant is technically feasible at a preliminary level, supported by approximately 2,048 tonnes per day of MSW generated in Serang City, Serang Regency, and Cilegon City, as well as nearby industrial steam demand. Under the base scenario, the project achieves a Project IRR of 10.29% and a positive Project NPV of approximately IDR 53,003 million. However, the Equity IRR of 7.12% and negative Equity NPV of approximately IDR 230,683 million indicate that the current financing structure is not yet sufficiently attractive to equity investors. The sensitivity analysis demonstrates substantial exposure to operating performance: under the pessimistic scenario, Project IRR falls to 3.15%, and Project NPV declines to negative IDR 362,921 million, while Equity IRR decreases to -2.39% and average DSCR falls to 0.76x. Conversely, the optimistic scenario yields a Project IRR of 19.74%, a Project NPV of IDR 771,668 million, and an Equity IRR of 20.71%, with average DSCR improving to 2.42x. These differences reflect the influence of waste throughput, operating hours, waste lower heating value, boiler efficiency, and steam

sales volume on financial performance. A Build–Operate–Transfer (BOT) PPP scheme is recommended, supported by reliable waste-supply agreements, secure tipping-fee and steam-payment mechanisms, and potential government support through instruments such as Viability Gap Funding (VGF) or Joint Crediting Mechanism (JCM) support, subject to eligibility and availability. The LCCN component is not yet suitable for immediate implementation because Indonesia's hydrogen ecosystem remains under development. The study concludes that a comprehensive feasibility study, including Front-End Engineering Design (FEED), detailed financial sensitivity testing, and validation of waste supply, steam offtake, and financing assumptions, is required before the project proceeds to investment.

Keywords: Waste-to-Steam, municipal solid waste incineration, capital budgeting, Public–Private Partnership, Banten Province

CHAPTER 1
INTRODUCTION

1.1 Industry Background

Municipal Solid Waste (MSW) generation shows a strong correlation with economic growth and urban development. As illustrated in Figure 1.1 the World Bank What a Waste 3.0 Global Snapshot of Solid Waste Management toward Circularity until 2050, countries with higher GDP per capita generally generate larger volumes of waste per person.

As Indonesia`s economy grows, municipal solid waste is expected to increase significantly. In 2022, The waste generation stood at around 0.53 Kg / capita / day, or 193 Kg/capita annually. This rate is still lower compared with high-income countries, and the gaps primarily reflects differences in income and daily life habits. The World Bank estimates Indonesia waste generation will increase to around 1.6 times from today`s waste generation, and by 2050 each person generates waste around 1.2-1.3 kg/ day, over twice compared with the 2022 figure. Over the years, GDP per capita is expected to increase from USD 4.730 to USD 11,000. As current waste is mostly sent to landfill, will therefore come under heavy pressure.

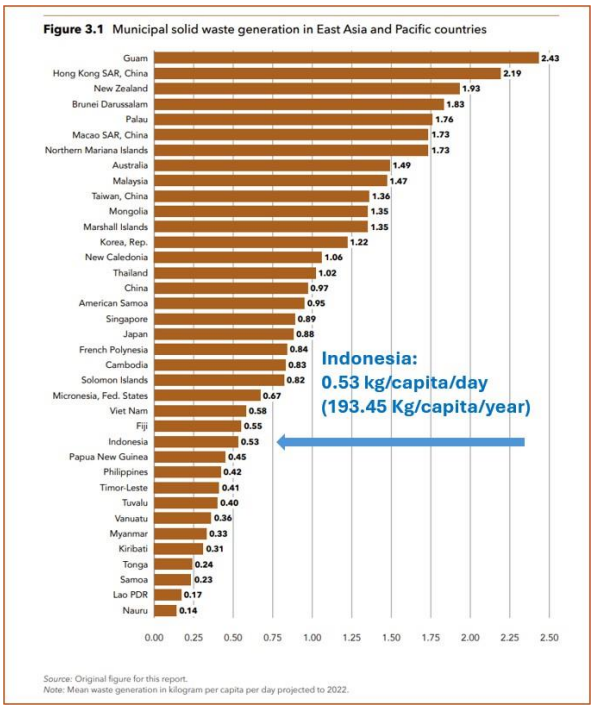


Figure 1.1 Waste Generation Increase with GDP Growth

Source: World Bank, 2025

Growing waste volumes create an opportunity to reposition waste from an environmental burden into an energy resource. Rather than Waste-to-Energy (WtE), Waste-

to-Steam (WtS) offers an alternative approach by converting residual waste into usable thermal energy for industrial applications. This opportunity becomes increasingly relevant considering the simultaneous growth of industrial energy demand and decarbonization targets. By utilizing municipal solid waste as feedstock for steam generation, WtS can support three strategic objectives simultaneously: reducing landfill dependency, supplying low-carbon industrial steam, and improving circular resource utilization
(Concept: Life Cycle Carbon Neutral / LCCN).

The steam generated from waste incineration plants can reach 300–400°C, making it suitable for medium- to high-temperature industrial applications. Industries identified as having strong potential demand include:

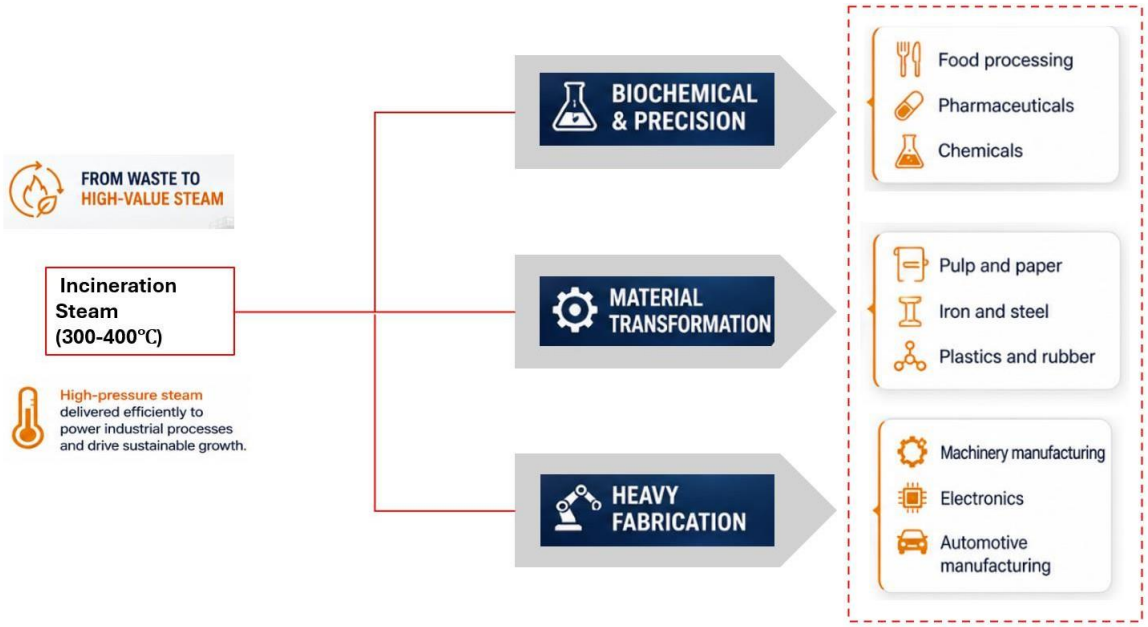


Figure 1.2 Strong Potential Demand

Source: Maki et al., 2021

Waste-to-Steam (WtS) is emerging as an advanced form of Waste-to-Energy (WtE) that converts municipal and industrial waste into usable thermal energy in the form of steam for industrial processes, district heating, and electricity generation. Unlike conventional WtE plants that prioritize electricity production, WtS directly utilizes recovered heat as process steam, enabling higher overall energy utilization by reducing conversion losses.

The development of the WtS industry is driven by three converging global trends: (1) increasing municipal solid waste generation, (2) industrial decarbonization pressure, and (3) demand for circular and resource-efficient energy systems. Recent research indicates that steam generated from waste treatment facilities can become an important alternative

utility source for industries with continuous thermal demand, supporting the transition toward low-carbon industrial ecosystems.

A growing number of international projects demonstrate that waste treatment plants are increasingly being repositioned from disposal infrastructure into energy hubs supplying steam directly to industrial users.

No	WtS Project	Capacity	Steam Off-taker	Location
1	Energia Aus Abfall	600 ton per day of waste 15,6 ton per hour of steam	Papermills, Package Factory	Switzerland
2	Juron	1,300 ton per day of waste 140 ton per hour of steam	Community Boiler of Sembcorp	Singapore
3	Gujarat	100 ton per day of waste 15,7 ton per hour of steam	Steam house	India

Figure 1.3 WtS Reference Project

Source: NIES, 2025

Figure 1–3 illustrates the Waste-to-Steam (WtS) process, which is an important component of the Life Cycle Carbon Neutral (LCCN). Municipal waste collected by garbage trucks is delivered to a waste pit, where negative pressure is maintained to prevent odors from escaping. The odor-containing air is reused as combustion air in the boiler, where odors are destroyed during combustion. The waste is mixed using a waste crane to create more uniform properties and stabilize combustion. The mixed waste is then fed into the incinerator, where it is dried and burned. Heat generated from combustion is recovered by the boiler to produce steam, which is supplied to factories for industrial use. After use, the steam condenses and returns to the boiler for reuse. Exhaust gas from the incineration process is treated through a bag filter and chemical injection system to remove pollutants before being released through the chimney in compliance with emission standards.

The remaining residues are separated into bottom ash and fly ash for further treatment. Through the incineration process, the waste volume is reduced to less than 10% of its original volume.

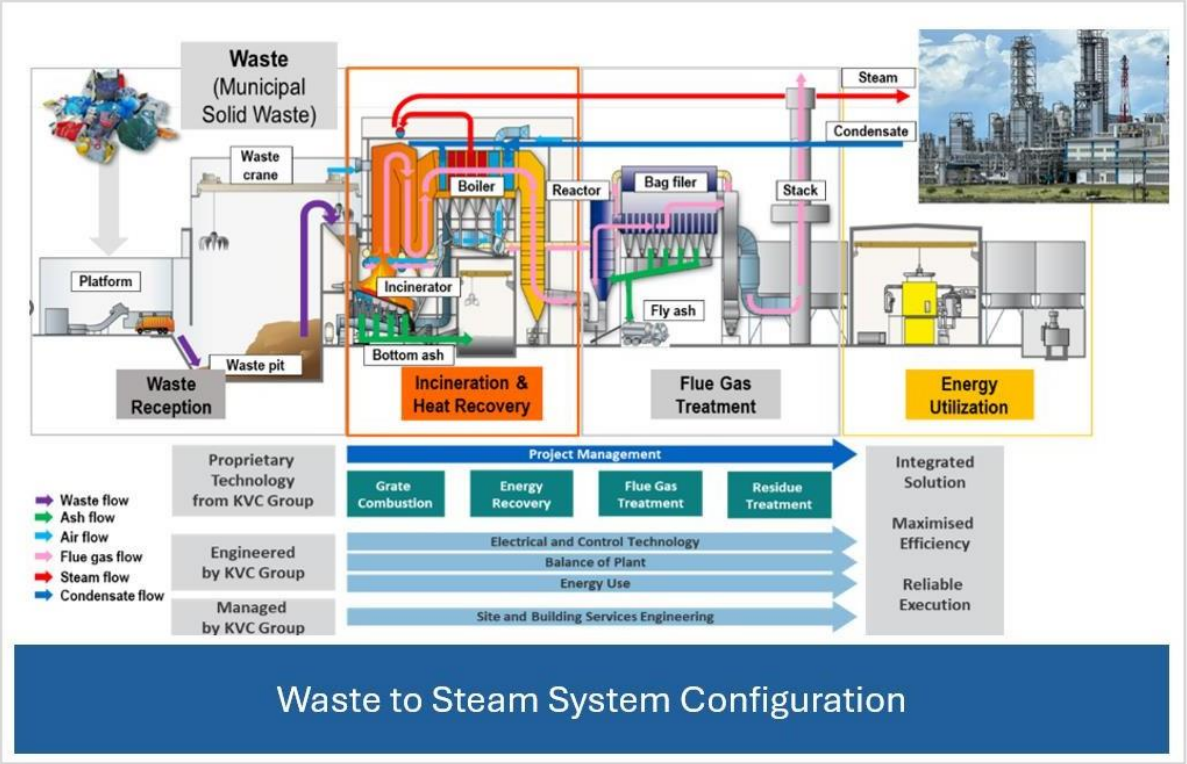


Figure 1.4 Waste to Steam System Configuration

Source: Kanadevia, 2026

Kanadevia Group accounted for approximately 33.7% of the global supplier market share between 2015 and 2024, making it one of the leading players in the global Waste Incineration industry. This market position reflects Kanadeva's extensive experience and long-term track record in delivering waste treatment and energy recovery facilities worldwide.

However, WtS still generates CO_2 emissions during combustion and therefore is not carbon neutral by itself. To achieve carbon neutrality, Figure LCCN introduces a second stage: Carbon Capture and Utilization (CCU). CO_2 emitted from the WtS process is captured and combined with green hydrogen produced from renewable electricity to create new raw materials, such as chemical feedstock and plastics.

Through this approach, carbon contained in waste is not simply released into the atmosphere but is continuously reused within the industrial system. Overall, LCCN consists of two integrated stages:

1. Waste-to-Steam (WtS): Efficient recovery and utilization of energy from waste.
2. Carbon Capture and Utilization (CCU): Recovery and reuse of CO_2 to produce new materials.

By combining these two stages, LCCN transforms waste treatment from a disposal process into a carbon circulation system aimed at achieving life-cycle carbon neutrality.

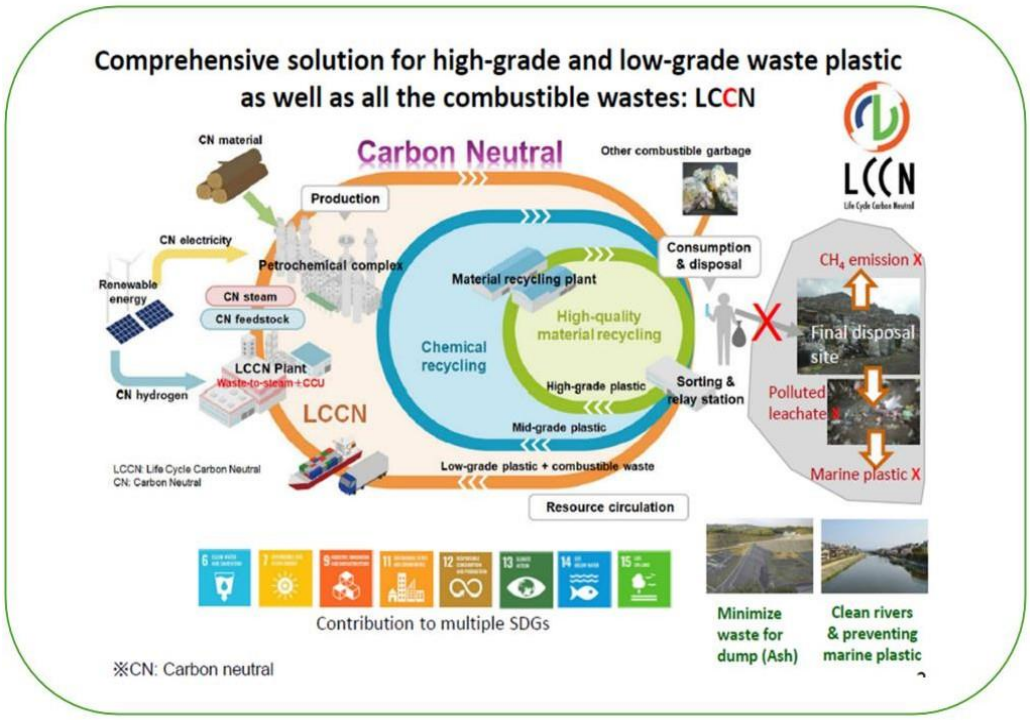


Figure 1.5 Waste to Steam with LCCN

Source: NIES, 2025

Population growth, urbanization, and industrial development in Indonesia have increased municipal waste generation and put pressure on the waste management system, which still relies heavily on landfills. In 2023, Indonesia generated around 56.63 million tons of waste, and approximately 60.99% was not properly managed, causing landfill capacity issues and environmental challenges.

At the same time, Indonesia's energy supply remains dominated by fossil fuels. In 2023, coal contributed 40%, oil 30%, and natural gas 17%, while renewable energy accounted for only 13% of the primary energy mix. To support energy transition and reduce emissions, the Government targets increasing renewable energy share to 19–21% by 2030 and 70–72% by 2060. In parallel, Indonesia's energy sector emissions are projected to peak at 1,069–1,242 $MtCO_2e$ by 2035, highlighting the need for alternative low-carbon energy sources.

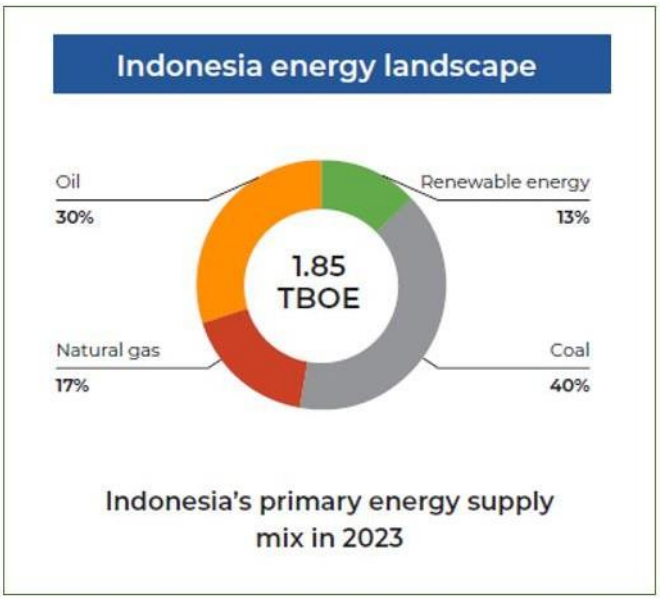


Figure 1.6 Indonesia Energy Landscape

Source: Indonesia Energy Transition Outlook 2025

To address both waste and energy challenges, the Government has strengthened waste management policies and introduced Presidential Regulation No. 109 of 2025 to accelerate waste processing into renewable energy.

The shift in Indonesia's waste management policy has attracted growing interest from international firms capable of turning regulatory ambition into operational infrastructure. Kanadevia Corporation, a company with extensive experience in thermal waste treatment, is among those now exploring project opportunities in the country, notably in Banten Province. One pathway under consideration is Waste-to-Steam (WtS), a process in which municipal solid waste is thermally treated to produce steam that can be supplied directly to industrial users. Compared with conventional disposal, WtS offers several advantages: it diverts waste away from overburdened landfills, reduces emissions associated with open dumping and decomposition, and provides industry with an alternative energy source. As such, it represents a promising contribution to Indonesia's efforts to decarbonize its energy mix while addressing a mounting waste problem.

1.2 Company Background

The Waste-to-Energy (WtE) sector has expanded considerably in recent decades, driven by the parallel pressures of rising waste volumes and the global push toward renewable energy. Firms operating in this field are distinguished less by technology alone than by their ability to manage projects across the entire life cycle, from feasibility

assessment and design to construction, operation, and long-term asset maintenance. This combination of technical and managerial capability has become a critical factor in determining which companies succeed in delivering large-scale WtE infrastructure. Kanadevia Corporation is widely regarded as one of the leading players in this regard.

Kanadevia
Technology for people and planet

Figure 1.7 Company Logo

Source: Kanadevia.com, 2026

KVC (a pseudonym name) Corporation is a leading Japanese engineering and technology company headquartered in Osaka. Founded in 1881, the company has evolved from its origins in shipbuilding and heavy industry into a global provider of environmental, energy, infrastructure, and industrial solutions. In October 2024, KVC shifting to reflect its strategic focus on sustainability, decarbonization, resource circulation, and the harmonious coexistence of humanity and nature. Today, KVC designs, constructs, and operates advanced waste-to-energy facilities, renewable energy systems, water and wastewater treatment plants, industrial machinery, marine engines, and infrastructure projects worldwide. Through its commitment to technological innovation and environmental stewardship, KVC aims to contribute to the realization of a sustainable, safe, and prosperous society while supporting the global transition toward a circular and low-carbon economy.

The commitment to technological innovation and environmental stewardship are reflected in the company values (see Figure 1.7). KVC corporate philosophy through standards of business behaviour are reflected to drive quality, safety, and compliance while still contributing to a sustainable future.

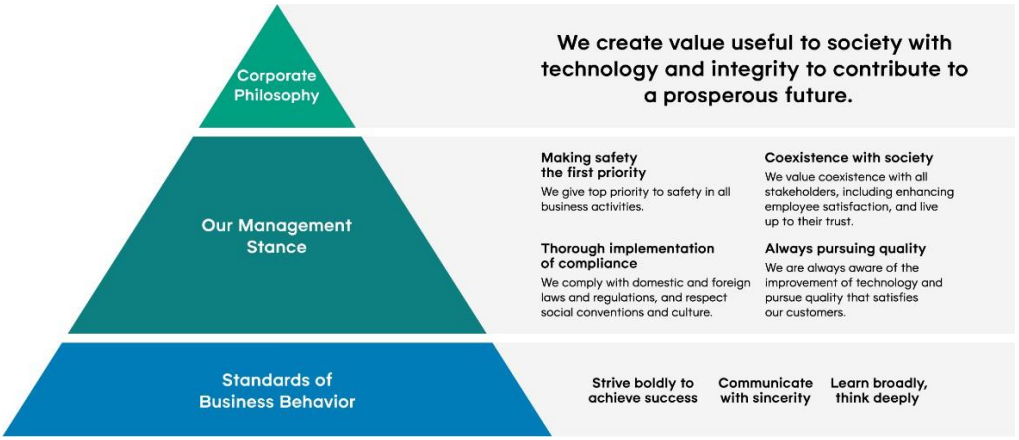


Figure 1.8 Company Values

Source: Kanadevia.com, 2026

With its long history, extensive technological expertise, and strong presence in the environmental and energy sectors, KVC Corporation has established itself as a leading provider of sustainable waste treatment and energy recovery solutions. Kanadevia Corporation (hereafter KVC) has a lot of substantial experience in development and operation of Waste to Energy plants across multiple countries, positioning it as a credible contributor to the global transition from waste into low carbon energy.

This study is further informed by the author who is working in Kanadevia Corporation as a business development of the proposed waste to steam project in Banten. The previous pre-feasibility study was carried out to assess the availability of municipal waste, confirm incineration specification, and estimate potential steam generation (see section 2.3.2 and 3.3). The technical showing that pre-fs servers a input technical data for thesis. The thesis independently develops the business model, financing structure and market strategic required to bring the project to be ready for investment.

1.3 Problem background.

Banten province has a strategic position in Indonesia`s national logistic and industrial corridor. As the western gateway of Java, it links the island to Sumatra via the Merak - Bakauheni ferry crossing, with Merak Port ranking among the busiest ferry terminals in the country. Its location has made Banten a gateway for people and commodity moving to western part of Indonesia, and this benefit helps Banten grows into an important area of industries, commerce and logistics. Banten`s gross domestic product (GRDP) was around IDR 936.2 trillion by 2025, or roughly IDR 74.67 million per resident, grew by 5.37% of that year, ahead of Indonesia`s 5.11%. Manufacturing sector provides the largest contribution to regional revenue, followed by trade and construction. This growth has also contributed in municipal waste generation, both tonnage and the variety of materials it contains. Most of waste sent to landfill. Sustained economic and industrial expansion, however, has been accompanied by a increase in both the quantity and complexity of municipal waste. Waste management in Banten province is still relies on landfill, while the deployment of advanced treatment technology is still limited.

These pressures are most pronounced in the Serang - Cilegon corridor, one of the province's principal urban and industrial zones, where rapid population growth, industrial development, and urbanization have placed considerable strain on existing landfill capacity.

In this context, a Waste-to-Steam project is particularly relevant. By converting waste into industrial steam, the project can help reduce dependence on landfills while also lowering the use of fossil fuels. This can support Indonesia's broader energy transition and decarbonization efforts. However, developing this type of waste management project in Banten Province remains challenging in terms of institutional coordination, financing type, and operational readiness.

One of the main challenges is the gap betweem what has been demonstrated technically and what is commercially ready for implementation. The previous Pre-Feasibility Study assessed key technical aspects, including waste availability, calorific value, and the selection of suitable technology. However, it didn't establish a practical business model, identify potential funding sources, or develop an investment-ready proposal. While international reference projects and existing studies can provide useful guidance on the technical aspect, this WtS project still needs to be assessed against Indonesia's policy environment, financing conditions, and the coordination requirements of local stakeholders.

As a result, the policy makers, project developers, investors still lack a combined business and financial framework, built on the Pre-Feasibility Study estimates of CAPEX, OPEX and financial indicators that will allow a long-term investment to be organised. This gap matters most in Banten where waste generation has grown faster than environmental master plan.

The problem is further compounded by the lack of feasible business models which adapted to local investment conditions. Without a well-structured such as Public-Private-Partnership (PPP), Build-Operate-Transfer (BOT) model, or meaningful collaboration among key stakeholders, waste management authorities, developers, remains constrained.

Institutional misalignment and unclear regulatory frequently impede the scaling of Waste incineration technologies, even though such technologies are consistent with national policy objectives. Indonesia`s ratification of Paris Agreement through Law No. 16/206, Presidential Regulation No. 98/2021 on the economic value of carbon, and Presidential Regulation No. 112/2022 on the acceleration of renewable energy development all affirm the role of waste-to-energy systems in achieving the country's climate targets.

If the missing knowledge, weak policy links and incomplete financial modelling are left unresolved, waste incineration proposals in Banten will probably never move past the idea stage. The province would then lose a chance to deal with its rising volume of waste, protect its environment and put its industrial base on a more sustainable footing. For this

reason, a thorough evaluation of whether waste incineration can work as a business in this particular location is needed. Such an evaluation would keep stakeholders properly informed, help attract investment and allow Banten to move toward an economy that is more circular and better prepared for climate change. With this in mind, the present study aims to support the project that the author's organisation is now developing. Taking the technical groundwork of the Pre-FS as its starting point, it sets out the business model, the funding strategy and the strategic plan for implementation that the project needs before it can be offered to investors. The thesis therefore provides the author's own analysis of business design, financial structure and strategic position. The Pre-FS technical findings are used as inputs and are not re-examined independently. The work covers financial structuring and investment appraisal, supported by four strategic tools (SWOT, Porter's Five Forces, PESTEL and VRIO), which are used to shape the project's value proposition, funding approach, main partners and route to implementation. In this way, the study lays down a business basis on which investors can act and on which the project can continue to be developed.

1.4 Research Questions

- What are the current conditions of waste generation, management systems, regulatory frameworks, and institutional arrangements in Indonesia and Banten Province that shape the context for project development?
- What business model and financing structure would best support the development and bankability of the WtS project in Banten Province, building on the existing Pre-FS technical foundation?
- To what extent can the proposed project reduce greenhouse gas emissions and environmental impacts compared to existing landfill-based waste management systems?
- What is the most suitable project scheme in terms of stakeholder involvement, financing structure, policy support, and implementation strategy for the WtS project?

1.5 Research Objectives

- To assess the current condition of waste generation, waste management systems, regulatory frameworks, and institutional arrangements in Indonesia and Banten Province as the foundation for project development.

- To develop a business model and financing structure that supports the development and bankability of the WtS project in Banten Province, building on the existing Pre-FS technical foundation.
- To quantify the potential environmental benefits of the project, including reductions in greenhouse gas emissions compared to conventional landfill practices.
- To identify an appropriate project implementation scheme, including stakeholder roles, financing mechanisms, policy support (e.g., subsidies for CO_2 reduction), and a feasible implementation timeline.

1.6 Research Scope

This study focuses on the analysis of a waste incineration project in Banten Province. The scope of the research is defined as follows:

1. **Geographical Scope**

   The analysis is limited to Banten Province, Indonesia, with particular emphasis on industrial areas where demand for steam energy is significant.

2. **Project Scope**

   The study examines a waste incineration-based system designed to convert municipal solid waste into thermal energy (steam), with consideration of its integration with Life Cycle Carbon Neutral (LCCN) objectives.

3. **Analytical Scope**

   The research adopts a project development and feasibility assessment approach , covering the following key aspects:

   - Market and demand analysis for steam utilization in industrial sectors
   - Technical analysis, including waste characteristics, calorific value, and technology selection
   - Financial analysis, including estimation of CAPEX, OPEX, revenue streams (tipping fees and steam sales), and investment indicators such as NPV, IRR, and DSCR
   - Legal and institutional analysis related to regulatory frameworks and stakeholder roles
   - Environmental analysis, focusing on reductions in greenhouse gas emissions compared to conventional landfill practices
   - Project implementation scheme analysis, including stakeholder roles, financing mechanisms, policy support (e.g., subsidies for CO_2 reduction).

4. **Data Scope**

   The study utilizes primary data, secondary data, including internal project reports, government reports, industry benchmarks, academic literature, and publicly available datasets. Where primary data could not be obtained, the study relies on assumptions and projections.

5. **Limitations of Study**

   The research covers only the early development and assessment phase of the project. It does not cover to detailed engineering scope, actual operation data, primary survey in the field. The financial and technical are based on assumptions and estimations, so they may not match with the actual operation data once the waste to steam plant is actually built and operated.

1.7 Research Benefits

This part provides what the study may offer to different groups of stakeholders. These benefits are divided into two categories:

1. **Theoretical Benefits**
   - Providing to academic literature related to Waste-to-Steam (WtS), circular economy, and sustainable environmental business development in Indonesia.
   - Contributing a research model or framework that can be utilized for further research on Waste to Steam, policy, or green energy development.
   - Enriching existing discourse on capital budgeting and strategic business structuring for renewable energy projects in emerging markets.

2. **Practical Benefits**
   - For policymakers: Providing insights and evidence-based recommendations to support Indonesian government decisions on waste-to-steam execution and policy frameworks.
   - For investors and project developer**:** Providing financial analysis (e.g., CAPEX, OPEX, NPV, IRR,) that can be utilized to guide Waste to Steam investment in Banten Province.
   - For industrial estate developers**:** Providing potential energy and waste solutions which align with industrial symbiosis and circular economy goals.

- For local communities and environmental stakeholders**:** Highlighting the environmental and social co-benefits of reducing landfill dependency and improving air quality through sustainable waste management.
- For developers and engineering consultants**:** Providing as a reference for planning, designing, or proposing Waste to Steam tailored to regional characteristics and constraints.

CHAPTER 2
EVIDENCE REVIEW

1.1 Analytical Framework

An analytical framework can be understood as the integration of theoretical concepts and empirical insights to address a research problem, enabling a more comprehensive understanding of the studied phenomenon (Imenda, 2014). In this study, the analytical framework is designed to examine a waste incineration utilization project in Banten Province. The framework incorporates key analytical dimensions, namely market and demand analysis, technical assessment, financial evaluation, legal and institutional review, environmental considerations, and risk analysis, as the main input variables.

These analytical components collectively inform the development of an appropriate project strategy and business model. Ultimately, the framework aims to evaluate the overall financial and business feasibility of the proposed waste incineration project as the primary output. Through this structure, the study illustrates how various internal and external factors influence the viability and implementation of waste incineration technology within the context of Banten Province.

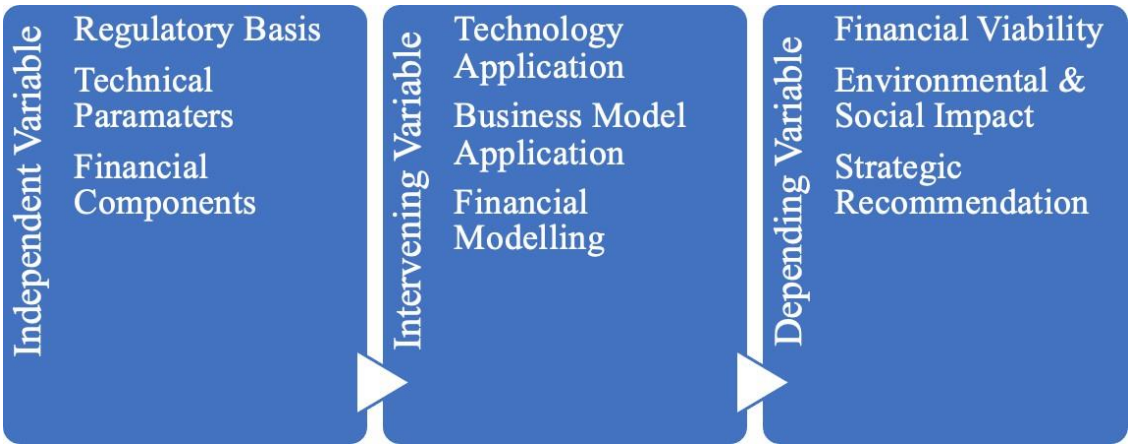


Figure 2.1 Analytical Framework

In this study we are following a mixed-methods approach to study the proposed waste incineration heat utilization project, which we will refer to as the Waste-to-Steam (WtS) project in the Province of Banten. First, we understand the overall strategic situation of the project by examining its external and internal dimensions. The external environment is studied within a PESTEL framework that considers the political, economic, social, technological, environmental and legal aspects of waste incineration development in

Indonesia. Second, the internal analysis is performed to assess KVC's resources, capabilities and state of project readiness.

All secondary studies are based on academic literature, government reports, industry publications, and media coverage. Building on this framework, the study is conducted to assess the feasibility of the project. A market and demand analysis is conducted to estimate the scale of the demand of steam for industrial consumers in Banten and a technical analysis of waste, calorific value and technology choice are performed. The project is evaluated on the basis of the three-investment metrics: Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period. If the NPV is positive and the IRR is greater than the weighted average cost of capital (WACC), the project is considered financially viable.

A legal and institutional assessment of the project and its alignment with the guidelines of LCCN is also conducted by the research. For a more robust assessment, a risk analysis is conducted to identify the major uncertainties that may affect project performance and to formulate appropriate mitigation measures. Scenario and sensitivity analyses are also conducted to assess how key parameters affect financial performance. The approach together with this combined strategy will offer an objective evaluation of the WtS project of Banten Province.

1.2 Literature Review

Table 2.1 Literature Review

Author	Title	Method	Results	Critical Review
Li et al. (2015)	Waste incineration industry and development policies in China	Descriptive and qualitative analysis of China's waste incineration industry chain (upstream/downstream), government policies, and subsidies.	China has transitioned from landfill to incineration due to land shortages. By 2013, MSW reached 172.4 million tons. Incineration can achieve >90% volume reduction.	While comprehensive in mapping the industry chain and policy landscape, the study notes that tail gas treatment technology and high investment costs remain significant barriers to industry competitiveness.
Lu et al. (2017)	Status and perspectives of municipal	Quantitative and comparative analysis using up-to-date data	MSW incineration in China boosted	This paper provides a rigorous technical

	solid waste incineration in China: A comparison with developed regions	from China versus the EU, U.S., Japan, South Korea, and Taiwan.	twelvefold in a decade. Moving grate technology dominates (68.1% in China, 87.9% in EU). China faces public protest due to substandard emissions caused by high moisture content in MSW and lack of operational experience.	comparison that highlights why Western technologies cannot be directly "plugged" into China without adjusting for unique waste compositions (high moisture/low calorific value).
Makarichi et al. (2018)	The evolution of waste-to-energy incineration: A review	Historical review and evolution analysis of MSW incineration from the late 19th century to modern high-efficiency CHP plants.	Incineration evolved from simple waste reduction to sophisticated energy recovery. There are ~1,179 plants globally with >700,000 MT/d capacity. Modern systems now integrate advanced flue gas cleaning and wastewater utilization.	The review successfully traces the "Throw Away society" roots but warns that while WtE solves the immediate disposal problem, it does not address the fundamental issue of growing global waste volumes.
Maki et al. (2022)	Using waste to supply steam for industry transition: Selection of target industries through economic evaluation and statistical analysis	The study estimated waste generation and composition using population and statistical data, then calculated potential steam output from waste treatment plants (WtPs). It also considered the physical limits of steam distribution. Industrial steam demand was analyzed based on production data, and a five-step approach was used to identify suitable industries. This	The study found that supplying steam from WtPs can be economically feasible, but only for certain industries. High-potential sectors identified include pulp, steel, and transportation machinery. Some industries, such as textiles and ceramics, become viable only at larger	While the methodology is comprehensive and scalable, the study is limited by its regional focus and incomplete coverage of certain industries. It also does not fully consider broader opportunities such as inter-industry heat sharing and integrated energy

		included cluster analysis, data envelopment analysis (DEA), regression, and decision tree analysis to evaluate economic feasibility and select target industries.	production scales. The study also found that a minimum cluster of 10–15 firms is needed to achieve profitability. However, results are specific to Aichi Prefecture, and some high-demand industries were not fully captured.	systems. Future research should develop more generalized models that can be applied across regions with varying industrial structures.
Luo et al. (2025)	Assessment of the Waste-to-Energy Potential for Industrial Steam Supply and Carbon Emission Reduction in Hainan, China	Modeled MSW collection and WtE capacity through 2030, assessing supply-demand matches for the manufacturing sector.	WtE steam can reduce manufacturing carbon emissions by up to 87.1% if subsidies are shifted from electricity to steam supply.	The research successfully links policy shifts to environmental gains but is a case study of a specific island province, which may limit its global generalizability.
Maki et al. (2021)	Technical and economic analysis of potential steam supply from waste treatment plants to industries in Aichi Prefecture, Japan	Spatial analysis using GIS to match industrial steam demand with WtE supply based on transport distances and production shipments.	Steam supply within a 1 km range is highly profitable, but profitability drops sharply as distance increases due to heat loss and infrastructure costs.	This study quantifies the physical constraints of steam transport, emphasizing that plant location is the most critical factor for successful urban-industrial symbiosis.
Zhang et al. (2016)	Decision framework for feasibility analysis of introducing the steam turbine unit to recover industrial waste heat based on economic and	Combined Cost-Benefit Analysis (CBA) and Life Cycle Assessment (LCA) into a nine-cell decision framework for waste heat recovery.	Case study results showed a payback period of 2.28 years, proving both economic viability and significant environmental load reduction.	The framework Is highly versatile, but the study notes that the "environmental load" of manufacturing the turbine itself must be weighed against long-term gains.

	environmental assessments			
Chen et al. (2025)	Industrial heat defossilization: A comparative analysis of waste incineration and clean energy scenarios	Used a difference-in-difference methodology to evaluate five scenarios comparing cogeneration, power generation, and high-pressure heating.	Cogeneration and high-pressure heating (15 Mpa, 550°C) outperformed standalone power generation, reducing fossil fuel use by 66 GJ/h. The study employs scenario modeling and the Difference-in-Difference (DID) method to evaluate energy, economic, and environmental outcomes across different WtS configurations (power-only, CHP, heating-only). These comparative tools enable a structured analysis of system performance, investment viability, and carbon reduction impacts, providing robust evidence for policymaking and investment decisions in the WtS domain.	The paper highlights the untapped potential of high-temperature steam supply but notes that green hydrogen integration is still limited by current PV power deficits.

Adi & Rarasati (2021)	Modelling of operational costs (tipping fees) and incentives to improve solid waste management services in Indonesia	Developed a mathematical model to calculate tipping fees and operational costs for waste-to-energy (WtE) projects in Indonesia.	Found that current tipping fees are often insufficient to cover operational costs, requiring government incentives and subsidies to ensure project viability.	While the model provides a strong financial baseline, it focuses heavily on costs and may benefit from incorporating environmental impact variables into the incentive structure.
Amrico & Dalimi (2023)	Economic Analysis Of Waste Power Plants Based On The Economic Scale-Case Study Merah Putih Waste Power Plant	Conducted an economic analysis of an incineration plant in Jakarta using LCOE, NPV, and IRR metrics across different capacities.	Identified a minimum feasible capacity of 8 MW (429 tonnes/day) with an LCOE of IDR 2,578.32/kWh and an IRR of 8.63%.	The study proves that scale is critical for profitability, but the high initial investment (IDR 505.8 billion) remains a barrier for smaller regions.

Source: NIES, 2026

1.2.1 Waste Incineration

Waste incineration, particularly municipal solid waste incineration (MSWI), is a vital part of modern waste management processes. Although it was first developed in the late 19th century, most of the earlier incineration technologies were primarily used for reducing the waste volume without recovering energy. Increasing waste generation caused by the fast urbanization and population growth have driven development of more sophisticated incineration technologies to meet the ever-growing demand. In this context, MSWI also plays an important role in cleaning up waste, thus reducing fossil fuel dependency (Makarichi, Jutidamrongphan & Techato, 2018).

The evolution of waste-to-energy (WtE) incineration is a step forward in integrated systems that can reduce waste and produce energy. Today's incineration plants have advanced combustion systems and energy recovery systems such as combined heat and power (CHP) to produce steam and electricity. As Li et al. (2015) point out, waste incineration will not only help in the disposal of waste and pathogen elimination but also will also recover the resources from waste by generating energy. This means that waste elimination, harmless treatment and resource utilization can be achieved simultaneously. This makes incineration one of the key technologies in the circular economy.

Incineration technology has evolved considerably over recent decades, with notable improvements in both combustion efficiency and emissions control. First-generation

incinerators operated with little or no flue gas treatment, resulting in serious air pollution and, consequently, strong public resistance. Contemporary facilities, by contrast, are equipped with sophisticated air pollution control (APC) systems, such as electrostatic precipitators, sorbent injection, and catalytic treatment, which substantially reduce emissions of particulate matter, acid gases, and dioxins. Nevertheless, Lu et al. (2017) emphasize that the control of certain flue gas constituents, particularly hydrogen chloride (HCl) and dioxins, continues to pose a considerable technical challenge, necessitating ongoing development of sorbent materials and adsorption technologies. Collectively, these developments have markedly enhanced the environmental credentials of modern incineration plants.

Several incineration technologies are currently in use, most notably moving grate, fluidized bed, and rotary kiln systems. Of these, the moving grate configuration is the most widely deployed, owing to its operational flexibility and its capacity to handle heterogeneous waste streams with limited pre-treatment. Its tolerance for fluctuations in waste composition and calorific value makes it especially well suited to large-scale municipal applications. Fluidized bed systems, on the other hand, depend on a more uniform feedstock and are more susceptible to variations in input quality. Although they may entail lower capital expenditure, their greater operational complexity diminishes their competitiveness at larger scales (Makarichi, Jutidamrongphan, & Techato, 2018). These differences underscore the need to match technology selection to the characteristics of the local waste stream.

Notwithstanding these technological gains, waste incineration continues to face substantial economic and operational constraints. The considerable capital and operating costs involved represent a major barrier to adoption, particularly in developing economies. Process efficiency is also strongly dependent on the calorific value and composition of the incoming waste. Lu et al. (2017) observe that elevated moisture content can impair combustion performance and may necessitate pre-treatment measures such as drying, which in turn add to operational complexity and cost. The requirement for advanced flue gas treatment further contributes significantly to total project expenditure.

From an industrial and policy standpoint, waste incineration has expanded rapidly in recent years, with China representing one of the most prominent examples. Li et al. (2015) attribute this growth to a combination of rising waste volumes, increasing land scarcity, and favourable government policy.

For landfilling, incineration is much cheaper and more efficient to use and has become more attractive in the densely populated urban and industrial areas. For incineration, the market is also quite capital intensive, government-dependent and operated by experienced operators, and as such, there are barriers to entry and competition. In a global context, incineration is already very well-established in developed countries such as Europe, the United States, and East Asia, where legal frameworks and technologies have been available to us. In this context it has been embedded within integrated waste management systems, and the landfill dependence has been dramatically reduced. In developing countries, however, because of the limited financial resources, lack of institutional capacity and technological difficulties, the uptake has been slow. Public acceptance is of course also a major concern as dioxins are considered toxic and persist in the environment (Makarichi, Jutidamrongphan & Techato, 2018).

Overall, waste incineration has developed into a well-established technology with multiple applications and it can be used to solve the waste problem and the energy problem. It is highly beneficial in terms of waste reduction, energy recovery and efficient land use. But implementation is dependent on different factors; technological capacity, environmental compliance, economic feasibility, policy and policy support. These findings underscore the necessity of a multi-level feasibility assessment particularly in emerging countries such as Indonesia, where the situation is very different from those in the international context.

1.2.2 Waste-to-Steam

Waste-to-energy (WtE) technologies are a key component of sustainable waste management that enables municipal and industrial waste to be converted into energy in the form of electricity, heat, or fuel (Chen et al., 2025). In the wider context of waste management, Waste-to-Steam (WtS) is a more specialized approach oriented to the recovery of thermal energy from waste incinerated to produce steam. The steam produced can then be used in a company's industrial processes, in district heating, and combined heat and power (CHP) systems. Although WtS is often part of larger WtE schemes, it plays an important role in industrial applications, such as chemical plants, manufacturing clusters, and industrial estates. WtE and WtS systems have become credible alternatives to conventional energy sources in many cities worldwide. These solutions could play an important role in decarbonization (which is still a huge part of global emissions). These solutions also support Sustainable Development Goal 11 (Sustainable cities and

communities), which is clearly in the making as all cities and industries should be planning for clean energy and waste management.

In the Paris Agreement, countries such as Japan and China have put these technologies as a good choice in their decarbonization strategies (Chen et al., 2025; Luo et al., 2025). It is clear that the advantages of WtS are most evident in industrial applications with low to medium-grade steam (i.e., less than 400°C). In Sweden, Japan, and South Korea, incineration facilities can provide process steam to the neighbouring industrial users, reducing their dependence on fossil fuels. This localized heat integration improves energy efficiency and also helps to promote a circular economy in industrial areas (Chen et al., 2025).

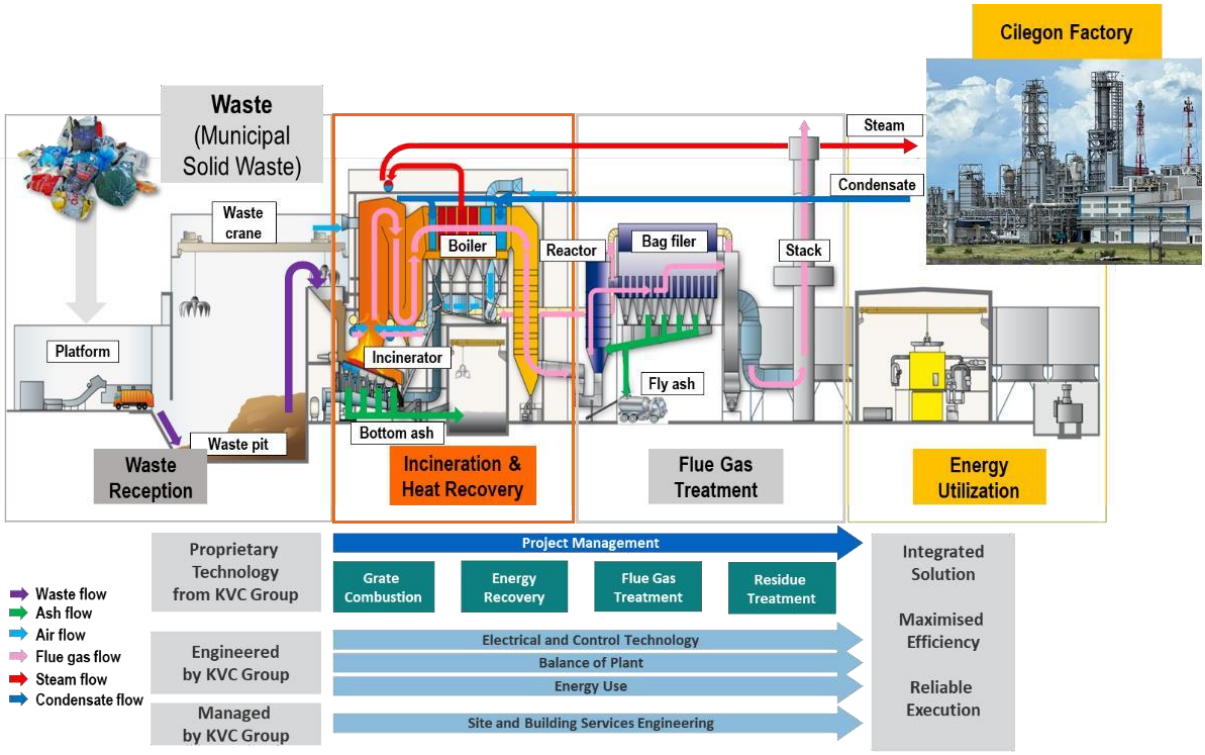


Figure 2.2 Waste to Steam System Configuration
Source: Kanadevia, 2026

1.2.3 Applied Technology

WtS technologies are particularly more beneficial in industrial settings that require low- to medium-grade steam (under 400°C). Case studies from Sweden, Japan, and South Korea show that incineration plants can provide process steam to nearby industrial users, reducing their reliance on fossil fuels. This localized heat integration supports both energy efficiency and circular economy models within industrial zones (Chen et al., 2025).

If combustion ash adheres to the surface of the heat transfer tubes, heat recovery efficiency will be reduced, so preventing the accumulation of combustion ash on the heat transfer tubes is important for efficient energy utilization.

Figure 2-3 shows our tail-end boiler, the technology applied in this study. Tail-end boilers have heat transfer tubes arranged vertically. Combustion exhaust gas passes between the vertically arranged heat transfer tubes and exchanges heat.

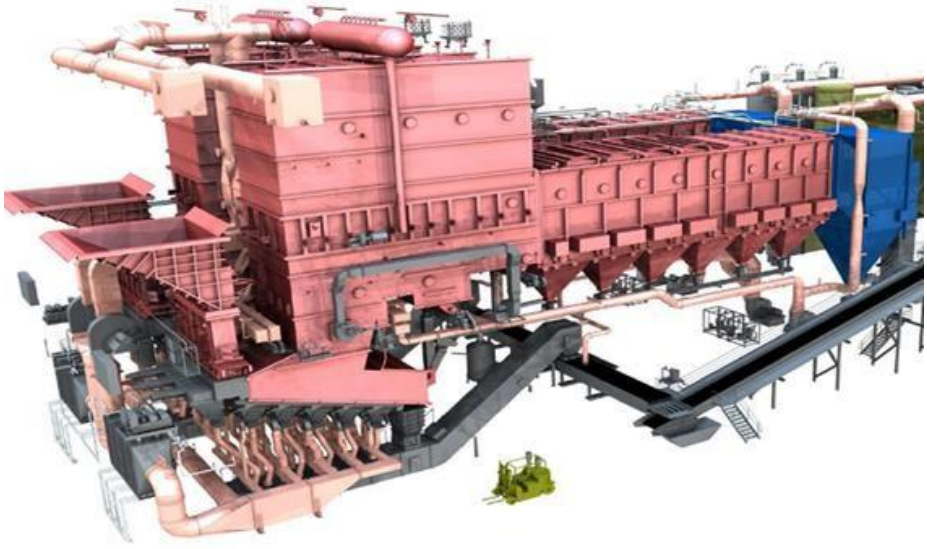


Figure 2.3 Tail-end Boiler

Source: Kanadevia, 2026

This makes it possible to prevent the adhesion and accumulation of combustion ash and other materials on the heat transfer tubes. Ash that has accumulated on the heat transfer tubes is removed by mechanically striking the tubes with a hammering device.

In this way, a tail-end boiler's unique feature is that it can efficiently supply steam over long periods of time by preventing combustion ash from adhering to the heat transfer tubes and increasing heat recovery efficiency.

Moreover, WtS projects often struggle with high capital costs and face growing competition from increasingly cost-effective renewable technologies like solar and wind (Chen et al., 2025). Therefore, rigorous economic evaluation, supported by real-world models and business frameworks, is essential to justify WtS investment in contexts such as Banten Province.

1.3 Business Scheme

The Pre-Feasibility Study establishes that the Waste-to-Steam (WtS) project will be developed under a Public–Private Partnership (PPP) model that combines the strengths of the private sector, government, financing institutions, and industrial users to support sustainable waste management and industrial decarbonization in Indonesia.

The project will be managed through the Special Purpose Company (SPC), a dedicated company that will manage the whole project lifecycle, from the project development, financing, construction, operations and long-term steam supply. The SPC is the central platform that can bring commercial, technical and operational interests together. Kanadevia Corporation may participate in project development by investing in the SPC and providing assistance to the SPC on the development of business planning, project structuring, technology selection and coordination with stakeholders. Kanadevia may also be the Engineering, Procurement and Construction (EPC) contractor for the facility design and construction and also the Operation and Maintenance (O&M) contractor for a stable and efficient plant operation throughout the project.

The project financing will be a combination of equity from sponsors and debt from banks. Long-term project viability is built on stable waste supply and guaranteed steam demand. The Local Government plays a key role by establishing long-term waste collection, transportation and supply agreements with the SPC. This provides reliable feedstock for the WtS facility, as well as to help in hygienic waste treatment and eliminate landfill dependency, lower greenhouse gas emissions, and improve environmental performance.

On the demand side, an industrial steam off -taker enters into a long-term Low Carbon Steam Purchase Agreement with the SPC and commits to purchasing steam generated by the facility. Because steam demand is a key factor in project bankability, participation of the steam off-taker as an investor in the SPC is considered beneficial, creating alignment between supply reliability, lower steam production costs, and long-term value creation. Support from the Central Government, including permits, guarantees, and facilitation mechanisms, further enhances project bankability and reduces investment risk.

To maximize efficiency and minimize transmission losses, the WtS facility and steam off-taker location should ideally be situated within approximately 2 km of each other.

Overall, this partnership model creates shared value where:

a. Government addresses municipal waste challenges and supports project implementation.
b. Industrial users receive reliable low-carbon steam supply.

c. Lenders and investors gain stable infrastructure returns.

d. Kanadevia contributes technology, investment, construction capability, and operational expertise across the entire project value chain.

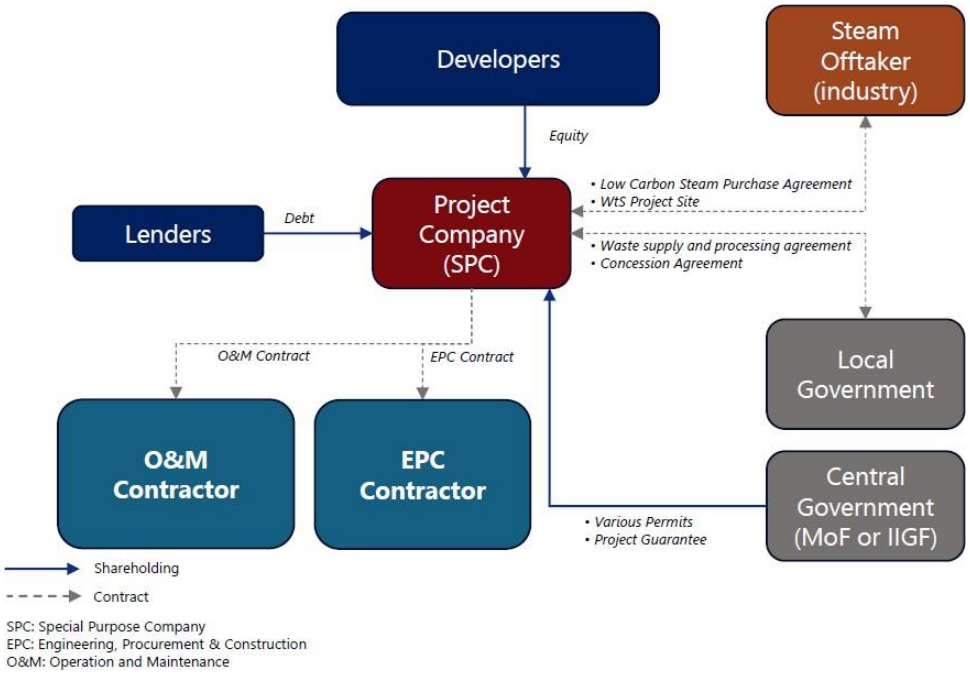


Figure 2.4 Business Scheme

Source:Kanadevia

The Waste-to-Steam (WtS) project applies to a risk-sharing model in Figure 2.5 among the Local Government, Steam Off-taker, and Developer to create a balanced and sustainable partnership. The Local Government is responsible for providing the project site, ensuring continuous waste supply (quantity and quality), and managing ash disposal. The government also shares risks related to regulation changes and inflation during operation.The Steam Off-taker commits to purchasing steam through a long-term Take-or-Pay agreement, ensuring stable project revenue. The off-taker also shares regulatory and operational inflation risks.The Developer is responsible for project financing, plant construction, and facility operation, including achieving performance targets. The Developer also manages construction-related inflation and shares regulatory risks.This allocation allows each party to manage the risks they can control, improving project feasibility and long-term stability.

Risk sharing Matrix

Risk / Allocation	Local Government	Steam Off-taker	Developer
Project site incl. residents' resettlement & soil risk	✓		
Waste supply with Quantity & Quality (Put or Pay)	✓		
Steam off take (Take or Pay)		✓	
Ash Disposal	✓		
Financing, Construction and Operation for WtS plant (incl. performance)			✓
Change of Laws & Regulations	✓	✓	[✓]
Inflation & Currency			
Construction Period			✓
Operation Period (adjustment concept to be agreed)	✓	✓	✓

Figure 2.5 Assumed Risk Sharing Matrix

Source: Kanadevia

1.3.1 Indicative Project Location

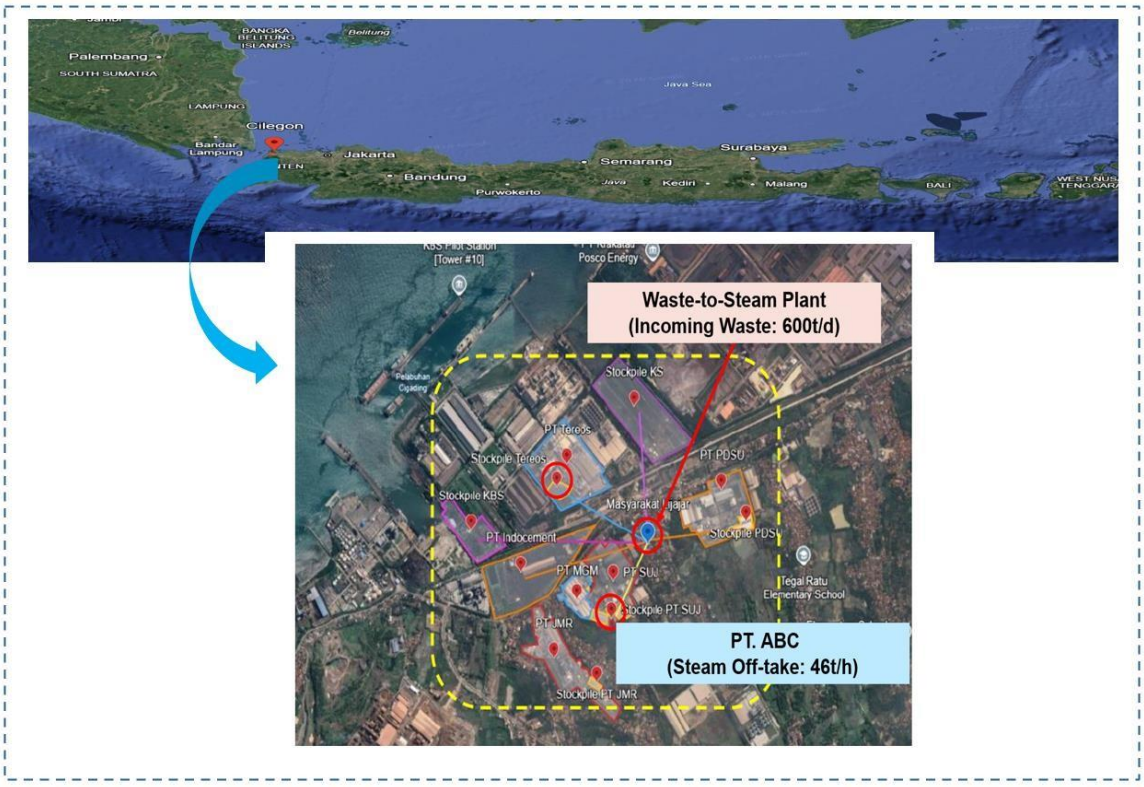


Figure 2.6 Indicative Project Location

Source: DLH Cilegon

The project is planned to be developed in the Cilegon area, located along Jl. Anyer and strategically positioned near the Krakatau Industrial Estate Cilegon (KIEC), Cilegon, Banten, Indonesia. However, key aspects including social impact, road accessibility, infrastructure readiness, soil and geotechnical conditions, and land ownership status will require further assessment and validation during the next stage of project development.

1.3.2 Waste Resource and Steam Specification

According to the Pre-FS, the Waste-to-Steam (WtS) plant capacity is set at 600 tons per day (TPD) as an initial, small-scale development (see Figure 2.7). Given Cilegon's strong industrial base, particularly in the chemical and manufacturing sectors, there is significant potential for future expansion, subject to confirmed steam demand.

Based on a lower heating value of 5,860 kJ/kg, the proposed 600 TPD WtS facility can produce approximately 46 tons of steam per hour at a temperature of 400°C and pressure of 4 MPa, meeting industrial steam requirements.

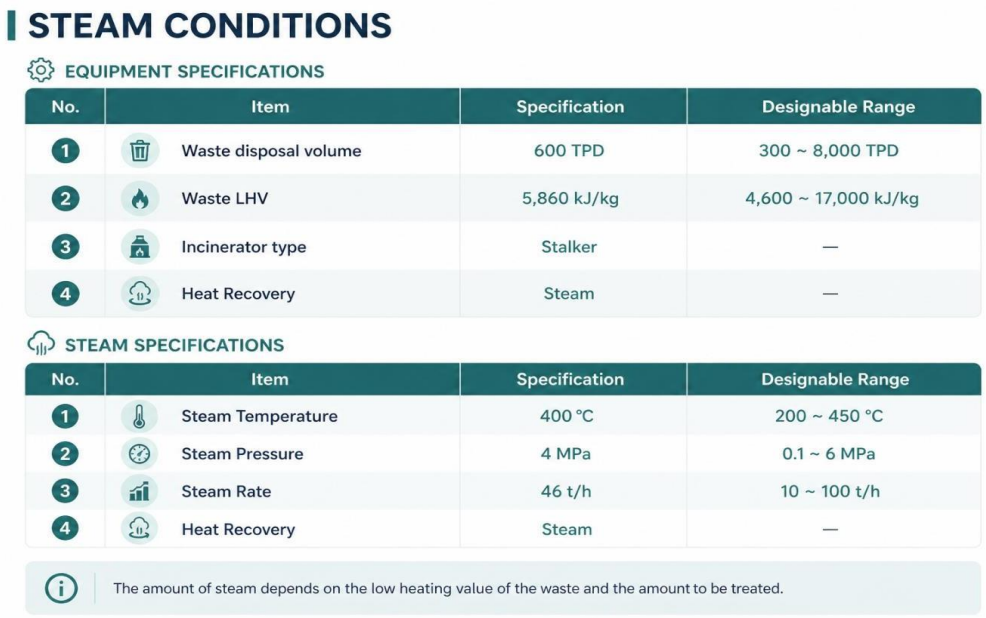


Figure 2.7 Steam Specification

Source: Kanadevia

To fulfil the 600 TPD waste requirement, Cilegon needs to collaborate with neighboring regions, namely Serang Regency and Serang City.

PARAMETER	SERANG City	SERANG Regency	CILEGON City
Administrative type	City (KOTA)	Regency (KABUPATEN)	City (KOTA)
Area (km2)	266.18	1,471.54	163.45
Population	745,557	1,815,551	460,402
Growth	1.48%	1.09%	1.46%
Key Economic Drivers	Trade, Services, Retails	Manufacturing trade, agriculture	Manufacturing, Trade, logistics (cigading port)
Waste			
Generation (TPD)	521	1,191	336
Transporte to Landfill (TPD)	419	128	290

Figure 2.8 Waste Resource

Source: Serang City Figure, 2026

From a technical standpoint, the system is supported by key components, including an incinerator boiler for efficient waste combustion, a steam generation system to convert thermal energy, and associated units for energy utilization. These integrated components form the core infrastructure necessary to ensure reliable and efficient operation of the waste-to-steam process.

1.3.3 Legal Analysis

The implementation of the Municipal Solid Waste (MSW) incineration and heat utilization project in Banten Province is governed by a comprehensive and multi-layered regulatory hierarchy (Kemitraan Indonesia Australian untuk Infrastruktur, 2021). At the constitutional level, Article 4 paragraph (1) of the 1945 Constitution of the Republic of Indonesia provides the overarching authority for state control over natural resources and national development. At the foundational level, the project must comply with the primary mandates of Law No. 18 of 2008 on Waste Management and Government Regulation No. 81 of 2012, which establish standards for domestic waste processing and promote sustainable waste handling practices. Specifically, within the regional jurisdiction, the project is subject to Banten Provincial Regulation (Perda) No. 8 of 2011 governing waste management within the province. Furthermore, as a regional initiative, the project aligns with the National Strategic Policy (JAKSTRANAS) under Presidential Regulation No. 97 of 2017, which is operationalized locally through Banten Governor Regulation (Pergub)

No. 27 of 2019 concerning the Provincial Strategic Policy for Waste Management (Jakstrada). These regulations ensure that the recovery of heat from incineration is not merely a commercial activity but also a fulfillment of provincial waste reduction targets and environmental mitigation commitments.

In parallel, sectoral regulations strengthen the legal basis for integrating waste processing with energy utilization. Law No. 30 of 2007 on Energy and Law No. 30 of 2009 on Electricity (as amended by Law No. 6 of 2023) provide the framework for energy development and electricity-related activities, while Law No. 32 of 2009 on Environmental Protection and Management ensures compliance with environmental safeguards and impact mitigation requirements. Law No. 23 of 2014 on Regional Government further defines the roles and responsibilities of local authorities, particularly in ensuring waste supply and public service delivery, which are critical for the continuity of WtS operations. Supporting regulations such as Government Regulation No. 14 of 2012 (as amended) on Electricity Supply Business Activities and Government Regulation No. 28 of 2025 on Risk-Based Business Licensing streamline project implementation and licensing processes. Additionally, Presidential Regulation No. 109 of 2025 explicitly promotes urban waste processing into renewable energy using environmentally friendly technologies, providing strong policy support for the development of Waste-to-Steam (WtS) projects.

Given the capital-intensive nature of incineration technology, the Government Contracting Agency (GCA), in this case the Banten Provincial Government, typically adopts a Public-Private Partnership (PPP) scheme. Consequently, the project's legal structure is bound by Presidential Regulation No. 38 of 2015 concerning PPP in infrastructure provision. This requires adherence to detailed procurement and financial frameworks, including Bappenas Regulation No. 4 of 2015 (as amended by No. 2 of 2020) and LKPP Regulation No. 29 of 2018 regarding the procurement of Implementing Business Entities (IBE). To enhance project bankability, the government may utilize fiscal support mechanisms such as Viability Gap Funding (VGF) under Ministry of Finance Regulation No. 223 of 2012 and infrastructure guarantees under MoF Regulation No. 260 of 2010, which are essential in mitigating financial risks associated with high-capital waste-to-energy investments.

Furthermore, the legal complexity increases if the project is classified under the national Waste-to-Energy (WtE) acceleration program. Under Presidential Regulation No. 35 of 2018, such projects are designated as National Strategic Projects, enabling accelerated licensing processes and access to specific feed-in tariffs. In this context, compliance with

energy sector regulations becomes critical, including adherence to MEMR Regulation No. 50 of 2017 on renewable energy utilization and PLN internal regulations for grid connection and electricity transactions. Additionally, the project must consider industrial policies such as Local Content Requirements (TKDN) under Ministry of Industry Regulation No. 54 of 2012, ensuring alignment with national industrial development goals while fulfilling environmental and employment standards within Banten Province. Collectively, this integrated regulatory framework provides both legal certainty and institutional support, reinforcing the feasibility and long-term sustainability of the WtS project.

1.3.4 Revenue Sources

The proposed project in Cilegon, Banten, represents a strategic transformation from traditional waste disposal into a high-value industrial utility model. By deploying advanced waste-to-steam technology, the facility functions as a bridge between urban waste management and the energy-intensive industrial corridors of Banten. The business concept is centered on the conversion of Municipal Solid Waste (MSW) into high-pressure steam, specifically engineered to meet the operational requirements of key regional sectors, including petrochemicals, sugar processing, and paper manufacturing. This integration creates a circular economy loop where the industry's energy demand directly incentivizes the diversion of waste from landfills, ensuring long-term project sustainability and operational synergy with Cilegon's industrial landscape.

The economic viability of the project is anchored in a "Triple Income" revenue model, which diversifies financial inflows and mitigates market-specific risks. The primary revenue stream is derived from Steam Sales, where energy is supplied to industrial off-takers at competitive rates, providing them with a "green" alternative to fossil-fuel-based steam. The second stream is the Tipping Fee (Biaya Layanan Pengolahan Sampah), a regulated payment from the local government for the service of processing municipal waste, as supported by the legal framework of *Perpres No. 35/2018*. Finally, the project capitalizes on Carbon Credits, monetizing the significant reduction in methane emissions and fossil fuel displacement.

This income structure is designed to provide a short-term payback that is profitable for companies as well as the province to be financially stable. As a means to make business profitable, it is important to local governments in Banten; not only is that business model profitable, it provides a sustainable waste solution that can be self-sustainably used for

landfill expansion and environmental restoration. Also, Cilegon, as a green industry environment, benefits from it because in the province, we have clean energy infrastructure. This alignment of the high business returns with public environmental objectives allows the project to stay in a strategic position in the regional development plan to meet the economic and social requirements of a modern infrastructure project.

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1.3.5 Capital Budgeting Framework & Financial Analysis

Capital budgeting is among the most consequential and complex areas of financial management, as it governs the allocation of resources to long-term strategic investments. Dayananda (2002) describes capital budgeting as the process of selecting investment projects that maximize shareholder value, typically involving substantial expenditure on long-lived assets. Such assets include the specialized machinery and infrastructure characteristic of capital-intensive facilities (Allen, Brealey, & Myers, 2011), of which Waste-to-Steam (WtS) plants are a representative example. In contrast to short-term financial planning, capital budgeting decisions are formulated well in advance and span extended horizons, commonly between five and fifteen years (Brickley, Misra, & Horn, 2006). Peterson and Fabozzi (2002) accordingly define capital budgeting as the systematic analysis of investment opportunities whose benefits are expected to accrue over more than one year. Sekwat (1999) argues that the sound application of capital budgeting techniques improves the quality of investment decisions and provides a rigorous basis for choosing among competing alternatives, a responsibility that generally rests with senior management (McGrath, Ferrier, & Mendelow, 2004).

Applying these techniques to the Cilegon WtS project requires careful consideration of both Capital Expenditure (CAPEX) and Operating Expenditure (OPEX). CAPEX comprises the substantial initial investment in land acquisition, civil infrastructure, and

equipment procurement, and, as the principal upfront cash outflow, it is a decisive input in establishing financial feasibility. OPEX, by comparison, captures the recurring costs of labour, maintenance, and utilities incurred over the operational life of the facility. Considering the two in combination yields a more realistic projection of the project's financial performance, which is particularly important for infrastructure-intensive developments in which the scale of initial investment and the efficiency of long-term operation jointly determine economic viability.

Among the techniques available for assessing investment viability, Net Present Value (NPV) and Internal Rate of Return (IRR) are the most widely applied in practice (Hermes, Smid, & Yao, 2007), while the Debt Service Coverage Ratio (DSCR) is a standard measure in project finance. For the Cilegon project, NPV is estimated by discounting projected cash flows against the required CAPEX. Because the project is oriented toward industrial steam supply rather than electricity generation alone, it is expected to achieve higher energy recovery efficiency, which constitutes a key driver of project value. The analysis examines whether the project's three revenue streams, namely steam sales, tipping fees, and carbon credits, are sufficient to cover OPEX and generate returns above the required rate of return over a 20-year concession period, after accounting for inflation and currency risks specific to the Indonesian market. A positive NPV under these conditions would indicate that the project creates value for its investors.

The IRR, in turn, provides a benchmark for comparing the project with alternative infrastructure investments in Banten. The project's return profile depends substantially on its ability to secure steam offtake from high-demand industries, such as petrochemicals and pulp and paper, and the investment is considered attractive where the IRR exceeds the Weighted Average Cost of Capital (WACC). Carbon credit revenues may further strengthen returns by providing a high-margin supplementary income stream, while the facility's location within the Cilegon industrial cluster is expected to reduce heat distribution costs. Together, these factors are likely to influence the project's attractiveness to private equity investors and international climate finance institutions.

Finally, the DSCR serves as a key indicator of financial resilience and bankability, particularly from the perspective of lenders. It is calculated as the ratio of Cash Flow Available for Debt Service (CFADS) to total debt service, comprising both principal and interest repayments. For infrastructure projects such as WtS facilities, lenders typically require a minimum DSCR in the range of 1.2 to 1.5 to ensure adequate protection against credit risk. In this respect, stable revenues underpinned by long-term steam supply

agreements and tipping fee arrangements are central to sustaining a healthy DSCR. Carbon credit income and the cost advantages associated with the plant's strategic location may provide additional cash flow stability and a buffer against operational and market uncertainty. A sufficiently strong DSCR would therefore reinforce lender confidence and complement the project's return profile, supporting both financial sustainability and reliable debt servicing throughout the project life cycle.

1.4 Site-Specific Evidence

1.4.1 Rapid waste growth is exceeding current landfill-based management.

Serang City, Serang Regency, and Cilegon City are experiencing population growth, industrial development, and urbanization, which continue to increase waste generation. By 2025, total waste generation is estimated to reach around 2,048 tons per day. However, waste management in the region still mainly depends on landfills.

This approach is becoming unsustainable due to limited landfill capacity, increasing environmental risks, and higher waste transportation needs. Therefore, the Waste-to-Steam (WtS) project is proposed as a long-term solution to reduce landfill dependency while converting waste into useful energy.

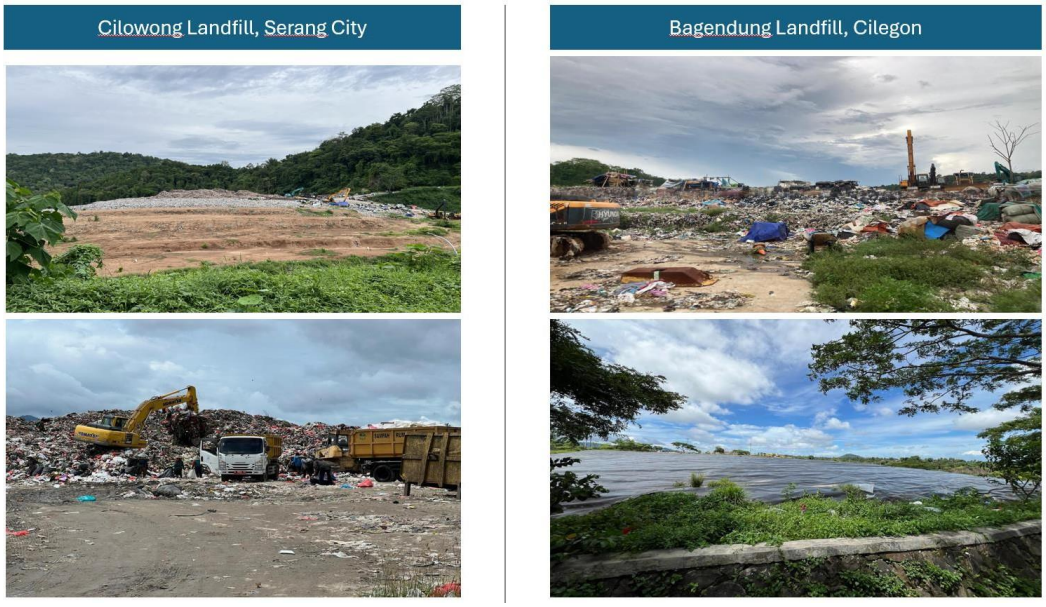


Figure 2.9 Cilowong Landfill and Bagendung Landfill

Source: DLH Cilegon, Serang

1.4.2 Waste Characteristics are suitable for Waste to Steam Technology (Thermal Technology)

As Figure 2.11, Waste is mainly composed of food waste (58.9%), followed by plastics (24.7%), paper (9.5%), and wooden material (3.1%). Other materials contribute less than 1%. With an estimated LHV of 5,860 kJ/kg, the waste characteristics are considered suitable for incineration technology, allowing efficient waste treatment and energy recovery while reducing landfill dependency.

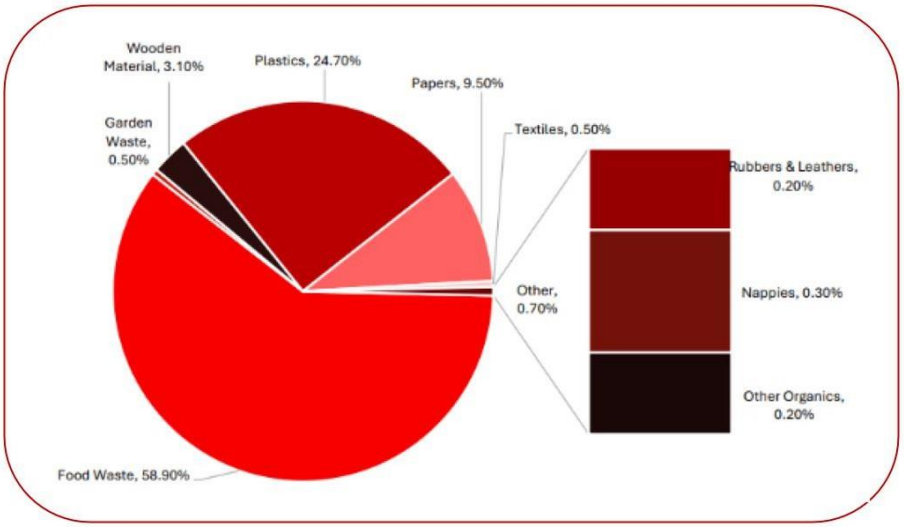


Figure 2.11 Indicative General Waste Composition in Banten Province

Source: SIPSN, 2026

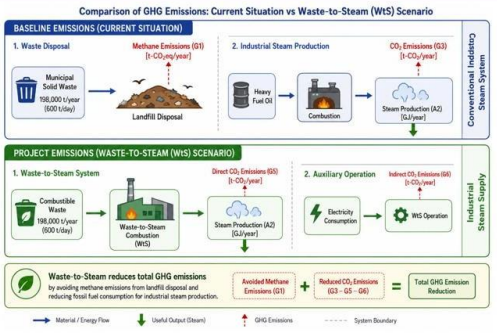
1.4.3 Carbon Emission Challenge from Fossil Fuel-based Steam Production

	Fuel	Emission Factor	Annual emissions	Note
1	LNG	0.0135(t-CO2/GJ)	**16,983(t-CO2/y)**	Does not include refining, transportation, etc.
2	Crude Oil	0.0187(t-CO2/GJ)	**23,525(t-CO2/y)**	Does not include refining, transportation, etc.
3	Coal	0.0245(tCO2/GJ)	**30,821(t-CO2/y)**	Does not include refining, transportation, etc.

Figure 2.12 Carbon Emission Generated from Fossil Fuel-Based

Source: Kanadevia, 2026

1.4.4 Carbon Emission Reduction through Waste-to-Steam



No	Item	Formula	Reduction
①	**Land fill Methane**	G1	**42,406 (t-CO2/y)**
②	**Fossil fuel reduction**	G3-G5-G6	**6,283 (t-CO2/y)**
Total		G1+G3-G5-G6	**48,690 (t-CO2/y)**

Annual reduction:48,690(t-CO2/y)
Project period20 years : 973,800(t-CO2)

Figure 2.13 Carbon Emission Reduction

Source: Kanadevia, 2026

1.4.5 High Energy Recovery through Waste-to-Steam

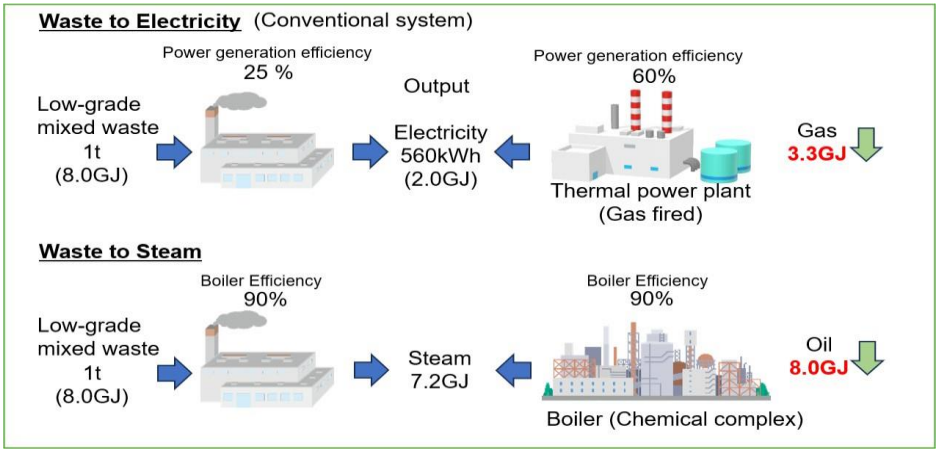


Figure 2.14 High Energy Recovery

Source: Kanadevia, 2026

CHAPTER 3
METHODOLOGY

3.1 Research Design

This study employs an applied research design, aimed at addressing practical and context-specific challenges related to the implementation of waste incineration technologies in Banten Province. The approach is both descriptive and analytical, as it seeks to describe existing conditions, such as industrial waste patterns, energy demands, and current waste management practices, while also analysing the financial and strategic feasibility of adopting waste incineration systems. A mixed-method approach is adopted, integrating both qualitative and quantitative methods. Quantitative analysis includes financial modelling tools such as Net Present Value (NPV), Internal Rate of Return (IRR), to evaluate economic viability. Meanwhile, qualitative data is gathered through policy review, stakeholder analysis, and examination of institutional and regulatory frameworks to assess non-financial enablers and barriers. This combination allows for a more comprehensive understanding of both the technical-economic feasibility and the broader strategic considerations for waste incineration adoption in the local context.

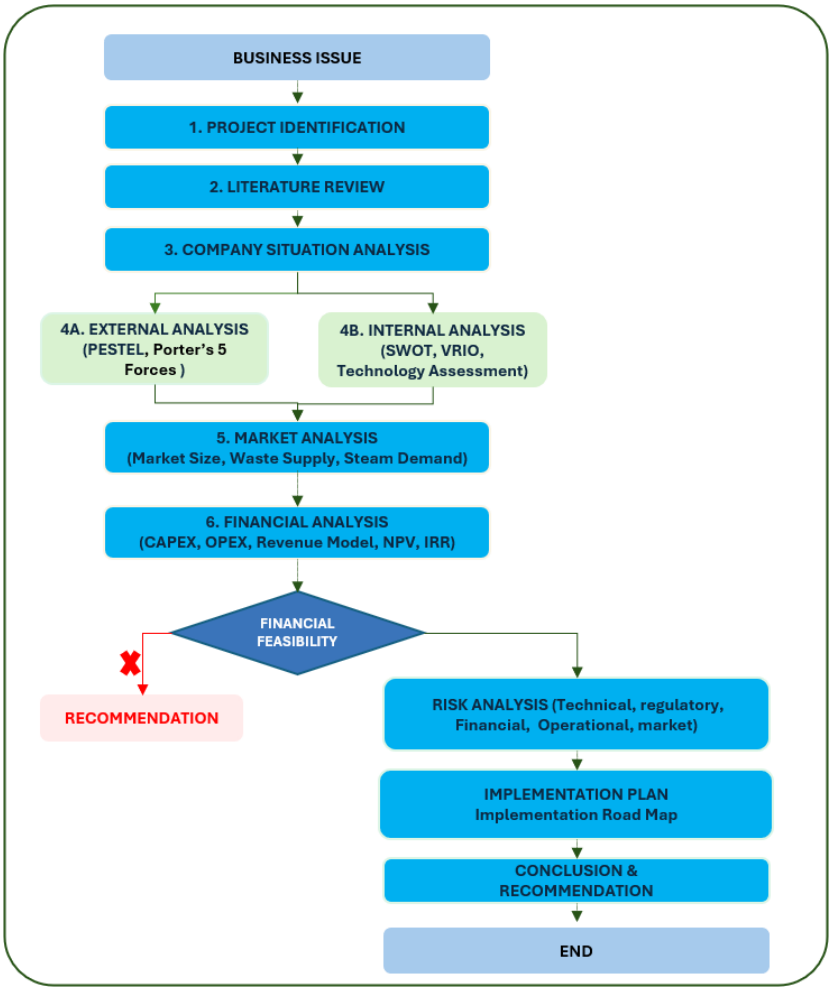


Figure 3.1 Research Design

Source: Kanadevia, 2026

3.2 Research Process

The research begins with a comprehensive literature review to examine global practices and frameworks for Waste-to-Steam (WtS) energy projects. Following this, the study formulates the research problem by identifying gaps in policy and business model adaptation in the context of Banten Province. Secondary data is collected from government reports, industry publications, and relevant academic sources, focusing on variables such as waste volume, capital and operational expenditure, and energy pricing. This data is analyzed using financial modeling tools (Capital Budgeting Model), including NPV, IRR, and to assess project feasibility. A sensitivity analysis is conducted to explore how changes in tipping fees, CAPEX, and steam pricing impact investment outcomes. Additionally, strategic frameworks like PESTEL, SWOT, Porter`s Five Forces and VRIO are employed to evaluate external and internal environment shaping project implementation. The process

concludes with interpretation of findings and recommendations for the project`s business model, financing strategy, and implementation pathway to support the development of WtS project in Banten Province.

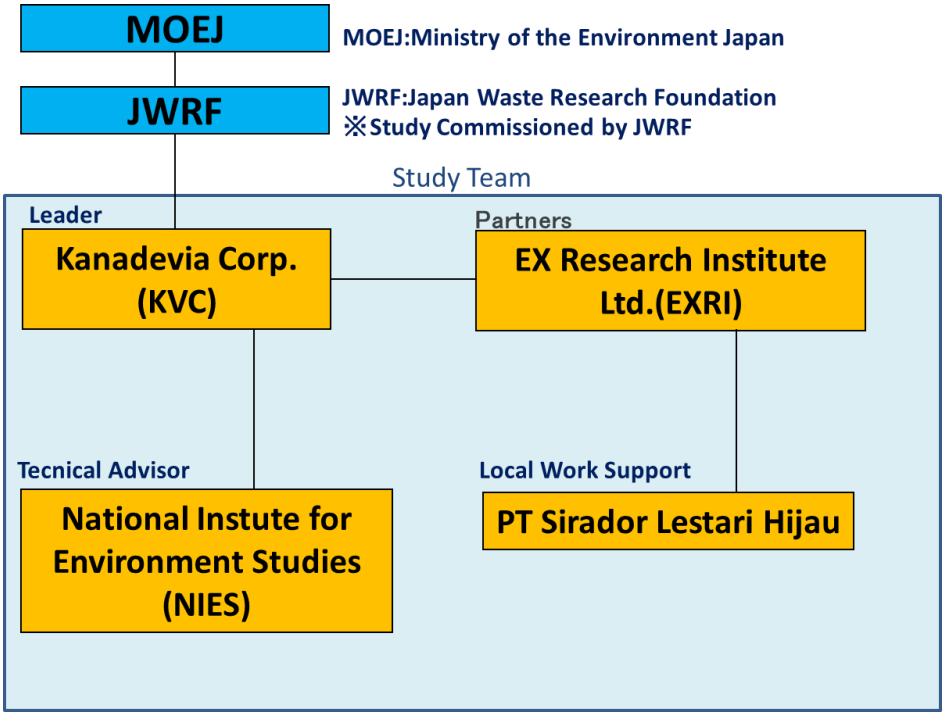


Figure 3.2 Investigation Structure

Source: Kanadevia, 2026

Moreover, Figure 1.7 illustrates the overall research structure and the roles of key stakeholders involved in this study. The research is led by Canadevia Corp. (KVC) as the main proponent, with EX Research Institute Ltd. (EXRI) acting as a key partner in developing the study framework. The National Institute for Environmental Studies (NIES) contributes as a technical advisor by promoting Low Carbon City Networks (LCCN) and Waste-to-Steam (WtS) technologies and supporting their societal implementation. Meanwhile, PT Sirador Lestari Hijau provides local work support, particularly through its expertise in Indonesian environmental technology, facilitating data collection from the Ministry of Environment and other relevant institutions, as well as coordinating field visits.

3.3 Data Acquisition

This research primarily relies on secondary data sources to assess the business viability of Waste-to-Steam (WtS) technologies in Banten Province. Data is gathered from a variety of credible and relevant institutions to ensure a comprehensive analysis. These sources include KVC’s internal reports and official publications from the Banten Provincial

Government, which provide regional data on waste generation, industrial zoning, and environmental policies. Additional data is sourced from the Ministry of Industry and the Ministry of Environment and Forestry (KLHK), particularly regarding national regulatory frameworks, waste-to-energy guidelines, and sustainability targets. Industry-specific insights and operational data are obtained from KVC reports, feasibility studies, and internal memos related to energy demand and waste management practices.

Building on the secondary input above, the author independently develops the financial structuring and investment analysis, strategic positioning assessment (SWOT, Porter's Five Forces, PESTEL, VRIO), and implementation/financing strategy presented in Chapter 3. This analytical work constitutes the author's original contribution to the thesis and is not part of the existing Pre-FS.

3.4 Data Analysis Method: Capital Budgeting Model

The financial evaluation of the project is based on four principal inputs: capital expenditure (CAPEX), operating expenditure (OPEX), tipping fees, and steam pricing. These parameters form the basis of the projected cash flows from which the project's key financial indicators, namely Net Present Value (NPV), Internal Rate of Return (IRR), and Debt Service Coverage Ratio (DSCR), are derived.

NPV measures the profitability of an investment by calculating the present value of its expected future cash flows, discounted at a rate that reflects the cost of capital, typically the Weighted Average Cost of Capital (WACC), and deducting the initial investment. A positive NPV indicates that the investment is expected to generate value in excess of its cost and may therefore be considered financially viable, whereas a negative NPV implies that the project would erode value. Owing to its direct link to value creation, NPV is widely regarded as a primary decision criterion for evaluating long-term investments and comparing mutually exclusive alternatives.

IRR is defined as the discount rate at which the NPV of all project cash flows, both inflows and outflows, equals zero, and may thus be interpreted as the break-even rate of return on the investment. A project is generally considered financially attractive when its IRR exceeds the required rate of return or cost of capital. Because it is expressed as a percentage, IRR offers an intuitive measure of investment efficiency or yield. It should, however, be interpreted alongside NPV, as it does not reflect the absolute scale of value created and may produce misleading rankings when projects differ substantially in size or cash flow timing.

DSCR assesses a project's capacity to meet its debt obligations from operating cash flows. It is calculated as the ratio of Cash Flow Available for Debt Service (CFADS) to total debt service, comprising principal and interest payments, over a given period. A DSCR above 1.0 indicates that the project generates sufficient cash flow to service its debt, while a value below 1.0 signals a shortfall and potential financial distress. In project finance, including WtS developments, DSCR is a central indicator of bankability, as lenders rely on it to evaluate credit risk and determine the terms of financing. Financial institutions typically require a minimum DSCR of between 1.2 and 1.5 to provide a buffer against fluctuations in revenue or operating costs. Maintaining a stable and adequate DSCR is therefore essential both for securing debt financing and for ensuring the project's long-term financial sustainability.

3.5 Business Situational Analysis

3.5.1 SWOT

The SWOT analysis is employed in this study as a strategic planning tool to identify the internal and external factors that are favorable or unfavorable to the achievement of the project's objectives. According to Kotler and Keller (2016), a SWOT analysis provides a comprehensive overview of a project's strategic position by balancing internal capabilities against environmental realities. In the context of the Cilegon, Banten waste incineration project, this qualitative assessment complements the quantitative financial evaluation (NPV, IRR, and DSCR) by providing a nuanced understanding of the operational landscape, stakeholder dynamics, and market conditions in Banten Province.

The internal analysis focuses on the Strengths and Weaknesses inherent in the project's design and the KVC waste-to-steam technology. Strengths include the high energy recovery efficiency of steam production compared to traditional electricity-only incineration, as well as the proximity of the facility to a dense cluster of industrial off-takers in Cilegon, which minimizes heat loss and distribution costs. Conversely, Weaknesses may involve the high initial Capital Expenditure (CAPEX) required for specialized incineration components and the technical challenges associated with maintaining a consistent steam quality from heterogeneous municipal solid waste streams.

The external analysis examines the Opportunities and Threats arising from the regional and national environment. Opportunities are driven by Indonesia's strategic shift toward renewable energy and waste reduction, as evidenced by *Perpres No. 35/2018*, and the growing demand for "green" steam from petrochemical and paper industries seeking to

defossilize their supply chains. On the other hand, Threats include potential fluctuations in waste supply volumes, public opposition to incineration facilities, and regulatory shifts that could impact the pricing of tipping fees or carbon credits. By synthesizing these four dimensions, the SWOT analysis facilitates the development of a robust risk mitigation strategy, ensuring the project's long-term resilience within the Banten industrial ecosystem.

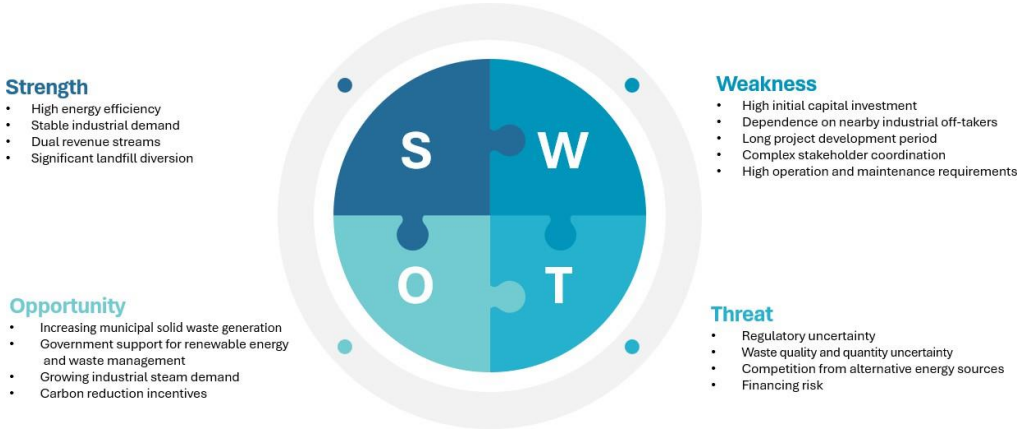


Figure 3.3 SWOT Analysis

3.5.2 Porter's 5 Forces Analysis

To complement the internal and external perspective of the SWOT analysis, this study utilizes Porter's Five Forces framework to evaluate the structural attractiveness and competitive dynamics of the industrial steam utility sector in Cilegon. As theorized by Porter (1979, 2008), the collective strength of these five forces determines the ultimate profit potential of an industry. For this study, the framework is adapted to assess the viability of a waste incineration plant operating as a localized monopoly or a competitive utility provider within an industrial cluster.

The first two forces, Threat of New Entrants and Bargaining Power of Suppliers, examine the barriers to entry and the control over raw materials. In Cilegon, entry barriers are high due to the significant CAPEX required for incineration technology and the complex regulatory licensing under *Perpres No. 35/2018*. The power of suppliers (the local government and waste collectors) is mitigated by the project's role in solving a public waste crisis, creating a mutually dependent relationship. Meanwhile, the Bargaining Power of Buyers focuses on industrial off-takers in the petrochemical and paper sectors. Their power is influenced by the availability of alternative energy sources, making competitive pricing against coal-fired or natural gas steam essential for securing long-term Steam Purchase Agreements (SPAs).

The final forces**,** Threat of Substitute Products and Intensity of Rivalry, address the competitive landscape of the energy market. Substitutes for waste incineration steam include conventional fossil-fuel boilers or emerging biomass solutions; however, the waste incineration project holds a unique advantage by simultaneously providing a waste disposal service (Tipping Fee) and carbon credits. The intensity of rivalry among existing players is currently low in the Cilegon waste incineration space, as the "Double Income" model allows the project to operate in a niche intersection of waste management and industrial utility. By analyzing these five forces, the study provides a strategic assessment of how the project can sustain high corporate profits while contributing to the regional industrial symbiosis.



Figure 3.4 Porter's 5 Forces Analysis

3.5.3 External Analysis

PESTEL analysis is a strategic framework used to assess external factors such as the macro-environmental factors that influence an industry, project, or policy. The acronym stands for Political, Economic, Social, Technological, Environmental, and Legal factors. It helps decision-makers identify external conditions that could create opportunities or pose risks, thereby guiding long-term planning and strategic alignment with the external environment.



Figure 3.5 PESTEL Analysis
Source: AKIS Network, 2026

In the context of waste incineration development in Indonesia, PESTEL analysis provides valuable insights into the broader ecosystem in which such projects would operate. From a political standpoint, Indonesia's government has issued several policy instruments supporting waste-to-energy initiatives, such as Presidential Regulation No. 35/2018. Economic considerations include the rising energy demand in industrial zones and the cost competitiveness of WtS compared to fossil-based thermal energy. On the social front, public perceptions of incineration technologies and community acceptance remain mixed, often influenced by environmental and health concerns. Technological factors involve the maturity and localization of WtS infrastructure and the integration of smart energy systems. Environmental conditions, such as high landfill pressure, greenhouse gas emissions, and land use challenges, further support the case for alternative waste treatment solutions like WtS. Lastly, legal and regulatory factors, such as waste management regulations and environmental permitting requirements, can significantly affect the implementation of WtS projects. PESTEL analysis could helps identifying the

key factors that may support or hinder project development, allowing stakeholders to develop strategies that are better suited to the local context and potential risks.

3.5.4. Internal Analysis

Internal analysis is a strategic management process used to evaluate an organization's internal conditions and identify strengths and weaknesses. According to Meesala (2015). Internal analysis focuses on the resources, capabilities, and core competencies that contribute to the organization's achievement and performance, while also highlighting areas that may need improvement. In this study, the internal analysis focuses on the availability and use of resources that are relevant to the project.

One of the main tools utilized for internal analysis is the VRIO framework that evaluates resources based on four dimensions: Value, Rarity, Imitability, and Organization. According to Cardeal (2012), these dimensions help assessing whether a resources can provide a sustained competitive advantage. Originally developed by Barney (1991), VRIO analysis shifts the focus from external market to internal market conditions, particularly resources and capabilities of a business. For the Cilegon WtS project, the framework analysis is used to assess whether the combination of KVC's technology, strategic industrial partnerships, and the "Double Income" business model can provide a sustainable advantage over alternative energy providers.

Value and Rarity, the first two dimensions, examine the fundamental strengths of the project's resources. A resources is considerably having value when it enables the project to grab advantage of market opportunities or address potential threats. In this case, an example is the ability to provide lower-carbon industrial steam at a competitive cost compared with natural gas. The rarity of facilities that can converting waste directly into industrial steam for industries such as petrochemicals and sugar are becoming relatively common. This may provide an additional advantage in the Cilegon industrial area, where access to suitable land and permits can also create barriers to entry.

The other two dimensions, Imitability and Organization, are about whether these advantages can be maintained over time. Imitability looks at how difficult it would be for competitors to replicate the project's business model. There may also be challenges in the incineration technology and how long-term Steam Purchase Agreements (SPAs) with industrial off-takers can be established to prevent new competitors from entering the market. Organization is the assessment of the project's structure and management so that the resources will be used effectively and with a fair value for them. If the project

integrates carbon credit management and government-supported tipping fees into the overall business model, then revenue generation may increase, with industrial off-taker reliability.

Resource / Capability	Valuable (V)	Rare (R)	Inimitable (I)	Organized (O)	Competitive Implication
1. Access to municipal waste supply through long-term agreements	✓	✓	✓	✓	Sustainable Competitive Advantage
2. Strategic location near industrial estate (e.g., Cilegon/KIEC)	✓	✓	✓	✓	Sustainable Competitive Advantage
3. High-efficiency Waste-to-Steam technology	✓	△	✗	✓	Temporary Competitive Advantage
4. Long-term steam off-take agreement with industrial customers	✓	✓	✓	✓	Sustainable Competitive Advantage
5. Integrated business model (tipping fee + steam sales)	✓	✓	△	✓	Temporary Competitive Advantage
5. Integrated business model (tipping fee + steam sales)	✓	✗	✗	✓	Competitive Parity
7. Engineering and project development expertise	✓	△	✗	△	Temporary Competitive Advantage
8. Access to government incentives and carbon finance (e.g., JCM)	✓	✓	△	△	Temporary Competitive Advantage

Figure 3.6 VRIO Analysis

3.5.5 Implementation Plan

The proposed implementation structure of the Waste-to-Steam (WtS) project in Bantern is under a Public-Private Partnership (PPP) scheme. The project is based on a Special Purpose Company (SPC) serving as the main executing entity and is formed through joint investment between developers (e.g., KVC, and other private partners) and the steam off-taker (e.g. industrial users in the Cilegon area) and experienced WtS operators. The SPC is responsible for designing, financing, building and operating the WtS facility. Expertly selected EPC partners, such as international technology suppliers and local companies, contribute to technical reliability as well as local adaptation. Financial assistance is from lenders and possibly from the Japanese Government, and the Central Government (e.g. Ministry of Finance or Indonesia Infrastructure Guarantee Fund) could provide guarantees on project risks. In parallel, the steam off-taker enters into a long-term steam purchase agreement with the SPC to guarantee revenue and project bankability, and so the two structures are well integrated. By sharing risks among the various parties, the project

becomes financially viable and also has a guaranteed supply of waste and steam demand. In addition, to optimize the efficiency of the WtS and reduce the cost of distribution, it should be located within the proximity of the steam off-taker (around 2 km). This scheme provides a sustainable method of disposing of waste and also a lot of benefits to the economy in terms of industrial steam capacity utilization and lower landfill use and reductions in greenhouse gas emissions as well. The Project Development Phase is expected to take 12 months, followed by 2 to 3 years of construction time after which the COD is expected to take place.

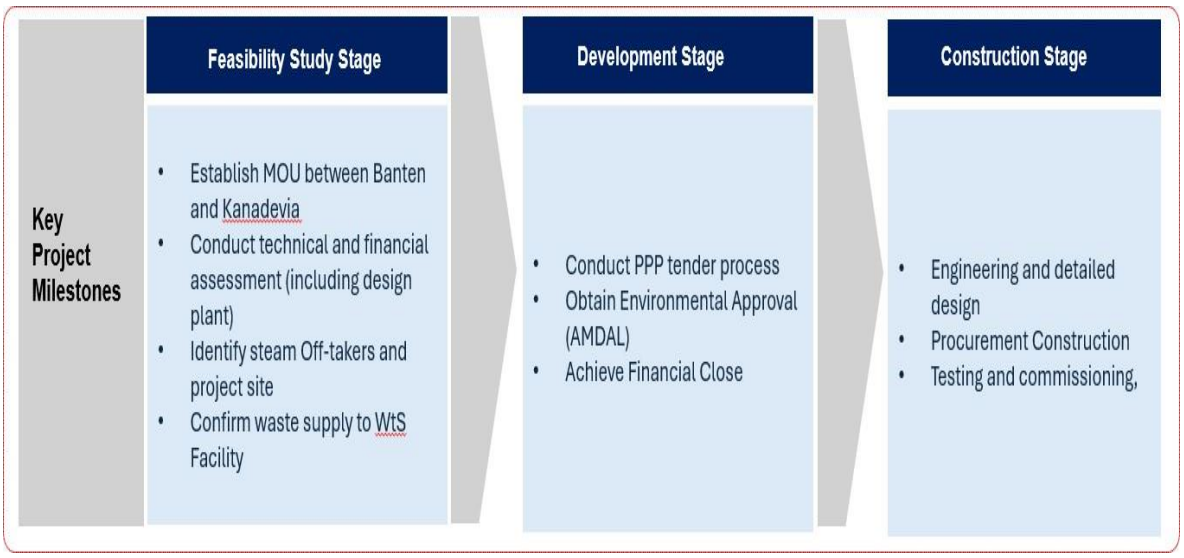


Figure 3.7 Project Implementation Phase

Source: Kanadevia

CHAPTER 4 ANALYSIS AND DISCUSSION

4.1 External Analysis with PESTEL Model

The PESTEL analysis is conducted to assess the macro-environmental conditions that may influence the development of the proposed Waste-to-Steam (WtS) project in Banten Province. While Porter's Five Forces evaluates competitive pressures within the industry, PESTEL provides a broader assessment of external factors that are largely beyond the direct control of the project developer but may significantly affect project implementation, investment attractiveness, and operational sustainability. The analysis considers six dimensions: Political, Economic, Social, Technological, Environmental, and Legal factors. These dimensions are particularly relevant to the proposed WtS project due to its characteristics as a capital-intensive infrastructure project that simultaneously involves municipal waste management, industrial energy supply, environmental regulation, public-sector participation, and private investment.

The PESTEL framework is useful for infrastructure projects because their implementation is affected not only by commercial conditions but also policy, regulation, environmental compliance, public acceptance, and institutional coordination (Yüksel, 2012). The results of the PESTEL assessment are presented in Table 4.1

Table 4.1 PESTEL Analysis

Factor	Analysis	Implication for the Waste to Steam Project
Political	Indonesia`s policy direction supports improved municipal waste management, landfill diversion, renewable-energy development, and industrial decarbonisation (Republic of Indonesia, 2025; Bappenas, 2025). The regulatory environment of Waste to Electricity has become more supportive, and local governments are expected to play a central role in securing waste, land and permits. However, policy supports alone does not ensure the	**Favourable, but execution dependent.** The project aligns with waste management and low carbon industrial policy. However, the project must establish a formal conditional mechanism involving Serang City, Serang Regency, Cilegon City, project company, and the industrial steam off taker. MOU should be converted into long term waste supply, land,

	project delivery, coordination among local government, ministries, environmental authorities, industrial customers and financiers remains necessary. Local political approval, regional budgeting, land readiness, and inter-governmental cooperation can delay implementation.	payment agreement before financial close.
Economic	The three area generate approximately 2,048 tpd of waste, with around 837 tpd transported to landfill. The proposed Waste to Steam plant requires 600 tpd. The plant would require 71.7% of the identified landfill bound stream, leaving a nominal 237 tpd surplus. The location near Cilegon`s industrial area creates a potential market for steam, where customers currently operate coal-based steam production. However, nominal waste availability is not same as contracted supply. The project may need viability support, secure tipping fee obligation and clear public-payment mechanism even where economic benefit is substantial (Semarang Waste-to-Energy Final Business Case, 2021; Yescombe, 2018).	**Moderately favourable, subject to contractual revenue certainty**. The project benefits from two revenue sources, tipping fees and steam sales. It should secure at least 720 tpd of contracted waste supply, equivalent to 120% of 600 tpd design capacity, to provide operating resilience. The project also needs steam supply agreement with minimum off take**.**
Social	Population growth and urbanization continue to increase waste generation while raising public concern regarding landfill capacity,	**Moderately favourable with manageable risk.** The project should be framed as a residual-waste solution that complements

	pollution, and environmental quality (World Bank, 2025; SIPSN/KLHK, 2024). However, Waste to Energy facilities often encounter public resistance related to air emissions, odours, health concerns, and transportation impacts (Lu et al., 2017). The social impacts must be addressed through specific mitigation measures, including livelihood considerations, stakeholder consultation, social-action planning, environmental disclosure, and clear allocation of community-related obligations.	not replaces source separation, recycling, composting, TPS 3R, TPST. A stakeholder-engagement plan should be prepared early and include community consultation, truck-route management, grievance procedures, local employment plans, transparent emissions disclosure, and a strategy for informal waste pickers or recyclers who could be affected by changes in the waste flow.
Technological	Waste-to-Steam technology utilizes proven moving-grate incineration, advanced combustion control, energy recovery systems, and flue gas treatment to convert municipal waste into industrial steam. Moving-grate technology is widely applied in municipal solid-waste incineration, but its suitability depends on site-specific waste quality, moisture content, calorific value, emissions requirements, and operating conditions (Lu et al., 2017). The proposed concept can also be integrated with Carbon Capture and Utilization (CCU) under the Life Cycle Carbon Neutral (LCCN) framework.	**Highly favourable.** The use of commercially proven technology reduces technical implementation risk while enabling efficient energy recovery and compliance with environmental standards. Future CCU integration also provides scalability toward long-term decarbonization objectives, increasing the project's strategic value.

Environmental	Waste-to-Steam can reduce landfill dependency and potentially reduce methane emissions, leachate generation, odour, vermin, and demand for future landfill capacity (Makarichi et al., 2018). However, environmental performance must be evaluated on a lifecycle basis. Relevant impacts include stack emissions, auxiliary fuel, waste transport, water use, wastewater, noise, odour, bottom ash, fly ash, air-pollution-control residues, and final disposal. The landfill and disposal arrangements may be inadequate for fly ash, bottom ash, and untreated waste unless additional land or licensed solutions are secured.	**Highly favourable.** The project directly addresses environmental challenges while supporting greenhouse gas reduction, circular economy principles, and renewable energy development. These environmental benefits strengthen the project's sustainability credentials and improve its attractiveness to government agencies, financiers, and industrial customers pursuing ESG objectives. The project must secure a compliant route fly ash bottom ash as residue.
Legal	Presidential Regulation No. 109/2025 provides a clear and comprehensive regulatory pathway for electricity-based waste processing (WtE), including a mandated off-taker (PT. PLN), a fixed purchase price of USD 0.20/kWh (Republic of Indonesia, 2025). However, the regulation categorizes non-electricity outputs, including steam under other follow-up products. As a result, Waste to Steam project fall outside the perpres`s core protections and	**Favourable for electricity-based projects, structurally unaddressed for Waste to Steam.** Perpres 109/2025 substantially de-risks PSEL project through a government-mandated off-taker and fixed tariff but provides no equivalent mechanism for steam. Even PSE Bioenergy and Renewable Fuel oil while also lacking a fixed Off taker are at least explicitly permitted to be sold commercially under regulation,

	depend entirely on privately negotiated commercial agreements for offtake and pricing certainty.	steam is not even given this baseline acknowledgement. This regulatory gap places full burden of offtake and pricing risk on privately negotiated agreements (the low carbon steam purchase agreement), making robust contractual and financial structuring rather than regulatory guarantee the primary determinant of project bankability.

Source: Author, 2026

The PESTEL analysis indicates that the Banten Waste-to-Steam project is strategically attractive. It supports better municipal waste management, reduces landfill dependence, and can supply lower-carbon process steam to industries in the Cilegon–Serang area. However, the main challenge is legal-commercial risk. Unlike electricity-based WtE projects, Waste-to-Steam has no regulated steam buyer or fixed tariff. The project's bankability therefore depends on long-term waste-supply and tipping-fee agreements, a creditworthy industrial steam offtaker, a bankable steam-purchase agreement, environmental compliance, and strong coordination among the relevant local governments and private partners (Semarang Waste-to-Energy Final Business Case, 2021; Yescombe, 2018)

4.2 Internal Analysis with VRIO Model

The VRIO analysis is conducted to assess whether the internal resources and capabilities supporting the proposed Waste-to-Steam (WtS) project can generate a sustainable competitive advantage. While the previous analyses evaluate the project from technical, financial, and external perspectives, the VRIO framework focuses specifically on the strategic value of the resources and capabilities available to the project, particularly those associated with KVC, its technology, experience, partnerships, and project-development capabilities. Each resource is evaluated based on four dimensions: Value, Rarity, Inimitability, and Organization. A resource that satisfies all four dimensions is considered capable of generating

a sustained competitive advantage, while resources that meet only some of the criteria may result in temporary competitive advantage, competitive parity, or an unrealized competitive potential (Barney, 1991; Cardeal, 2012). The results of the assessment are presented in Table 4.2.

Table 4.2 VRIO Analysis

Resource or Capability	Valuable (V)	Rare (R)	Inimitable (I)	Organized (O)	Competitive Implication
1. Advanced Waste-to-Steam (WtS) Technology	Yes	No	No	Yes	**Competitive parity** Waste-to-Steam technology is valuable and necessary, but similar technology can be supplied by other qualified technology providers
2. Extensive Global WtE Project Experience	Yes	Yes	Yes	Yes	**Sustained competitive advantage** KVC`s International WtE experience reduces project risk and increases confidence among governments, lenders, and customers
3. Engineering, Procurement & Construction (EPC) Capability	Yes	No	No	Yes	**Competitive Parity** EPC capability is essential but available from several qualified engineering firms
4. Future LCCN Platform: Waste-to-Steam + CCU	Yes	Yes	Yes	No	**Potential competitive advantage** Future CCU and hydrogen integration could differentiate the project, subject to the implementation of Indonesia's National Hydrogen Strategy
5. Strategic Industrial Network and Steam Off-taker Access	Yes	No	No	Yes	**Competitive parity** Access to nearby industrial steam customers is valuable, but other developers can also pursue similar offtake opportunities.
6. PPP, Regulatory and Stakeholder Coordination Capability	Yes	No	No	Yes	**Competitive parity** Strong coordination capability helps secure waste supply, permits, tipping-fee commitments, and steam-offtake agreements. However, other qualified developers can build or acquire similar capability.
7. Financial Strength and Project Financing Capability	Yes	No	No	Yes	**Competitive Parity** Financing is important but generally available to qualified developers and consortium partners

Source: Author, 2026

Overall, the VRIO assessment suggests The VRIO analysis indicates that KVC's strongest current competitive advantage is its extensive global Waste-to-Energy experience, which can reduce technical, construction, operational, and lender-confidence risks. Most other resources, including technology, EPC capability, industrial access, stakeholder coordination, and financing, are necessary for project delivery but can also be obtained by competing developers. The LCCN concept, including CCU and hydrogen integration, should be treated as a long-term strategic option rather than a current competitive advantage. Indonesia's hydrogen infrastructure, standards, storage, transport, market, and regulatory framework are still developing; therefore, the immediate project should focus on establishing the Waste-to-Steam business model and securing bankable contracts (Ministry of Energy and Mineral Resources, 2023).

4.3 Porter's 5 Forces Analysis

Porter's Five Forces analysis is performed to assess the competitive structure and industry appeal of the proposed waste-to-steam (WtS) project in Banten Province. While the VRIO analysis is focused on the internal resources and capabilities that could give the project

an advantage in the competitive environment, Porter's Five Forces is concerned with the external pressures on the market structure, profitability and sustainability to the project in the longer run. Porter (2008) states that the profitability and competitive dynamics of an industry are determined by the five forces: the threat of new entrants, bargaining power of suppliers, bargaining power of buyers, threat of substitute products and rivalry among existing competitors. For the proposed WtS project, these are particularly relevant as the project is not only technology driven but also access to waste and industrial steam, long-term contracts, specialized technology and equipment, competition from other waste treatment and industrial energy solutions. It follows the research on waste-to-energy systems for industrial steam supply where we found that waste availability and industrial steam demand are in good relation and both economic and infrastructure-related factors are important for project development as well. The results of the analysis are given in Table 4.3.

Table 4.3 Porter's 5 Forces Analysis

Force	Assessment	Analysis	Strategic Implication
Threat of New Entrants	**Low–Moderate**	Developing a Waste-to-Steam facility requires substantial capital investment, advanced incineration technology, engineering expertise, environmental permits, long project-development periods, and strong relationships with government agencies. Project developers must also secure long-term waste-supply agreements and industrial steam-offtake contracts. These requirements create material barriers to entry (Semarang Waste-to-Energy Final Business Case, 2021; Yescombe, 2018).	Entry barriers provide some protection. The project should secure waste supply, land, permits, and steam offtake early to strengthen first-mover advantage.
Bargaining Power of Suppliers	**Moderate-High**	Key suppliers include technology providers, EPC contractors, boiler and grate suppliers, flue-gas-	Use competitive procurement, fixed-price EPC terms,

		treatment providers, emissions-monitoring suppliers, ash-handling providers, and O&M contractors. Compare several technology/EPC options and find differences in availability, lender acceptability, spare-parts support, and ability to meet stringent emission standards. This shows that qualified, bankable suppliers are limited, especially for proven large-scale thermal treatment.	performance guarantees, liquidated damages, long-term spares support, and an independent owner's engineer. Avoid selecting technology based only on lowest CAPEX.
Bargaining Power of Buyers	**High**	The main buyer in the Waste-to-Steam project is the industrial steam off-taker. Unlike electricity-based WtE projects, direct industrial steam has no regulated purchaser or fixed tariff. For direct industrial steam sales, the project company bears the marketability and offtake risk. Industrial steam buyers may retain bargaining power because they can continue using existing coal- or gas-fired boilers and other thermal-energy alternatives. The commercial viability of waste-derived steam is therefore influenced by distance, heat loss, steam specification, price, and reliability (Maki et al., 2021; Maki et al., 2022).	Secure a long-term Low-Carbon Steam Purchase Agreement before financial close. Include minimum offtake or take-or-pay obligations, tariff indexation, payment security, credit support, steam specifications, and outage provisions.

Threat of Substitute Products	**Moderate**	The most direct substitute is self-generated steam from coal- or gas-fired boilers. Other substitutes include biomass boilers, electrified heat, waste-heat recovery, solar thermal, hydrogen in the long term, and energy-efficiency improvements. Different waste-treatment and energy-recovery pathways can compete for the same municipal waste or energy demand.	Position Waste-to-Steam as a reliable, competitively priced, lower-carbon steam solution. Demonstrate the customer's total avoided cost, including fuel, boiler maintenance, carbon exposure, and ESG value, not only the steam tariff.
Industry Rivalry	**Moderate**	Rivalry is limited by high capital requirements, complex permitting, and specialist operating capability. However, competition may increase as more domestic and international investors seek waste treatment opportunities. Danantara's national PSEL programme has attracted interest from more than 100 domestic and international companies across investment, technology, EPC, and O&M. Competition for WtE projects is increasing	Build an early-mover position by securing municipal waste concessions, industrial steam relationships, site access, pipeline routes, and credible environmental compliance. Seek international grant support or technical-assistance funding to conduct a detailed industrial-steam market and offtake feasibility study

Source: Author, 2026

Overall, Porter's Five Forces analysis indicates that the Waste-to-Steam project has strategic potential but faces significant commercial challenges. High capital costs, technical requirements, environmental permits, and the need for long-term waste-supply and steam-

offtake contracts create barriers to entry (Semarang Waste-to-Energy Final Business Case, 2021; Yescombe, 2018). However, industrial steam buyers have strong bargaining power because they can continue using coal, natural gas, biomass, or other steam-generation alternatives. The competitiveness of waste-derived steam will depend on its price, reliability, technical specification, and distance from the industrial customer (Maki et al., 2021; Maki et al., 2022).

Competition in Indonesia's waste-to-energy sector may increase as Perpres No. 109/2025 supports the development of waste processing into renewable energy and encourages participation by project developers, technology providers, EPC contractors, and O&M companies (Republic of Indonesia, 2025). Therefore, the project should secure waste supply, tipping-fee commitments, plant land, and a long-term steam-of-offtake agreement at an early stage. It should also seek grant or technical assistance support to conduct a detailed feasibility study on industrial steam demand, steam pricing, pipeline requirements, and potential off-takers.

4.4 SWOT Analysis

The SWOT analysis evaluates the strategic position of the proposed Waste-to-Steam project by considering internal and external factors that may affect project implementation and bankability. It complements the technical and financial feasibility assessments by identifying the project's key strengths, weaknesses, opportunities, and threats (Kotler & Keller, 2016).

In this study, Strengths and Weaknesses refer to internal factors related to Kanadevia Corporation, including its Waste-to-Energy experience, moving-grate technology, FEED capability, Indonesian market presence, PPP experience, commercial capability, financing role, and EPC/O&M capability. These internal factors were assessed through a semi-structured interview with a key Business Development representative of PT. Kanadevia Indonesia.
The interview covered the following questions:

1. How many Waste-to-Energy or waste-incineration plants has Kanadevia delivered globally?
2. How has Kanadevia's moving-grate technology performed in projects with high-moisture, low-LHV, and variable mixed municipal solid waste?
3. Which project functions can Kanadevia provide directly under contract, including technology supply, FEED, EPC, commissioning, O&M, and maintenance?

4. What experience does Kanadevia have in Indonesia or comparable markets regarding government coordination, PPP development, permitting, and stakeholder engagement?
5. Does Kanadevia have experience in direct industrial steam sales or long-term Steam Purchase Agreements in Indonesia or other countries?
6. How does Kanadevia assess the competitiveness of waste-derived steam against coal, gas, biomass, and self-generated steam?
7. Can Kanadevia invest equity, arrange financing, support lender due diligence, or provide parent-company support for the project?
8. Can Kanadevia independently undertake the full EPC and O&M scope for this project in Indonesia?

The interview responses provide evidence for the internal Strengths and Weaknesses presented in Table 4.4. The interview indicates that Kanadevia has relevant strengths in global Waste-to-Energy experience, moving-grate technology, FEED capability, and Indonesian PPP project-development exposure. However, the interview also identifies limitations in direct industrial-steam commercialisation, steam-market analysis, equity investment, financing support, and the ability to independently provide full EPC and O&M services in Indonesia.

Opportunities and Threats refer to external factors beyond Kanadevia's control, including waste availability, industrial steam demand, policy and regulation, competing energy sources, financing opportunities, environmental requirements, and stakeholder acceptance. These factors were assessed using secondary data, policy review, and the technical and financial analysis in this study.

Table 4.4 Strengths and Weakness

Strengths (Internal)	Weaknesses (Internal)
S1. Global Waste-to-Energy delivery track record. Kanadevia has delivered approximately 1,635 plants globally, supporting its technical credibility and reducing perceived technology-selection and implementation risk. The relevance of this strength should be confirmed through comparable moving-grate WtE references.	**W1. No direct industrial-steam commercial experience.** Kanadevia does not have demonstrated experience in direct industrial-steam sales or long-term Steam Purchase Agreements. The project will require specialist support to structure a bankable Steam Purchase Agreement.

S2. Adaptable moving-grate technology capability. Kanadevia has operating references in multiple countries, including ASEAN projects with waste characteristics similar to Indonesia, and states that its technology can accommodate fluctuating waste composition. Final performance remains subject to Banten waste-characterisation results.	**W2. Limited steam-market commercial analysis capability.** Kanadevia is not familiar with assessing waste-derived steam competitiveness against coal, gas, biomass, and self-generated steam. A specialist consultant is needed to assess market pricing and customer value proposition.
S3. FEED and technology-provider capability. Kanadevia can provide FEED and technology services, supporting technology selection, process design, and technical project preparation. Limitation: full EPC, commissioning, O&M, maintenance, and performance-guarantee scope has not been confirmed.	**W3. No equity-investment or financing-support role.** Kanadevia is primarily a technology-provider company and does not intend to invest equity, arrange financing, support lender due diligence, or provide parent-company support. A separate sponsor and financing strategy are required.
S4. Indonesian market-development and PPP experience. Kanadevia operates an Indonesian business-development office and has experience developing WtE projects in Indonesia under a PPP scheme. This may support government engagement and project-development activities.	**W4. Reliance on local EPC and O&M partners.** Kanadevia cannot independently undertake the full EPC and O&M scope in Indonesia. Delivery will require local construction and O&M partners, plus additional Kanadevia engineering resources for coordination. This creates interface-management and accountability risk.

Source: Author, 2026

Table 4.5 Opportunities and Threats

Opportunities (External)	Threats (External)
O1. Increasing waste generation and landfill pressure. The three source areas generate about 2,048 TPD of waste,	**T1. Waste supply may not be guaranteed.** The 837 TPD going to landfill is not automatically a 600-TPD contractual supply. The project needs long-term contracts covering

supporting the need for additional waste-treatment capacity.	volume, quality, collection, transport, payment, and supply-shortfall remedies.
O2. Industrial steam and decarbonisation market. Cilegon industries may need process steam and may seek to reduce reliance on coal-, gas-, or oil-fired boilers. WtS can potentially supply part of this demand.	**T2. Competition from conventional fossil-fuel steam.** Industrial customers can continue using coal-, oil-, or gas-fired boilers if WtS steam is not sufficiently competitive in price, quality, and reliability.
O3. Regional cooperation and policy support. Perpres No. 109/2025 supports the processing of urban waste into renewable energy and enables cooperation between neighbouring local governments. This can support waste aggregation across the Cilegon–Serang area	**T3. Environmental, permitting, and public-acceptance risk.** Emissions breaches, fly-ash handling, wastewater approval, and local or NGO opposition as major WtE risks. A serious emission breach can result in shutdown.
O4. Public and climate-finance support. VGF, guarantees, concessional loans, grants, JCM support, and similar mechanisms may reduce financing pressure. VGF and guarantees can improve project affordability and investor interest.	**T4. Uncertainty over Perpres 109/2025 eligibility.** The project should confirm whether a 600-TPD steam-only plant qualifies for any Perpres-related incentives. PSEL-specific provisions may not apply unless the project also meets the requirements for electricity generation.
O5. Consortium formation opportunity. The project can combine Kanadevia's technology and FEED capability with local EPC and O&M capacity, industrial-steam commercial expertise, project sponsorship, and financing capability.	

Source: Author, 2026

The SWOT analysis indicates that Kanadevia provides a credible technical foundation for the proposed WtS project through its global WtE experience, adaptable moving-grate

technology, FEED capability, and Indonesian PPP-development exposure. However, Kanadevia's confirmed role is primarily technology and FEED provision. The project therefore requires external capability in industrial steam commercialisation, steam-market analysis, project sponsorship, financing, local EPC, O&M, and partner coordination.

Based on these findings, the strategic planning for the proposed Waste-to-Steam project is structured using the TOWS framework, which matches internal strengths and weaknesses with external opportunities and threats to develop practical strategies (Weihrich, 1982). The strategy is organised into four pillars: leveraging strengths, mitigating weaknesses, capturing opportunities, and defending against threats. The project should be developed through a consortium-based structure supported by long-term waste-supply, tipping-fee, and steam-offtake agreements

The four strategic pillars are presented in Table 4.6.

Table 4.6 Strategic Pillar of WtS Project

Strategic Pillar	Objective
Leverage Strengths	Use Kanadevia's WtE experience, moving-grate technology, FEED capability, and Indonesian PPP experience.
Mitigate weaknesses	Address gaps in steam commercialisation, financing, EPC, O&M, and local delivery through partners and specialist advisers.
Capture opportunities	Use landfill pressure, industrial decarbonisation demand, policy support, and potential PPP or climate-finance support.
Defend against threats	Secure waste supply, tipping-fee payment, steam offtake, environmental compliance, stakeholder support, and clear partner responsibilities.

Source: Author, 2026

The strategic pillars are consistent with the WtE literature. A Waste-to-Steam project requires reliable waste supply, sufficient industrial steam demand, suitable technology, environmental controls, policy support, and stakeholder acceptance (Xu et al., 2025; Caferra et al., 2023; Liu et al., 2021).

Kanadevia can support the project through its technology and FEED capability. However, the project also needs partners for steam commercialisation, financing, local EPC and O&M, and project coordination. The TOWS strategies are presented in Table 4.7.

Table 4.7 TOWS strategy

Strategy	SWOT factors used	Key Action
SO1. Develop a credible WtS project concept	S1, S2, S3, O1, O3	Use Kanadevia's WtE experience, moving-grate technology, and FEED capability to prepare the technical concept, waste-treatment design, and environmental-control plan.
SO2. Build government and stakeholder support	S4, O1, O3, O4	Use Kanadevia's Indonesian PPP experience to engage local governments on waste supply, land, permits, tipping fees, and project-preparation support.
SO3. Position WtS as a lower-carbon solution	S1, S2, S4, O1, O2	Position the project as an integrated solution for residual-waste treatment, landfill diversion, and lower-carbon industrial steam. Demonstrate the environmental and industrial decarbonisation benefits compared with continued landfill disposal and fossil-fuel-based steam generation.
WO1. Strengthen steam-commercial capability	W1, W2, O2	Appoint a specialist adviser to assess steam demand, steam price, competing fuels, and bankable Steam Purchase Agreement terms.
WO2. Form a project consortium	W3, W4, O3, O4, O5	Partner with an equity sponsor, local EPC contractor, O&M provider, financial adviser, and industrial-steam commercial adviser.
WO3. Seek financial support	W3, O4	Explore PPP support, JCM, grants, guarantees, VGF, concessional finance, and strategic investors.

ST1. Secure waste quality and environmental performance	S1, S2, S3, T1, T4	Conduct a waste audit and apply appropriate waste-acceptance criteria, emission controls, residue management, and environmental monitoring.
ST2. Develop reliable steam specifications	S1, S2, S3, T2, T3	Define steam pressure, temperature, quality, availability, and maintenance arrangements for industrial customers.
WT1. Secure key contracts before financial close	W1–W4, T1–T5	Do not proceed to financial close before waste supply, tipping fees, steam offtake, land, permits, local EPC/O&M, and financing arrangements are secured.
WT2. Manage project and consortium risks	W3, W4, T4, T5	Clearly define each partner's scope, performance guarantees, warranties, responsibilities, and coordination procedures.
WT3. Use conservative assumptions	W1–W4, T1–T4	Test low steam price, low tipping fee, low waste delivery, low LHV, high CAPEX, project delay, and financing-risk scenarios before investment approval.

Source: Author, 2026

The TOWS strategy recommends a phased and contract-first development approach. Before financial close, the project should secure long-term waste supply, tipping-fee payment, industrial steam offtake, land and pipeline access, and regulatory certainty.

Kanadevia can support the project through FEED and technology services. However, the project also requires partners for steam commercialization, financing, local EPC and O&M, and project coordination. Technology, financial support, and potential benefits under Perpres No. 109/2025 may improve project viability, but they should not replace the need for bankable long-term contracts.

4.5 Regional Policy and Planning Analysis

4.5.1 National Policy Planning Review

The National Long-Term Development Plan (RPJPN) 2025–2045, established through Law No. 59 of 2024, sets Indonesia's long-term development direction and provides the

framework for national development planning through 2045. As part of our environmental and waste-management agenda, national planning is focused on the redesign of waste management as a whole from the upstream to the downstream. The policy direction is to address the ongoing problem of waste collection and treatment and disposal, and the pressure on landfill capacity. National planning documents identify the need to increase waste processing facilities, enhance waste collection services, enhance governance and finance and accelerate the adoption of effective and environmentally sound waste-management technologies. The RPJPN sets a long-term goal of 90% of waste to be processed at waste-treatment facilities by 2045 and about 10% of waste to be left in the system to be disposed of as residual waste by 2045. The national roadmap also calls for full household access to waste collection services by 2045. This direction is relevant to the proposed Waste-to-Steam (WtS) project because thermal waste treatment can be a part of a whole system for management of waste. In addition, the literature also stresses that Waste-to-Energy (WtE) should be viewed in the context of the wider waste hierarchy and circular economy framework, not as a replacement for waste prevention, reuse and recycling.

Awino and Apitz (2024) stress the need for the integration of waste hierarchy principles, resource recovery and system-level considerations in the analysis of municipal solid waste management strategies. Waste-to-Energy (WtE) such as production plants that recover electricity or generate useful heat is a tool for waste management and energy recovery. Instead of being applied to all the waste streams after high-priority waste-management options have been made operational. Recent studies show that thermal treatment with energy recovery is able to reduce waste volume and produce energy; its environmental performance is affected by the waste characteristics, emission control, residue management and its place in the waste-management system (Jamilatun et al., 2023; Awino & Apitz, 2024). A WtE facility can reduce the amount of waste that has to be disposed of in the landfill and recover energy in the forms of electricity, heat, or, where technically and commercially feasible, industrial steam.

The National Medium-Term Development Plan (RPJMN) 2025–2029, established through Presidential Regulation No. 12 of 2025, represents the first five-year implementation phase of the RPJPN 2025–2045. The RPJMN translates the long-term development direction into national priorities, programs, targets and implementation frameworks. In the waste-management sector, the RPJMN advocates for integrated waste-management reform from upstream to downstream, including better waste collection, waste processing, recycling and treatment infrastructure. National planning documents also reveal the challenges of increasing waste generation and limited landfill capacity as waste generation is estimated to reach around 82.2 million tonnes per year by 2045 and landfill space could be constrained by 2028.

The RPJMN also lays out a medium-term direction to increase the amount of waste processed at treatment facilities. The 2025-2029 roadmap targets 38% of waste to be processed at waste-treatment facilities by 2029, with 20% recycling, whilst the RPJPN vision is to get 90% of waste processed by 2045. As such, the government planning will take into account the recycling, composting, material recovery and energy recovery activities as part of the treatment process, rather than one single technology. This combined approach is in line with the wider literature in this field which emphasizes that the appropriate waste treatment technology depends on the type of waste, the local infrastructure, the environmental impact and the economic situation (Jamilatun et al., 2023). The proposed waste-to-steam project is thus in line with the national planning direction because it is able to process municipal waste, reduce the amount of waste that ends up in the landfill and give back the energy in the form of industrial steam. It can therefore contribute to both waste treatment and energy recovery as long as there is a stable industrial steam demand. This is supported by the recent studies in the field of WtE systems for industrial steam supply that indicate that the matching of the waste to the industrial steam demand is also a crucial part of the technical and economic viability of such systems.

However, policy alignment alone does not guarantee financial support, project approval, or commercial viability. The project must still demonstrate compliance with applicable technical, environmental, financial, waste-supply, and regulatory requirements. In particular, the proposed project should be assessed against Presidential Regulation No. 109 of 2025 concerning Urban Waste Management through Waste Processing into Renewable Energy Based on Environmentally Friendly Technology, which provides the current national regulatory framework for urban waste processing into renewable energy. The regulation defines waste processing into renewable energy as the processing of waste using environmentally friendly technology to produce, among others, electricity, bioenergy, renewable fuel, or other co-products while reducing waste volume. Therefore, the project's alignment with national policy should be understood as a supporting policy condition, while its actual feasibility remains dependent on technical, environmental, contractual, financial, and regulatory assessments.

4.5.2 Waste Management Regulatory Framework

The 2025–2034 Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik* or RUPTL) sets out Indonesia’s electricity-development direction for the next ten years. The plan targets a 34.3% share of new and renewable energy in the additional generating capacity planned to 2034. It also projects a substantial increase in electricity generated from

municipal waste, from 98 GWh in 2025 to 2,242 GWh in 2034 (PLN, 2025). This indicates that municipal waste is expected to play a larger role in Indonesia's electricity and renewable-energy planning.

Under RUPTL, municipal waste can be used as an energy source through the development of Waste-to-Energy facilities, commonly known as PLTSa. Previously, the development of PLTSa was guided by Presidential Regulation No. 35 of 2018, which focused on accelerating PLTSa development in 12 selected cities.

Presidential Regulation No. 35 of 2018 was repealed and replaced by Presidential Regulation No. 109 of 2025 on Urban Waste Management through Processing Waste into Renewable Energy Using Environmentally Friendly Technology. Perpres No. 109/2025 broadens the national framework for waste-to-energy development and is no longer limited to the original 12 cities. Under the new framework, regional governments that meet the applicable technical, administrative, financial, land, waste-supply, and regulatory requirements may participate in WtE development. This provides a possible policy pathway for regions outside the original 12 cities, including the Special Region of Yogyakarta, subject to fulfilment of all required criteria.

Perpres No. 109/2025 introduces the broader concept of *Pengolahan Sampah menjadi Energi Terbarukan* (PSE), namely waste processing using machinery and/or equipment to convert waste into renewable-energy products. Within this framework, *Pengolahan Sampah menjadi Energi Listrik* (PSEL) refers specifically to waste processing that produces electrical energy through environmentally friendly technology, including PLTSa. The regulation also changes the institutional structure for PSEL development, including the role of BPI Danantara as the implementing entity. In addition, regional governments are required to provide project land through a cost-free *pinjam pakai* arrangement during the construction and operating periods. The cooperation agreement must also address land availability, waste collection and transport commitments, cooperation duration, default, and compensation if the required waste supply is not met.

Although Perpres No. 109/2025 is now in force, projects that had already commenced under Perpres No. 35/2018 may continue under the previous framework. A project is generally considered to have commenced if: the regional government has appointed the developer; a cooperation agreement has been signed between the regional government and the developer; or a Power Purchase Agreement (*Perjanjian Jual Beli Listrik* or PJBL) has been signed between PLN and the developer. However, projects that face implementation difficulties may be able to adopt the new framework, subject to the applicable requirements and approvals.

The RUPTL 2025–2034 remains an important national planning document because it is prepared with reference to the National Electricity General Plan (*Rencana Umum Ketenagalistrikan Nasional* or RUKN) and the National Energy Policy (*Kebijakan Energi Nasional* or KEN). Therefore, RUPTL's renewable-energy target and projected contribution from waste-based electricity remain relevant for national electricity planning. However, project developers should confirm the latest implementing rules, project eligibility, tariff arrangements, PLN offtake requirements, and institutional responsibilities under Perpres No. 109/2025 before relying on RUPTL projections for an individual WtE project.

The RUPTL and Perpres No. 109/2025 are most directly relevant to electricity-generating WtE or PSEL projects. A Waste-to-Steam project may be aligned with the broader PSE and waste-management policy objectives, but it does not automatically receive the same PLN offtake, electricity-tariff, or PJBL arrangements available to qualifying PSEL projects. Therefore, industrial steam sales must be supported by separate, long-term Steam Purchase Agreements with industrial off takers.

4.5.3 Alignment between National and Regional Development Planning Documents.

Project implementation should be aligned with Indonesia's National Development Planning System, which covers long-term, medium-term, and annual development plans at both central and regional levels. 12 Hierarchically, the following are the planning documents produced in the National Development Planning System and their relationship with the regional development planning system:

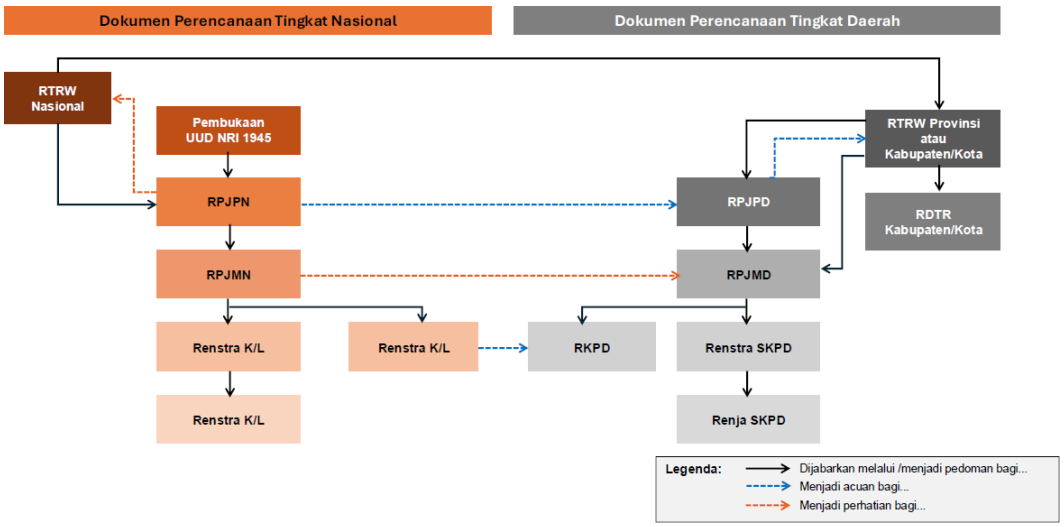


Figure 4.1 Hierarchy of the National Development Planning System

Source: Author, 2026

Alignment with planning documents is important because Indonesia applies a programme-based and performance-based budgeting approach, commonly described as *money follows programme*. Under this approach, budget allocation should support priority programmes and measurable development outcomes. Therefore, projects that are included in relevant planning documents are more likely to receive support from regional governments and be considered in budget preparation.

Consistency with national and regional planning documents is also important when seeking external financing. This is particularly relevant for projects proposed under a Public–Private Partnership (PPP) scheme, designated as National Strategic Projects, or submitted for foreign loans and grants. In Indonesia, external-loan planning generally follows a sequence of planning documents, including the Blue Book, Green Book, and the project activity list. Inclusion in these documents may be required before a project can proceed to the next stage of external financing preparation.

At the regional level, the Regional Government Work Plan (*Rencana Kerja Pemerintah Daerah* or RKPD) serves as a reference for preparing the Draft Regional Budget (*Rancangan Anggaran Pendapatan dan Belanja Daerah* or RAPBD). Therefore, projects requiring regional-government funding, including tipping fee payments, supporting infrastructure, land provision, collection systems, or waste transport, should be reflected in the RKPD and in the work plans of the relevant regional agencies (*Rencana Kerja Perangkat Daerah* or Renja PD). Under Law No. 25 of 2004, the RKPD is derived from the Regional Medium-Term Development Plan and serves as a guide for preparing the draft regional budget.

Proper alignment with the Regional Spatial Plan (Rencana Tata Ruang Wilayah or RTRW) and Detailed Spatial Plan (Rencana Detail Tata Ruang or RDTR) is also essential. These documents determine permitted land use, zoning, infrastructure corridors, and land allocation. In the case of a Waste-to-Steam project, spatial conformity is very important for the plant site, waste-transport routes, ash disposal facilities, water and wastewater facilities, and industrial steam pipelines. Complying with the RTRW and RDTR can decrease land use conflicts and allow for a smooth licensing process. If a project is not included in national or regional planning documents, it may be seen as being inconsistent with government priorities. This will delay project preparation, restrict access to public funding, require changes in planning documents, and reduce support from relevant government institutions.

The project should therefore be included in national planning documents such as the Government Work Plan (Rencana Kerja Pemerintah or RKP), ministry or agency strategic plans (Renstra), and ministry or agency work plans (Renja). At the regional level, it should be reflected in the RPJPD, RPJMD, RKPD, Regional Agency Strategic Plan (Renstra PD), and Regional Agency Work Plan (Renja PD). The project must therefore be consistent with national and regional development planning documents. This is an indication that the project serves government development goals, addresses regional waste and energy needs, is available for budget and financing support, and is less subject to licensing and implementation issues.

4.6 Waste management in Cilegon, Serang City and Serang Regency.

Serang City, Serang Regency, and Cilegon City generate approximately 2,048 tonnes per day of municipal solid waste. Of this total, approximately 837 tonnes per day are transported to landfill, while the remaining estimated waste is not transported to landfill. These figures are based on the author's compilation of available municipal waste data and should be confirmed through a detailed waste audit before project implementation (SIPSN/KLHK, 2024). This creates pressure on landfill capacity and environmental risks.



Figure 4.2 Waste Management in Three Areas

Source: Author, 2026

4.6.1 Waste collection services

Waste in Serang City, Serang Regency, and Cilegon City is generated by households, markets, businesses, public facilities, workplaces, and industrial areas. The waste is collected

and transported to temporary disposal points and sorted or recovered and sent to landfill sites. Food waste, recyclable materials, and hazardous waste (B3) can be separated from the local collection and treatment system (SIPSN/KLHK, 2024). Collection coverage and supporting infrastructure are still important as the amount of waste that is produced does not always equal the amount of waste that can be collected, transported and delivered to a treatment facility. The waste that is not collected could be at risk of unmanaged disposal. These are the conditions that should be verified through field surveys, local-government records and a detailed waste audit at the feasibility-study stage (SIPSN/KLHK, 2024). For the proposed Waste-to-Steam project, the initial feedstock should be waste already collected and trucked to the landfill or transfer facility. Uncollected waste should only be considered as a future source once collection coverage, vehicles, transfer capacity and transport systems have been enhanced. In this scenario, feedstock delivery risk is lower in the startup phase.

4.6.2 Facilities and infrastructure

Waste-management infrastructure contains collection vehicles and temporary collection points (*Tempat Penampungan Sementara* or TPS), transfer points, sorting activities, recycling and composting projects, RDF facilities or planned RDF development, and landfill sites. In Cilegon City, waste is transferred to TPS, sorted to organic and inorganic materials if possible, composted and recycling or alternative-fuel efforts are taken to Bagendung Landfill. Bagendung Landfill is about 10 hectares and relatively close to the city, so it may be used for waste transport. Landfill disposal is the main disposal site of residual waste. This puts pressure on the landfill capacity and may lead to environmental problems as a result of leachate, odour, open burning and uncontrolled disposal if there are no waste-management systems in place (Republic of Indonesia 2008; SIPSN/KLHK 2024). Informal waste pickers may help to recover recyclable materials at landfill sites and collection points. They should be considered to be a part of the project and the potential impact of the project in the feasibility study stage and should be the subject of stakeholder consultation. The proposed 600-tones-per-day waste-to-steam facility should complement upstream waste reduction, source separation, recycling, composting, RDF development, and landfill management. After the recovered material has been collected, the plant should receive residual combustible waste. It should be located close to the industrial steam user and be able to reduce the cost of steam pipeline and heat loss to make steam supply commercial (Maki et al., 2021).

4.6.3 Institutions involved

At the national level, waste management is governed by Law No. 18 of 2008 on Waste Management and related regulations. Key national institutions include the Ministry of Environment, which is responsible for national waste-management policy, environmental safeguards, and monitoring; the Ministry of Home Affairs, which supports local-government governance and cooperation; the Ministry of Finance, which is relevant to fiscal policy, PPP support, and financial-support mechanisms; and Bappenas, which is responsible for national development planning and project prioritisation (Republic of Indonesia, 2008; Republic of Indonesia, 2014; Republic of Indonesia, 2025).

In terms of provincial government, the Banten Provincial Government has a central role in regional waste-management planning, coordination of local governments, environmental monitoring and inter-city infrastructure. The Banten Provincial Environment Agency and other provincial institutions responsible for pollution control and hazardous-waste management play a vital role for environmental compliance, waste management coordination and completion of the proposed Waste-to-Steam project (Republic of Indonesia, 2014; Republic of Indonesia, 2008).

In the city and regency level, Cilegon City, Serang City, and Serang Regency governments are responsible for daily waste collection, transportation, TPS and landfill management, local budgeting, public awareness, local regulations and waste management to treatment facilities. The roles of their respective environmental agencies (DLH) are at the heart of these functions (Republic of Indonesia, 2008; Republic of Indonesia, 2014).

The proposed project should clearly define the roles of local governments, provincial government, project company, industrial steam off-taker, collection providers and community stakeholders. Waste collection, sorting, material recovery, transport, and treatment can be done by community groups, RT/RW associations, waste banks, informal waste pickers, aggregators, and private operators. Their roles should be defined by collection-service agreements, waste-supply agreements, operating procedures and performance standards, for example. A special-purpose company, long-term waste-supply contracts with the local government, and a long-term Steam Purchase Agreement with the industrial off-taker should be part of the project structure. Such agreements are needed in order to allocate responsibilities and take on risks of the project and ensure project bankability (Semarang Waste-to-Energy Final Business Case, 2021; Yescombe, 2018).

4.7 Technical and Economic Analysis

4.7.1 Feedstock Assessment

Feedstock availability is one of the key determinants of the technical and commercial feasibility of the proposed Waste-to-Steam (WtS) project in Banten Province. Unlike conventional steam-generation facilities that rely on relatively standardized fuels, a WtS facility depends on municipal solid waste (MSW), whose availability, composition, moisture content, and energy characteristics can vary significantly across locations and over time. The availability, characteristics, and composition of the waste stream are important factors in determining the sustained operation and profitability of WtE systems, while the heating value of the waste is a key parameter in assessing its suitability as an energy feedstock (Alao et al., 2022).

These variations directly affect combustion performance, plant operating conditions, energy recovery, and steam production. Moisture content has a direct effect on calorific value and self-sustained combustibility of MSW; higher moisture content reduces the effective energy available from the waste and may increase the need for operational or auxiliary energy inputs (Komilis et al., 2014). Furthermore, dynamic modelling of a full-scale MSW incineration plant shows that fluctuations in waste properties including moisture content, heating value, and composition affect plant response and process stability. The study also found that changes in waste humidity can influence the response time of steam production (Magnanelli et al., 2020). As such, the feedstock assessment in this study assesses waste quantity, waste quality, Lower Heating Value (LHV), and waste availability. These factors are combined in order to determine if the proposed 600 tons per day (TPD) WtS facility can obtain sufficient and technically suitable feedstock while maintaining the required operating conditions for reliable steam production.

4.7.2 Waste Quantity Analysis

Waste quantity and long-term availability are fundamental in the feasibility of the proposed Waste-to-Steam (WtS) facility, because it is assumed that the plant will always supply sufficient and reliable supply of municipal solid waste. Feedstock availability is considered a critical factor for WtE implementation and waste treatment capacity should be compared to the expected availability and nature of the waste stream during the project period (Alao et al., 2022; Istrate et al., 2023). The consideration in this study is to consider the present waste availability in the Cilegon-Serang area, and the potential for the development of

municipal waste supply during the future. While the waste in the current environment indicates the feedstock availability, a scenario assessment is necessary to evaluate whether there is enough waste to support the facility for the remainder of the facility's life. This is consistent with waste management planning studies that account for the potential uncertainty of waste supply in the future and the changes in waste flows to allocate treatment capacity and facilities (Mohammadi & Harjunkoski, 2020; Istrate et al., 2023).

Waste quantity assessment indicates that the wider Cilegon–Serang area has a sufficient aggregate waste resource base to support the proposed 600 tons per day (TPD) WtS facility, based on the current collected waste identified in the assessment. So far almost 419 TPD of waste is collected from Serang City, 128 TPD from Serang Regency and 290 TPD from Cilegon City is sent to landfill without treatment - that is around 837 TPD of garbage collected within these three target areas. WtS facility is proposed to be located in Cilegon City, near industrial steam off-taker, so the ability to collect the waste from the three municipalities is a key consideration in establishing a sufficient feedstock base for the facility. The use of multiple waste sources is also consistent with the supply chain view of WtE systems in which waste sources, treatment facilities and energy markets are connected in a network (Mohammadi & Harjunkoski, 2020).

Table 4.8 Indicative Waste Quantity and Potential Availability by Municipality

Area	Waste Generation (TPD)	Waste Transported to Landfill (TPD)	Potential Feedstock to WtS
Serang City	521	419	☑
Serang Regency	1.191	128	☑
Cilegon City	336	290	☑
Total	2.048	837	☑

Source: Author, 2026

The approximately 837 TPD of potentially available collected waste is sufficient to cover the nominal 600 TPD initial plant capacity, providing a theoretical surplus of approximately 237 TPD, or 39.5% above the plant's nominal requirement. However, this surplus should not be interpreted as a guaranteed operational reserve because the 837 TPD represents the currently collected waste transported to landfill, rather than contracted and guaranteed WtS feedstock. The distinction is important because WtE capacity planning needs

to account for actual waste availability and future changes in waste flows rather than relying solely on aggregate waste generation figures (Istrate et al., 2023).

Consequently, the project should not rely solely on the existing collection volume without additional feedstock-supply security mechanisms. Any disruption in municipal collection, diversion of waste to alternative treatment facilities, changes in waste-management policy, seasonal fluctuations, or lower-than-expected delivery could reduce plant utilization. Literature on WtE supply-chain planning similarly recognizes uncertainty in waste supply as an important consideration when designing waste-treatment systems and determining the allocation of waste to treatment facilities (Mohammadi & Harjunkoski, 2020). Therefore, long-term waste-supply agreements, minimum-volume commitments, and coordination with the relevant local governments would be important mechanisms for reducing feedstock risk.

In addition to currently collected waste, approximately 1,211 TPD of uncollected waste has been identified across the target area, calculated as the difference between total waste generation of 2,048 TPD and the 837 TPD currently transported to landfill. This additional volume indicates that the underlying waste-resource base is significantly larger than the initial plant requirement. However, uncollected waste should not be treated as immediately available feedstock, because additional collection infrastructure, transportation capacity, transfer facilities, and municipal coordination would be required before this volume could reliably reach the WtS facility. Therefore, the principal feedstock issue is not necessarily an absolute shortage of waste in the region, but rather whether the existing collected waste and a portion of the currently uncollected waste can be progressively integrated into a reliable, contractually secured, and technically suitable collection and delivery system. This distinction is important because successful WtE implementation depends not only on the existence of a large waste resource but also on the ability to establish a reliable waste-supply chain connecting waste sources to the treatment facility.

4.7.3 Waste Projection Analysis

The long-term availability of municipal solid waste is a critical consideration for the proposed Banten Waste-to-Steam (WtS) project because the facility is expected to operate continuously over an extended project period. While the current waste supply provides an initial indication of feedstock adequacy, long-term feasibility depends on whether sufficient waste can be consistently collected, allocated, transported, and delivered to the facility throughout its operating life.

The future municipal-waste volume for this study is estimated by combining projected population growth with assumed per-capita waste generation rates for each municipality.
The projection approach uses the following inputs:

1) Population projection for each municipality, developed using population trends observed over the most recent ten years period. Historical population data were obtained from *Badan Pusat Statistik* or BPS.
2) Per-capita municipal waste generation rates, expressed in kilograms per person per day. These rates were established with reference to available local waste data, Indonesian standards and regulations, as well as international benchmark data.

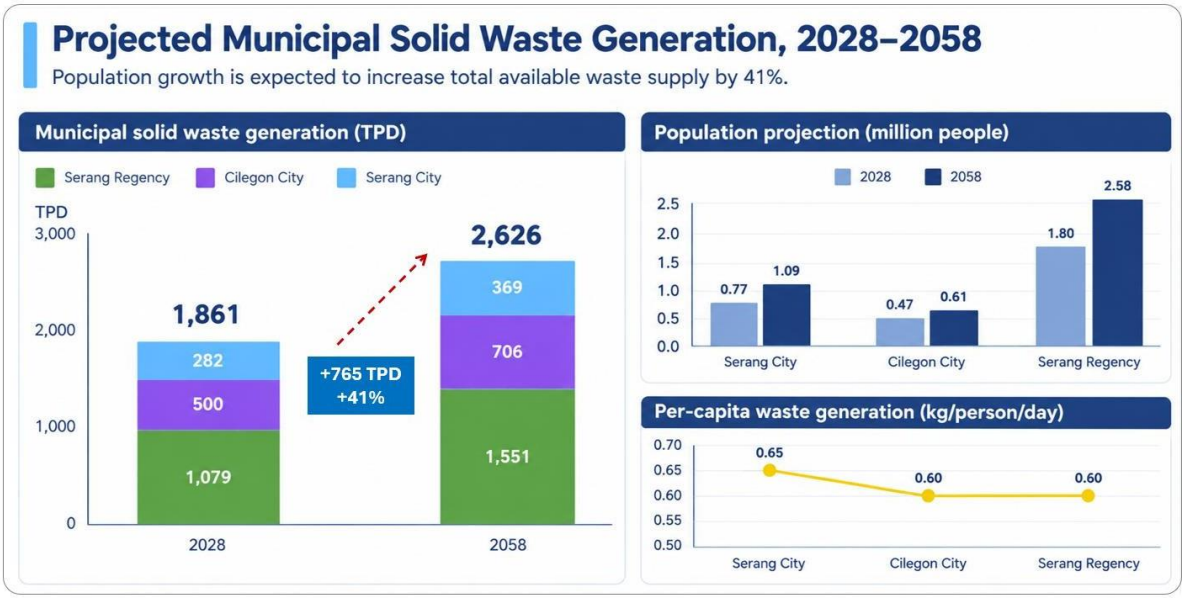


Figure 4.3 Waste Generation Forecast in Banten Province from 2028 – 2058

Source: Author, 2026

The projected waste-waste generation indicates a steady expansion of the municipal solid-waste resource across the greater serang area. Total waste generation is estimated to increase from approximately, 1,861 tonnes per day in 2028 to 2,626 tpd in 2058, representing an overall increase of approximately 41% over the 30-years projection period. The projected increase is driven primarily by population growth, as the per capita waste generation consumption are maintained at constant level throughout the forecast period. Serang City applies a per-capita generation of 0.65 kg /person/day, while Cilegon city and Serang Regency apply 0.60 Kg/person/day. Thus, the forecast does not rely on any additional assumptions regarding future consumption growth, economic growth, or increase of waste generation per

person. This result suggests that the three areas have a growing municipal resource base in the long run. With the proposed Waste to Steam project, this provides a rationale for an integrated waste-supply plan in the three areas. However, the forecast is about gross waste generation and not guaranteed WtS feedstock.

4.7.4 Waste Quality Analysis

Waste quality is an important aspect to consider in the technical assessment of the proposed Banten Waste-to-Steam (WtS) project as municipal solid waste is a heterogeneous feedstock instead of one. The physical composition, moisture content and calorific value of municipal waste can influence combustion stability, heat recovery efficiency, steam generation and ultimately the financial performance of the plant. Therefore, the waste-quality assessment should be carried out to determine if the municipal waste available for thermal treatment is good enough.

Based on the waste composition data published by Kementerian Lingkungan Hidup for Banten Province in 2024, the municipal waste stream is dominated by food waste at 58.9% and plastics at 24.7% and paper at 9.5% and wood at 3.1% as each waste type is relatively small. As the preliminary design decision, the Waste to Steam Project in Banten has adopted the assumed LHV (Lower Heating Value) of 4,600 - 17,000 kJ/kg (or 1,400 Kcal/kg as a reference value) as a design parameter for combustion performance on the ground, steam generation and initial equipment sizing. The final design value should be verified with a sample waste and laboratory testing. The LHV is within the designable range with a desired value of 4,600 - 17,000 kJ/kg and the overall waste material is suitable for incineration and energy recovery.

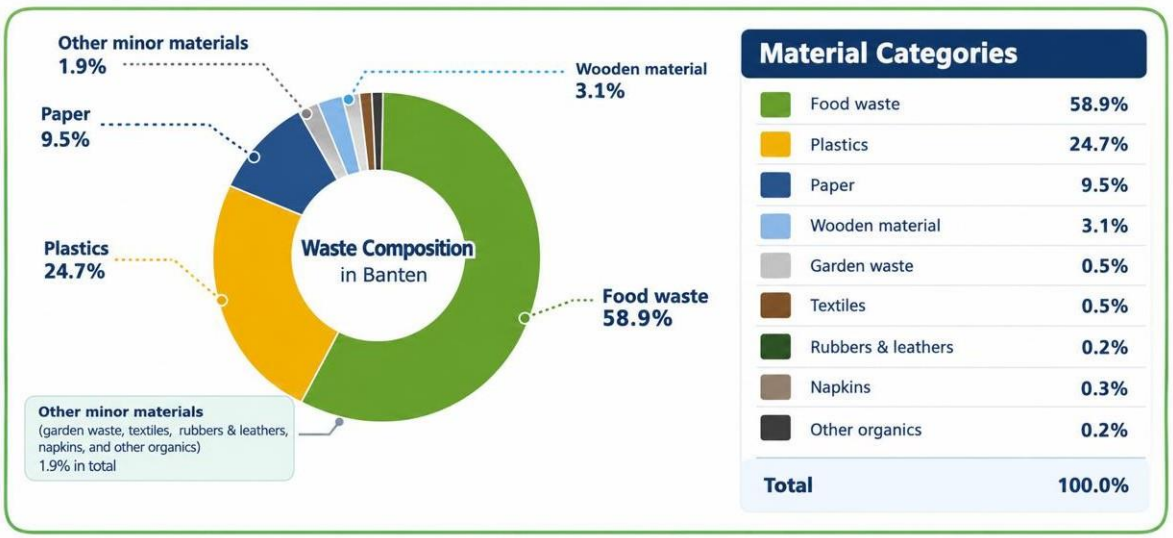


Figure 4.4 Indicative General Waste Composition in Banten Area

Source: SIPN-Sistem Informasi Pengelolaan Sampah Nasional, 2026

4.8 Market Analysis

4.8.1 Market Size from Projected Waste Generation

The Waste-to-Steam opportunity is supported by a growing long-term municipal waste resource base. According to the estimated municipal waste generation in 2028 to 2058, waste volume is expected to increase from about 1,863 tonnes per day in 2028 to 2,626 tonnes per day. Assuming the waste quality and conversion efficiency of the project, this would translate to an increase in gross steam-generation potential from 142.7 tonnes per hour in 2028 to 201.3 tonnes per hour in 2058 - approximately 41% over the projection period. Gross steam generation potential (with 8,000 operating hours) in total can increase from 1.14 million tonnes per year (2028) to 1.61 million tonnes per year (2058). The growth in the waste volume is indicative of the long-term potential of WtS development. In fact, it has been argued from the literature that MSW generation, accumulation, composition and energy content are important factors to consider when predicting the potential of WtE to be recovered from the environment, and that changes in the availability of waste in the medium term must be taken into account when considering the size of WtE deployment (Khan et al., 2022). More specifically, Luo, Gong, and Xia (2025) developed a WtE assessment framework that integrates MSW forecasts with WtE steam-supply modelling and industrial steam-demand matching, illustrating the relevance of projected waste growth in the context of future industrial steam-supply potential.

Accordingly, the projected increase in steam-generation potential should be interpreted as an indication of the expanding resource-side market potential, rather than as an immediate requirement for equivalent plant-capacity expansion. Actual WtS capacity should continue to be determined by the availability of secured feedstock, plant operating requirements, steam demand, infrastructure constraints, and commercial commitments. This distinction is particularly important because WtE systems require appropriate matching between waste supply and energy demand to achieve effective resource utilization.



Figure 4.5 Waste-to-Steam Market Potential Based on Projected Waste Generation

Source: Author, 2026

4.8.2 Market Size of the industrial Coal-Substitution opportunity in KIEC Industrial Estate

This market assessment identifies an industrial steam-demand cluster of approximately 1,437 tonnes per hour. The demand is built on nearly 179,000 tonnes of coal consumption per month, and there is a significant supply chain of industrial process heat and a potential for an alternative to coal-based steam generation in industrial industries. Industrial steam systems are crucial to process industries because steam is used as an energy transfer medium to supply heat to multiple industrial consumers. In industrial parks, centralized steam systems can serve multiple users. However, the economics of steam distribution depend upon consumer load, steam requirements, and the distance between steam generation and consumers (Zhang et al., 2023).

Importantly, the market is concentrated rather than highly fragmented. The top six potential customers are estimated to have 94% of total estimated steam demand, and the five largest coal consumers have about 87% of identified coal use. This concentration creates a practical commercial path: instead of building the project around a large number of small customers, the project can find a small number of high-volume anchor off-takers at first. This is also in line with the need for WtE steam supply to match industrial demand identified by Luo, Gong, and Xia (2025), whose analysis of the spatial relation between MSW and industrial steam demand determines the potential for WtE steam supply. PT. Asahimas Chemical is the largest of these opportunities, with an estimated steam demand of 437 tonnes per hour (around 30% of the total estimated market). Other major demand centres include CPO processing, salt

production, sugar refining, and petrochemicals. All of them together form a diverse but concentrated customer base with continued process-heat needs.

The concentration of demand is commercially important as the development of a dedicated steam supply system needs sufficient and stable heat loads to justify investment in the generation and distribution system. The industrial park steam system research shows that the overall heat load of consumers and the distance between the energy station and the consumers can have serious implications on the steam system design and cost. The market is in favor of a phased development strategy. The first phase should focus on the largest potential steam off-taker, verify their actual steam pressure and land requirements, and assess the willingness of the steam off-taker to enter into a long-term Steam Purchase Agreement (SPA). As more customer commitments, feedstock availability, and the infrastructure are secured, further expansion of capacity can be achieved. This is consistent with the supply-demand matching principle applied in the recent work by WtE industrial steam, where the scale and location of steam supply need to be compared with projected waste resources and industrial demand.

With the assumed municipal solid waste LHV of 5.86 GJ per tonne and the waste-to-steam boiler efficiency of 80%, to supply 100% of the identified demand would require about 18,850 tonnes of municipal waste per day. This is a very large feedstock requirement compared to the estimated waste resource for the proposed project.

Therefore, the commercial opportunity should initially be evaluated based on a defined share of the addressable market, such as 10%, 25%, or 50%, rather than assuming immediate full replacement of existing coal-based steam. This approach allows the project to align steam demand with the realistically available waste resource while progressively increasing supply as feedstock and customer commitments develop. The importance of matching WtE steam capacity with both available MSW and industrial steam demand is also demonstrated in the Hainan case study by Luo, Gong, and Xia (2025).



Figure 4.6 Waste-to-Steam Market Potential Based on Industrial Coal-Substitution Demand

Source: Author, 2026

4.9 Financial Analysis

The financial analysis assesses the economic feasibility, financing requirements, profitability, liquidity and debt-services capacity of the proposed 600 tpd waste-to-steam project. The assessment is based on a 20-year operating period, which construction in 2027-2028 and commercial operation commencing in 2029.

4.9.1 Data Input and Assumptions

The following data inputs and assumptions are used to estimate the required revenue streams and the project`s financial projections.

1. Macroeconomic

1) Project Exchange Rate, Indonesia Consumer Prices, and US Inflation Rate.

The macroeconomic assumptions are based on the Ministry of Finance's long-term economic-growth forecast and associated macroeconomic assumption. The USD/IDR series assumes 3.0% annual IDR depreciation from a 2026 base rate of IDR 17,643/USD. Indonesia Consumer Prices is assumed at 3.0% in 2027, 2.75% in 2028, and 2.5% thereafter. US inflation is assumed at 2.3% in 2027, 2.1% in 2028, and 2.0% thereafter. These assumptions are used in the financial analysis to convert all CAPEX and OPEX reflected in USD to IDR, as well as adjusting the prices and stream revenue to reflect the inflation rate. The CAPEX and OPEX presented in the report is using currency rate of 1 USD = 17,643 IDR as per exchange rate in September 2026 adjusted with inflation.

2) Average Base Lending Interest Rate of Bank

The table below shows the interest rate used to determine the financial feasibility of the project. The interest rate used is base lending rate for corporate lending published by Indonesian banks that have previously been involved in infrastructure projects in Indonesia. The rates showed below are based on the latest publications from Otoritas Jasa Keuangan. The average base interest from the four banks is 9.97 %, used to calculate the interest payment as the loans are dominated in IDR.

Table 4.9 Bank's Corporate Lending Interest Rate

Bank	Corporate Lending Interest Rate (%)
PT. Bank Rakyat Indonesia (Persero), Tbk	9.95
PT. Bank Mandiri (Persero), Tbk	9.95
PT. Bank Negara Indonesia (Persero), Tbk	9.95
PT. Bank Danamon Indonesia, Tbk	10.00
PT. Bank Permata, Tbk	10.00
Average	***9.97***

Source: Author, 2026

2. Capital Expenditure (CAPEX)

A. EPC Cost of Civil Works and Core Equipment.

The table below shows a summary of the CAPEX for civil works and core equipment included PPP Company Cost. The CAPEX is converted in IDR and adjusted for inflation.

Table 4.10 EPC Cost

EPC Cost	Price (in IDR Million)
Total Cost of Core Equipment, Civil Works, PPP Company Cost	924,150

Source: Author, 2026

B. Non-EPC Cost

The Non-EPC Costs that are included in the financial assumptions.

Table 4.11 Non-EPC Cost

Non-EPC Cost	Price (In IDR Million)
Insurance During Cost, VAT, PPh 22, Other financing Fees	92,275

Source: Author, 2026

3. Total Investment Cost

Based on the EPC Cost, Non-EPC Cost and other relevant capital expenditure, the below table shows the total investment cost.

Table 4.12 Total Investment Cost

Total Investment Cost	Price (In IDR Million)
EPC Cost	924,150
Non-EPC Cost	92,275
Total	**1,016,425**

Source: Author, 2026

4. Operating Expenditure (OPEX)

The operating expenditure is stated on annual basis and inflated using rate stated in the macroeconomic assumptions. The figure presented are year one operational expenditure.

Table 4.13 OPEX

Operating Cost	Price (In IDR Million)
Fixed Cost	26,427
Variable Cost	24,394
Total	**50,821**

Source: Author, 2026

(1) Fixed Cost

The fixed costs are fixed expenditure required to operate and maintenance the plant. The fixed cost is inflated using rate stated in the macroeconomic consumption.

(2) Variable Cost

The variable costs are defined as the cost that are directly related to the operations of the Waste to Steam Plant and the cost related to the processing of municipal solid waste.

5. Joint Credit Mechanism (JCM Subsidy)

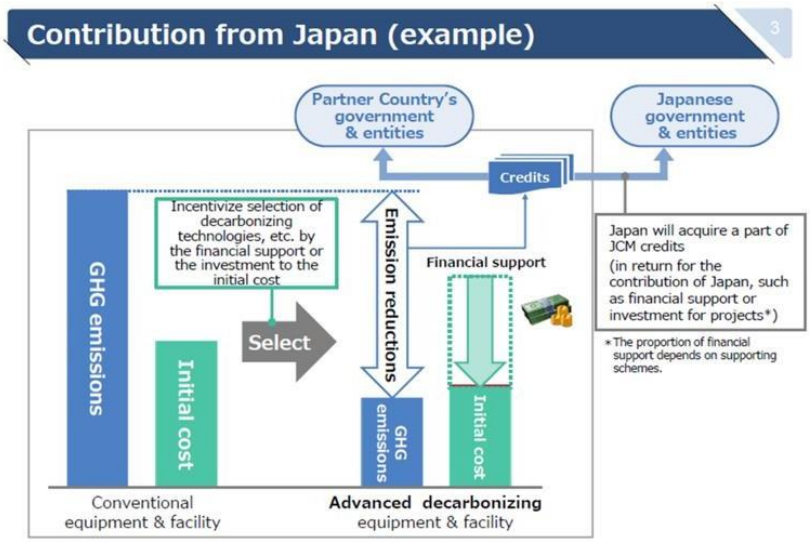


Figure 4.7 Joint Credit Mechanism for WtS Banten Project

Source: Author, 2026

JCM subsidy covers many sectoral scope, including energy efficiency, renewable energy, deforestation and forest degradation, waste management, fugitive emission, and manufacture industry. The JCM subsidy can cover up to 49% of total CAPEX. However, this project assumes a more conservative subsidy level of 33% of total CAPEX.

Table 4.14 JCM Subsidy

JCM Subsidy	Price (In IDR Million)
33% of total CAPEX	304,970

Source: Author, 2026

6. Working Capital

The calculation of this financial analysis statement the amount of the required working capital using the following consumptions.

(1) Operating Cash 30 days of operating expenses

(2) Receivable 30 days of operating (cash) revenue

(3) Payable 30 days of operating expenses

7. Depreciation and Book Value at the End of the Concession

For accounting purposes, the assets' accounting life is treated as equal to the life of the PPP project, with a nominal Residual Value of IDR 1.

8. Capital Structure

The project's financing mix comprises the sponsor's equity contribution and senior debt raised from lending institutions. In Indonesia, infrastructure public–private partnership (PPP) projects commonly use debt-to-equity ratios ranging from 80:20 to 70:30. For this Project, CAPEX financing is assumed at a 70:30 debt-to-equity ratio, informed by financing structures used in comparable power projects in Indonesia.

Table 4.15 Capital Structure of Loan Facility

Loan Facility	
Type of Loan	Indonesian Bank Loan
Loan Periods	10 Years
First Loan Withdrawal	2027
Target Debt Service Coverage Ratio (DSCR)	1.20x

Source: Author, 2026

9. Cost of Equity, Cost of Debt and Weighted Average Cost of Capital (WACC)

A discount Cash Flow (DCF) analysis is used to evaluate the Project`s financial viability. It estimates the value of project by converting its expected future cash flows into present-value terms. The project operating cash flows are discounted using the WACC, which represents the project`s overall cost of financing from both debt and equity. For the analysis, the WACC is assumed to be 9.49%. The Cost of Debt is calculated after tax. The cost of equity of the project is estimated using the Capital Asset Pricing Model (CAPM) with the following formula.

Table 4.16 DCF of WtS Project

Item	Value	Notes
Risk Free Rate (Rf)	8.02%	10 years Indonesia Government Bond
Equity Market Risk Premium (EMRP)	7.50%	Indonesia Equity Risk Premium
β (Beta)	0.72%	Median of leveraged beta of waste management
Cost of Equity (Ke)	13.42%	

Source: Author, 2026

10. Taxation

Corporate Income Tax

The Project applies a corporate income tax rate of 22%. In addition, a seven-year tax holiday is included as a business-development assumption to assess the potential benefit of tax incentives.

11. Revenue steam forecast

The project has two revenue streams, tipping fee and steam sales. Tipping Fee is based on a fee of IDR 300,000 per tonne waste processed, with an annual waste volume of 198,000 tonnes. Steam-sales revenue is based on a selling price of IDR 300,000 per tonne and annual sales volume of 353,390 tonnes. Both revenue streams are assumed to increase by 3% per year to reflect annual price escalation.

Tipping Fee

The proposed tipping-fee benchmark of IDR 300,000 per tonne is based on the estimated landfill-cost budgets of Serang City, Serang Regency, and Cilegon City.

The landfill-cost budget for each area is estimated at 0.7% of its average three-year regional expenditure. This budget is compared with each area's waste generation to determine an affordable tipping-fee contribution.

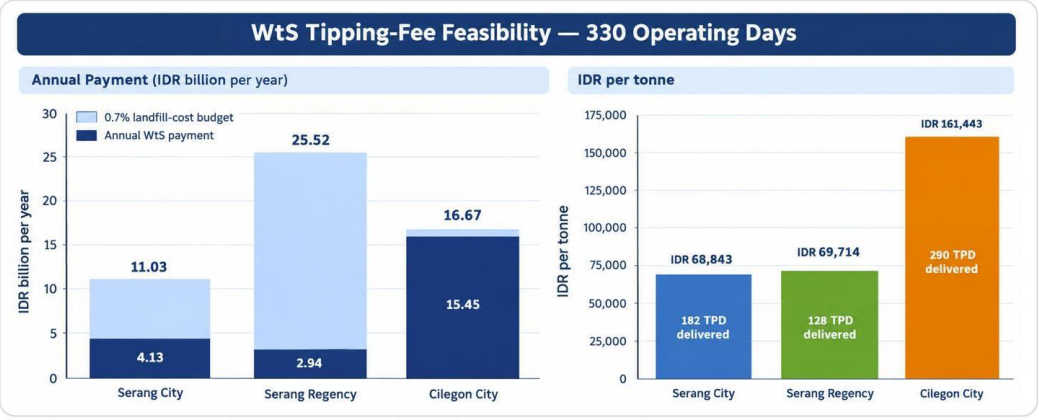


Figure 4.8 WtS Tipping Fee

Source: Author, 2026

Steam Sales

The proposed steam price of IDR 300,000 per tonne is a preliminary benchmark. It is reasonable because coal fuel alone may cost around IDR 200,000–258,000 to produce one tonne of steam, depending on coal quality. The proposed price also covers other costs, such as coal transport, boiler operation, maintenance, water treatment, and ash handling. The final steam price should be adjusted after confirming the steam specification and the buyer's actual coal and boiler costs.

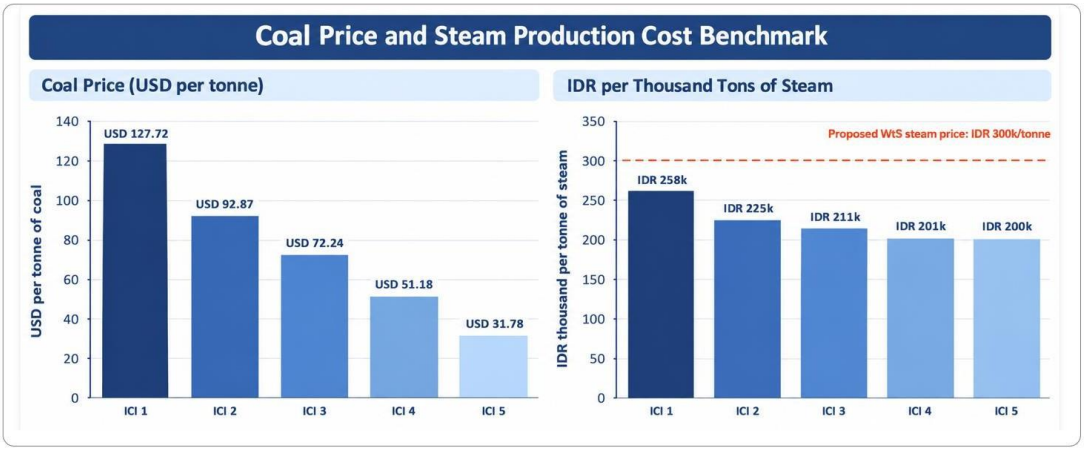


Figure 4.9 Coal Price and Steam Production Cost Benchmark

Source: Author, 2026

4.9.2 Financial Statement

The following pages contain estimate of forecast income statement, balance sheet and cash flow of the project, reflected on annual basis, taken from the financial model that supports the business development of Waste to Steam Project in Banten Province.

Profit and Loss (P&L)

The Profit and Loss (P&L) or Income Statement of the Project estimates the annual revenue, expenses and profits incurred during the entire Project period.

P&L (Income Statement - *IDR Million*)

Description	Unit	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
		Construction		Operation								
A. Project Revenue												
Tipping Fee	*Rp mn*	-	-	59,400	61,182	63,017	64,908	66,855	68,861	70,927	73,055	75,246
Steam Sales	*Rp mn*	-	-	106,017	109,198	112,473	115,848	119,323	122,903	126,590	130,388	134,299
Total Revenue	*Rp mn*	-	-	165,417	170,380	175,491	180,756	186,178	191,764	197,517	203,442	209,545
B. Operating Costs												
Variable Opex	*Rp mn*	-	-	(24,394)	(25,126)	(25,880)	(26,656)	(27,456)	(28,279)	(29,128)	(30,002)	(30,902)
Fixed Opex	*Rp mn*	-	-	(26,427)	(27,748)	(29,136)	(30,593)	(32,122)	(33,728)	(35,415)	(37,185)	(39,045)
EBITDA	*Rp mn*	-	-	114,596	117,505	120,476	123,507	126,600	129,756	132,974	136,255	139,599
Depreciation	*Rp mn*	-	-	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)
EBIT (Operating Profit)	*Rp mn*	-	-	68,388	71,298	74,268	77,300	80,393	83,549	86,767	90,048	93,392
C. Financing Costs & Tax												
Interest Expense (IDC + Debt Interest)	*Rp mn*	-	-	(64,691)	(64,691)	(64,691)	(58,221)	(51,752)	(45,283)	(38,814)	(32,345)	(25,876)
EBT (Profit Before Tax)	*Rp mn*	-	-	3,698	6,607	9,578	19,078	28,641	38,265	47,952	57,702	67,515
Corporate Income Tax	*Rp mn*	-	-	-	-	-	-	-	-	-	(12,695)	(14,853)
Net Profit	*Rp mn*	-	-	3,698	6,607	9,578	19,078	28,641	38,265	47,952	45,008	52,662

Description	Unit	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
A. Project Revenue												
Tipping Fee	*Rp mn*	77,504	79,829	82,223	84,690	87,231	89,848	92,543	95,320	98,179	101,125	104,158
Steam Sales	*Rp mn*	138,328	142,478	146,752	151,155	155,690	160,360	165,171	170,126	175,230	180,487	185,901
Total Revenue	*Rp mn*	215,832	222,307	228,976	235,845	242,920	250,208	257,714	265,446	273,409	281,611	290,060
B. Operating Costs												
Variable Opex	*Rp mn*	(31,829)	(32,783)	(33,767)	(34,780)	(35,823)	(36,898)	(38,005)	(39,145)	(40,320)	(41,529)	(42,775)
Fixed Opex	*Rp mn*	(40,997)	(43,047)	(45,199)	(47,459)	(49,832)	(52,324)	(54,940)	(57,687)	(60,571)	(63,600)	(66,780)
EBITDA	*Rp mn*	143,006	146,476	150,010	153,606	157,265	160,986	164,769	168,614	172,518	176,482	180,505
Depreciation	*Rp mn*	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)	(46,208)
EBIT (Operating Profit)	*Rp mn*	96,799	100,269	103,802	107,398	111,057	114,779	118,562	122,406	126,311	130,275	134,297
C. Financing Costs & Tax												
Interest Expense (IDC + Debt Interest)	*Rp mn*	(19,407)	(12,938)	(6,469)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
EBT (Profit Before Tax)	*Rp mn*	77,391	87,331	97,333	107,398	111,057	114,779	118,562	122,406	126,311	130,275	134,297
Corporate Income Tax	*Rp mn*	(17,026)	(19,213)	(21,413)	(23,628)	(24,433)	(25,251)	(26,084)	(26,929)	(27,788)	(28,660)	(29,545)
Net Profit	*Rp mn*	60,365	68,118	75,920	83,771	86,625	89,527	92,478	95,477	98,522	101,614	104,752

Figure 4.10 P&L Statement

Source: Author, 2026

Balance Sheet

The Balance Sheet statement of the Project estimates the assets, liabilities and equity during the entire project period.

Balance Sheet - IDR Million

Description	Unit	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
		Construtions		Operation								
Assets												
Cash	*Rp mn*	-	-	342,240	394,723	385,479	385,728	395,532	414,952	444,052	470,199	503,992
Accounts Receivable	*Rp mn*	-	-	15,038	15,489	15,954	16,432	16,925	17,433	17,956	18,495	19,050
Inventory	*Rp mn*	-	-	2,218	2,284	2,353	2,423	2,496	2,571	2,648	2,727	2,809
Net PP&E	*Rp mn*	462,075	924,150	877,943	831,735	785,528	739,320	693,113	646,905	600,698	554,490	508,283
Total Assets	*Rp mn*	462,075	924,150	1,237,438	1,244,232	1,189,313	1,143,904	1,108,066	1,081,861	1,065,354	1,045,911	1,034,134
Liabilities												
Accounts Payable	*Rp mn*	-	-	4,620	4,807	5,001	5,204	5,416	5,637	5,867	6,108	6,359
Tranche A -- Outstanding Balance	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Tranche B -- Outstanding Balance	*Rp mn*	323,453	646,905	646,905	646,905	582,215	517,524	452,834	388,143	323,453	258,762	194,072
Total Liabilities	*Rp mn*	323,453	646,905	651,525	651,712	587,216	522,728	458,250	393,780	329,320	264,870	200,430
Equity												
Paid-in Capital (cumulative Equity Injection)	*Rp mn*	138,623	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245
JCM Subsidy	*Rp mn*	-	-	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970
Retained Earnings (cumulative Net Profit les	*Rp mn*	-	-	3,698	10,305	19,883	38,961	67,602	105,867	153,819	198,827	251,489
Total Equity	*Rp mn*	138,623	277,245	585,913	592,520	602,097	621,176	649,816	688,081	736,034	781,041	833,703
Total Liabilities and Equity	*Rp mn*	462,075	924,150	1,237,438	1,244,232	1,189,313	1,143,904	1,108,066	1,081,861	1,065,354	1,045,911	1,034,134

Description	Unit	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Assets												
Cash	*Rp mn*	545,481	594,713	651,739	781,299	913,704	1,049,003	1,187,244	1,328,475	1,472,743	1,620,095	1,770,575
Accounts Receivable	*Rp mn*	19,621	20,210	20,816	21,440	22,084	22,746	23,429	24,131	24,855	25,601	26,369
Inventory	*Rp mn*	2,894	2,980	3,070	3,162	3,257	3,354	3,455	3,559	3,665	3,775	3,889
Net PP&E	*Rp mn*	462,075	415,868	369,660	323,453	277,245	231,038	184,830	138,623	92,415	46,208	-
Total Assets	*Rp mn*	1,030,070	1,033,771	1,045,285	1,129,353	1,216,289	1,306,141	1,398,957	1,494,788	1,593,679	1,695,679	1,800,833
Liabilities												
Accounts Payable	*Rp mn*	6,621	6,894	7,179	7,476	7,787	8,111	8,450	8,803	9,172	9,557	9,960
Tranche A -- Outstanding Balance	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Tranche B -- Outstanding Balance	*Rp mn*	129,381	64,691	0	0	0	0	0	0	0	0	0
Total Liabilities	*Rp mn*	136,002	71,584	7,179	7,476	7,787	8,111	8,450	8,803	9,172	9,557	9,960
Equity												
Paid-in Capital (cumulative Equity Injection)	*Rp mn*	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245	277,245
JCM Subsidy	*Rp mn*	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970	304,970
Retained Earnings (cumulative Net Profit les	*Rp mn*	311,854	379,972	455,892	539,663	626,288	715,815	808,293	903,770	1,002,293	1,103,907	1,208,659
Total Equity	*Rp mn*	894,069	962,187	1,038,106	1,121,877	1,208,502	1,298,029	1,390,508	1,485,985	1,584,507	1,686,122	1,790,874
Total Liabilities and Equity	*Rp mn*	1,030,070	1,033,771	1,045,285	1,129,353	1,216,289	1,306,141	1,398,957	1,494,788	1,593,679	1,695,679	1,800,833

Figure 4.11 Balance Sheet Statement

Source: Author, 2026

Cash Flow Statement

The Cash Flow Statement shows all cash flow in and out of the project. The net cash flow in the cash movement balance that is added to the opening cash balance to determine the closing cash balance.

Cashflow Statement - IDR Milllion

Description	Unit	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
		Construction		Operation								
A. Cash Flow from Operations												
Net Profit	*Rp mn*	-	-	3,698	6,607	9,578	19,078	28,641	38,265	47,952	45,008	52,662
Add back: Depreciation	*Rp mn*	-	-	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208
Add back: Interest Expense (shown as a financing outflow b	*Rp mn*	-	-	64,691	64,691	64,691	58,221	51,752	45,283	38,814	32,345	25,876
(Increase) / decrease in Accounts Receivable	*Rp mn*	-	-	(15,038)	(451)	(465)	(479)	(493)	(508)	(523)	(539)	(555)
(Increase) / decrease in Inventory	*Rp mn*	-	-	(2,218)	(67)	(69)	(71)	(73)	(75)	(77)	(79)	(82)
Increase / (decrease) in Accounts Payable	*Rp mn*	-	-	4,620	187	195	203	212	221	230	240	251
Total Cash Flow from Operations	*Rp mn*	**-**	**-**	**101,961**	**117,174**	**120,137**	**123,161**	**126,247**	**129,394**	**132,604**	**123,183**	**124,360**
B. Cash Flow from Investing												
CAPEX	*Rp mn*	(462,075)	(462,075)	-	-	-	-	-	-	-	-	-
Total Cash Flow from Investing	*Rp mn*	**(462,075)**	**(462,075)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
C. Cash Flow from Financing												
Equity Injection	*Rp mn*	138,623	138,623	-	-	-	-	-	-	-	-	-
Tranche A Drawdown	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Tranche B Drawdown	*Rp mn*	323,453	323,453	-	-	-	-	-	-	-	-	-
JCM Subsidy	*Rp mn*	-	-	304,970	-	-	-	-	-	-	-	-
Debt Repayment	*Rp mn*	-	-	-	-	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)
Interest Paid (IDC + operating interest)	*Rp mn*	-	-	(64,691)	(64,691)	(64,691)	(58,221)	(51,752)	(45,283)	(38,814)	(32,345)	(25,876)
Dividend Payments (0 by default -- add a distribution policy if	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Total Cash Flow from Financing	*Rp mn*	**462,075**	**462,075**	**240,279**	**(64,691)**	**(129,381)**	**(122,912)**	**(116,443)**	**(109,974)**	**(103,505)**	**(97,036)**	**(90,567)**
D. Net Change in Cash Flow	*Rp mn*	**-**	**-**	**342,240**	**52,484**	**(9,244)**	**249**	**9,804**	**19,420**	**29,100**	**26,147**	**33,793**
E. Beginning Cash Balance	*Rp mn*	-	-	-	342,240	394,723	385,479	385,728	395,532	414,952	444,052	470,199
F. Ending Cash Balance	*Rp mn*	**-**	**-**	**342,240**	**394,723**	**385,479**	**385,728**	**395,532**	**414,952**	**444,052**	**470,199**	**503,992**

Description	Unit	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
A. Cash Flow from Operations												
Net Profit	*Rp mn*	60,365	68,118	75,920	83,771	86,625	89,527	92,478	95,477	98,522	101,614	104,752
Add back: Depreciation	*Rp mn*	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208	46,208
Add back: Interest Expense (shown as a financing outflow b	*Rp mn*	19,407	12,938	6,469	0	0	0	0	0	0	0	0
(Increase) / decrease in Accounts Receivable	*Rp mn*	(571)	(589)	(606)	(624)	(643)	(663)	(682)	(703)	(724)	(746)	(768)
(Increase) / decrease in Inventory	*Rp mn*	(84)	(87)	(89)	(92)	(95)	(98)	(101)	(104)	(107)	(110)	(113)
Increase / (decrease) in Accounts Payable	*Rp mn*	262	273	285	298	311	324	338	353	369	385	402
Total Cash Flow from Operations	*Rp mn*	**125,586**	**126,861**	**128,186**	**129,559**	**132,405**	**135,299**	**138,241**	**141,231**	**144,268**	**147,352**	**150,481**
B. Cash Flow from Investing												
CAPEX	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Total Cash Flow from Investing	*Rp mn*	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
C. Cash Flow from Financing												
Equity Injection	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Tranche A Drawdown	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Tranche B Drawdown	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
JCM Subsidy	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Debt Repayment	*Rp mn*	(64,691)	(64,691)	(64,691)	-	-	-	-	-	-	-	-
Interest Paid (IDC + operating interest)	*Rp mn*	(19,407)	(12,938)	(6,469)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Dividend Payments (0 by default -- add a distribution policy if	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Total Cash Flow from Financing	*Rp mn*	**(84,098)**	**(77,629)**	**(71,160)**	**(0)**	**(0)**	**(0)**	**(0)**	**(0)**	**(0)**	**(0)**	**(0)**
D. Net Change in Cash Flow	*Rp mn*	**41,488**	**49,233**	**57,026**	**129,559**	**132,405**	**135,299**	**138,241**	**141,231**	**144,268**	**147,352**	**150,481**
E. Beginning Cash Balance	*Rp mn*	503,992	545,481	594,713	651,739	781,299	913,704	1,049,003	1,187,244	1,328,475	1,472,743	1,620,095
F. Ending Cash Balance	*Rp mn*	**545,481**	**594,713**	**651,739**	**781,299**	**913,704**	**1,049,003**	**1,187,244**	**1,328,475**	**1,472,743**	**1,620,095**	**1,770,575**

Figure 4.12 Cash Flow Statement

Source: Author, 2026

4.9.3 IRR, NPV, FCF Analysis

FCF Analysis — Free Cash Flow to Firm (FCFF) & Free Cash Flow to Equity (FCFE) - IDR Million

Description	Unit	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Building Blocks												
Project Free Cash Flow (= Total CFO before financing + Total CFI)	*Rp mn*	(462,075)	(462,075)	101,961	117,174	120,137	123,161	126,247	129,394	132,604	123,183	124,360
Interest Expense (IDC + Debt Interest)	*Rp mn*	-	-	64,691	64,691	64,691	58,221	51,752	45,283	38,814	32,345	25,876
Interest Paid (cash)	*Rp mn*	-	-	64,691	64,691	64,691	58,221	51,752	45,283	38,814	32,345	25,876
Net Borrowing (Drawdown - Repayment)	*Rp mn*	323,453	323,453	-	-	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)	(64,691)
Free Cash Flow to Firm (FCFF)												
Less: Interest Tax Shield (= Interest Expense x CIT rate)	*Rp mn*	-	-	14,232	14,232	14,232	12,809	11,386	9,962	8,539	7,116	5,693
FCFF (= Project FCF - Interest Tax Shield)	*Rp mn*	**(462,075)**	**(462,075)**	**87,729**	**102,942**	**105,905**	**110,352**	**114,861**	**119,432**	**124,065**	**116,067**	**118,667**
Free Cash Flow to Equity (FCFE)												
FCFE (= Project FCF + Net Borrowing - Interest Paid)	*Rp mn*	**(138,623)**	**(138,623)**	**37,270**	**52,484**	**(9,244)**	**249**	**9,804**	**19,420**	**29,100**	**26,147**	**33,793**
Equity Injection	*Rp mn*	138,623	138,623	-	-	-	-	-	-	-	-	-
Equity Cash Flow (= -Equity Injection + FCFE)	*Rp mn*	**(277,245)**	**(277,245)**	**37,270**	**52,484**	**(9,244)**	**249**	**9,804**	**19,420**	**29,100**	**26,147**	**33,793**

Description	Unit	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Building Blocks												
Project Free Cash Flow (= Total CFO before financing + Total CFI)	*Rp mn*	125,586	126,861	128,186	129,559	132,405	135,299	138,241	141,231	144,268	147,352	150,481
Interest Expense (IDC + Debt Interest)	*Rp mn*	19,407	12,938	6,469	0	0	0	0	0	0	0	0
Interest Paid (cash)	*Rp mn*	19,407	12,938	6,469	0	0	0	0	0	0	0	0
Net Borrowing (Drawdown - Repayment)	*Rp mn*	(64,691)	(64,691)	(64,691)	-	-	-	-	-	-	-	-
Free Cash Flow to Firm (FCFF)												
Less: Interest Tax Shield (= Interest Expense x CIT rate)	*Rp mn*	4,270	2,846	1,423	0	0	0	0	0	0	0	0
FCFF (= Project FCF - Interest Tax Shield)	*Rp mn*	**121,316**	**124,015**	**126,763**	**129,559**	**132,405**	**135,299**	**138,241**	**141,231**	**144,268**	**147,352**	**150,481**
Free Cash Flow to Equity (FCFE)												
FCFE (= Project FCF + Net Borrowing - Interest Paid)	*Rp mn*	**41,488**	**49,233**	**57,026**	**129,559**	**132,405**	**135,299**	**138,241**	**141,231**	**144,268**	**147,352**	**150,481**
Equity Injection	*Rp mn*	-	-	-	-	-	-	-	-	-	-	-
Equity Cash Flow (= -Equity Injection + FCFE)	*Rp mn*	**41,488**	**49,233**	**57,026**	**129,559**	**132,405**	**135,299**	**138,241**	**141,231**	**144,268**	**147,352**	**150,481**

Figure 4.13 FCF Analysis

Source: Author, 2026

Project IRR (FCFF method, unlevered)	10.30%
Project NPV (FCFF discounted at WACC)	53,003
Equity IRR (FCFE method)	7.10%
Equity NPV (FCFE Discounted at Ke)	-230,683

Figure 4.14 Summary of Financial Statement

Source: Author, 2026

The project appears economically viable at the project level, but it is not yet attractive for equity investors under the current financing structure. The positive Project NPV and 10.30% Project IRR show that the asset can generate value; however, the negative Equity NPV and 7.10% Equity IRR indicate that returns to shareholders are insufficient after debt costs and equity injections.

4.10 Sensitivity Analysis

Table 4.17 Financial Sensitivity Analysis

Metric	Pessimistic	Moderate (Base)	Optimistic
WACC	9.49%	9.49%	9.49%
Cost of Equity (Ke)	13.42%	13.42%	13.42%

Project IRR (FCFF)	3.15%	10.29%	19.74%
Project NPV at WACC (IDR mn)	(362,921)	53,003	771,668
Equity IRR (FCFE)	-2.39%	7.12%	20.71%
Equity NPV at Ke (IDR mn)	(528,233)	(230,683)	283,459
Average DSCR	0.76x	1.37x	2.42x
Minimum DSCR (operating years)	0.50x	0.93x	1.67x

Source: Author, 2026

Project profitability is highly sensitive to operating performance, as demonstrated by the substantial variation in financial returns across the three scenarios. Project IRR decreases from 10.29% in the Base scenario to 3.15% under pessimistic conditions, representing a decline of 7.14 percentage points. Similarly, Project NPV decreases from a positive IDR 53.0 billion to a negative IDR 362.9 billion. Conversely, under the Optimistic scenario, Project IRR increases to 19.74%, while Project NPV reaches IDR 771.7 billion. These findings indicate that the project's economic viability depends significantly on its ability to secure sufficient waste throughput, maintain plant operating availability, and generate adequate steam output.

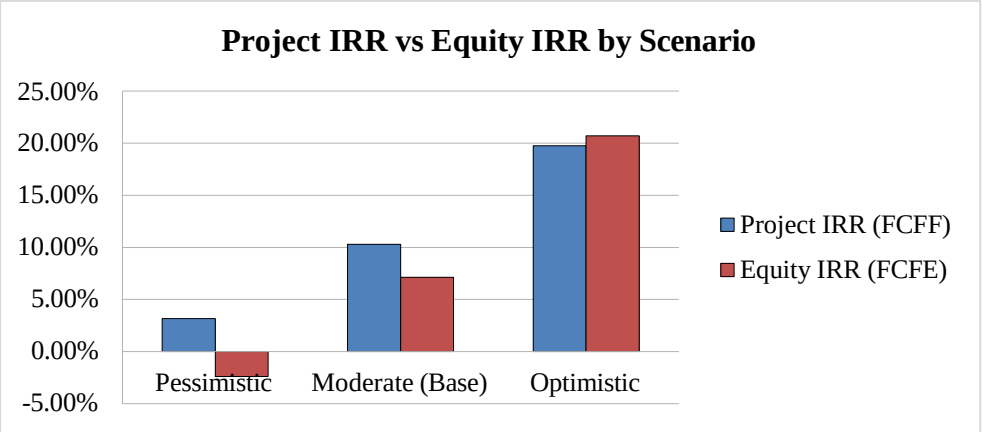


Figure 4.15 Scenario Comparison of Project IRR vs Equity IRR

Source: Author, 2026

Equity returns demonstrate greater vulnerability to adverse operating conditions. Equity IRR declines from 7.12% in the Base scenario to -2.39% in the Pessimistic scenario, while Equity NPV remains negative in both scenarios, amounting to IDR -230.7 billion and IDR -528.2 billion, respectively. Under the Optimistic scenario, however, Equity IRR increases to 20.71% and Equity NPV becomes positive at IDR 283.5 billion. These results suggest that, under the current financing and capital-cost assumptions, the project does not generate sufficient returns for equity investors in the Base scenario, as the Equity IRR of 7.12% falls below the cost of equity of 13.42%. Consequently, improvements in operational performance and revenue generation are essential to enhance the project's attractiveness to equity investors.

Debt-servicing capacity also represents a significant financial risk, particularly under pessimistic operating conditions. Average DSCR decreases from 1.37x in the Base scenario to 0.76x in the Pessimistic scenario, while minimum DSCR declines from 0.93x to 0.50x. A DSCR below 1.00x indicates that cash flow available for debt service is insufficient to cover scheduled debt obligations during the relevant period. Although the Base scenario achieves an average DSCR above 1.00x, its minimum DSCR of 0.93x indicates a potential debt-servicing shortfall in at least one operating year. In contrast, the Optimistic scenario records an average DSCR of 2.42x and a minimum DSCR of 1.67x, reflecting substantially stronger debt-servicing capacity. Overall, these findings highlight the importance of maintaining reliable plant operations and sufficient revenue generation to ensure financial sustainability and mitigate debt-servicing risks.

Table 4.18 Financial Sensitivity Relative to the Base Scenario

Indicator	Pessimistic change vs. Base	Optimistic change vs. Base
Project IRR	-7.14 percentage points	+9.45 percentage points
Project NPV	-IDR 415,924 mn	+IDR 718,665 mn
Equity IRR	-9.51 percentage points	+13.59 percentage points
Equity NPV	-IDR 297,550 mn	+IDR 514,142 mn
Average DSCR	-0.61x	+1.05x
Minimum DSCR	-0.43x	+0.74x

Source: Author, 2026

The results demonstrate a substantial downside exposure. Relative to the Base case, the Pessimistic scenario reduces Project NPV by IDR 415.9 billion, while the Optimistic scenario increases it by IDR 718.7 billion. These differences highlight the importance of validating the engineering assumptions before making an investment decision.

Table 4.19 Engineering Sensitivity Analysis

Metric	Pessimistic	Moderate (Base)	Optimistic
Waste delivered to plant (TPD)	540	600	837
Operating hours per year	7,200	7,920	8,000
Waste LHV (GJ per tonne)	4.60	5.86	6.50
Boiler efficiency	76.0%	80.0%	83.0%
Plant processing capacity (TPD)	600	600	837
Tipping-fee volume (t/yr)	162,000	198,000	279,000
Steam sales volume (t/yr)	215,619	353,390	573,056

Source: Author, 2026

Waste throughput is a critical driver of the project's financial performance, as it determines the volume of waste available for processing and the amount of tipping-fee revenue

that can be generated. In the Pessimistic scenario, delivered waste decreases by 10% from the Base scenario, declining from 600 TPD to 540 TPD. Conversely, the Optimistic scenario assumes an increase of approximately 39.5%, reaching 837 TPD. Lower waste throughput may constrain plant utilization and reduce revenue generation, whereas higher throughput can improve operational performance, provided that sufficient feedstock supply and processing capacity are available.

Plant operating hours also influence annual waste processing and steam production. The Pessimistic scenario assumes 7,200 operating hours per year, representing a 9.1% decrease from the Base scenario of 7,920 hours. This reduction may reflect increased downtime, maintenance requirements, or lower plant availability, limiting the total volume of waste processed and steam produced annually. In contrast, the Optimistic scenario assumes 8,000 operating hours per year, allowing for greater operational utilization and potentially higher revenue generation.

The lower heating value (LHV) of waste is another important determinant of energy recovery. Under the Pessimistic scenario, the LHV decreases to 4.60 GJ per tonne, compared with 5.86 GJ per tonne in the Base scenario. This indicates that each tonne of waste contains less recoverable energy, potentially reducing the amount of steam generated even when feedstock availability remains adequate. Conversely, the Optimistic scenario assumes an LHV of 6.50 GJ per tonne, providing greater energy potential for steam generation and improving the prospects for revenue from steam sales.

Boiler efficiency further influences the conversion of waste energy into usable steam. The Pessimistic scenario assumes a boiler efficiency of 76%, compared with 80% in the Base scenario, indicating a lower proportion of thermal energy being converted into useful output. Under the Optimistic scenario, boiler efficiency increases to 83%, supporting more effective energy recovery. Therefore, maintaining adequate boiler performance is essential to maximizing steam production and improving the overall efficiency of the Waste-to-Steam facility.

These engineering factors collectively influence steam sales volume, which represents a key revenue driver for the project. Steam sales volume decreases from 353,390 tonnes per year in the Base scenario to 215,619 tonnes per year in the Pessimistic scenario, a decline of approximately 39.0%. Conversely, the Optimistic scenario projects steam sales of 573,056 tonnes per year, an increase of approximately 62.2% relative to Base. This substantial variation highlights the sensitivity of project revenue to feedstock characteristics, plant availability, and

energy conversion efficiency. Consequently, reliable waste supply, effective plant operations, and efficient steam generation are essential to improving the project's financial viability.

4.11 PPP Business Model Analysis

The proposed Waste-to-Steam (WtS) project should use a Build–Operate–Transfer (BOT) Public–Private Partnership (PPP) model. Under this model, a private project company builds and operates the WtS plant. At the end of the contract period, the plant is transferred to the local government. This model is suitable because the WtS project needs high investment at the beginning. The private sector can provide funding, technology, construction, and operational skills. The local government can pay for waste-treatment services through tipping fees over the contract period instead of paying the full construction cost at the start. This study compared BTOM, BOT, and BOO schemes and selected BOT because it allows the government to receive the plant at the end of the contract, avoids high upfront government spending, and keeps construction and operating responsibility with the private sector.

4.11.1 PPP Scheme Options

Table 4.20 PPP Scheme

PPP Form	Description	Application to WtS Project
BTOM *Build, Transfer, Operate, Maintain*	The private party designs and builds the facility, transfers it to the government after construction, and continues to operate and maintain it	The WtS plant and steam infrastructure would become government-owned at completion, while the SPC would operate the facility under an operating agreement
BOT *Build, Operate, Transfer*	The private party finances, designs, builds, operates, and maintains the facility during the PPP period; ownership is transferred to the government at the end	The SPC would develop and operate the WtS plant and steam pipeline during the concession, then transfer the agreed assets to the GCA at expiry

BOO *Build, Own, Operate*	The private party finances, builds, owns, and operates the facility during and after the contract period	The SPC would retain ownership of the WtS plant and may continue operating or selling the steam after the PPP agreement ends

Source: Author, 2026

4.11.2 Assessment of PPP Forms

Table 4.21 PPP Scheme Assessment

Factor	BTOM	BOT	BOO
Legal and asset-management suitability	Possible, but the WtS assets would need to be registered as government assets immediately after construction. This may create administrative complexity while the private party remains responsible for operation and maintenance	Suitable because the SPC retains ownership and operational control during the concession, while the GCA receives the assets at the end	Possible in principle, but less suitable where the government provides land, waste-supply support, and possible viability support
Government upfront capital requirement	The GCA may need to make annuity or leaseback payments after asset transfer, creating financial and administrative complexity	No major upfront government CAPEX. The SPC funds construction and recovers investment through tipping fees and steam sales over the concession term	No major upfront government CAPEX, but the GCA does not receive the facility at the end

Compatibility with VGF or government support	May be possible, but early transfer of assets complicates the structure	Strongest option because the assets transfer to the GCA at the end, which is consistent with the asset-transfer principle used for VGF-supported PPP projects	Less suitable if VGF is required because VGF-supported PPP projects generally require transfer of project assets to the government
Asset life and residual value	The GCA owns the asset early but must manage ownership issues while the SPC operates it	Strongest option. WtS assets may continue operating after the concession, so the GCA receives their residual value and can continue operations, appoint a new operator, or extend the agreement	Weakest option for the GCA because the SPC retains the asset's residual value and may continue charging users after the PPP term
Construction and operating risk	The SPC can manage construction and O&M risk, but early government ownership may weaken the clarity of lifecycle responsibility	The SPC remains responsible for design, financing, construction, operation, maintenance, emissions compliance, and asset condition until handback.	The SPC manages risk, but the GCA has less control over asset handback and long-term waste-treatment continuity
Steam-business flexibility	Steam sales can be managed by the SPC, but the government would own the physical	Suitable. The SPC can manage industrial steam sales during the	Suitable for steam sales, but creates long-term public-

	assets before steam contracts end	concession, while the GCA procures waste-treatment services	service and asset-control concerns
Bankability	More complex for lenders because ownership transfers early, while private parties still need to finance and operate the assets	Most bankable if supported by long-term waste supply, tipping-fee payment security, Steam Purchase Agreements, and step-in rights for lenders	Can be bankable commercially, but may be less attractive to government and may not qualify for government support
Overall assessment	Less preferred	**Recommended**	Less preferred

Source: Author, 2026

4.11.3 Project Structure

The figure shows the main parties in the WtS project and their relationships.

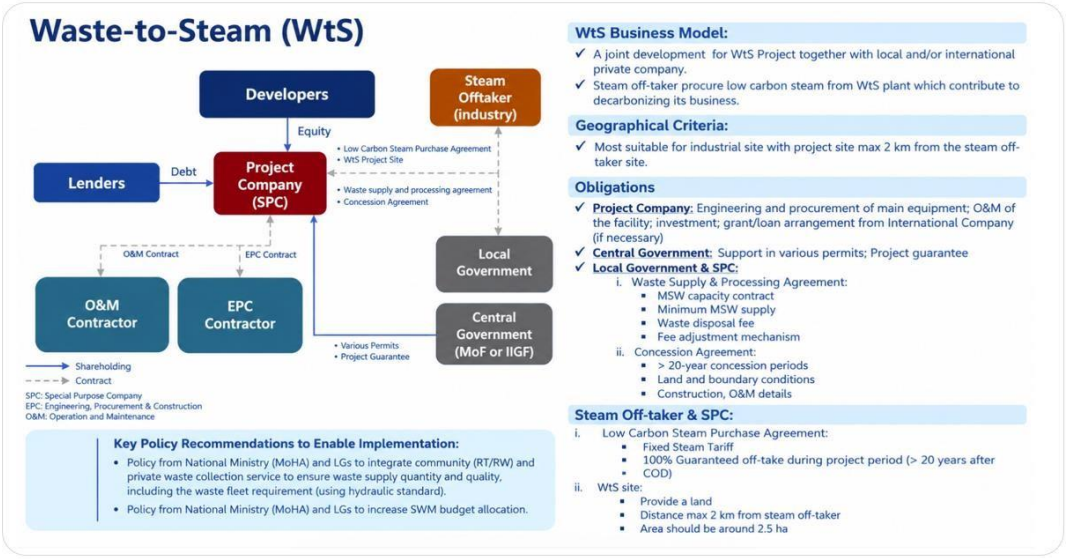


Figure 4.16 Project Structure

Source: Author, 2026

A Special Purpose Company (SPC) is established by developers, who provide equity, while lenders provide debt financing. The SPC manages the project and appoints an EPC

contractor to build the plant and an O&M contractor to operate and maintain it. The local government provides land, supplies waste, and pays the tipping fee through a Waste Supply and Processing Agreement and a Concession Agreement.

Industrial customers buy steam from the SPC through a long-term Steam Purchase Agreement. This agreement should include the steam tariff, steam quality, minimum purchase volume, and take-or-pay requirement. The central government may support the project through permits, guarantees, VGF, grants, or concessional loans. The WtS plant should be located close to the industrial steam buyer to reduce pipeline costs and heat loss. The project earns income from two sources: tipping fees from local governments and steam sales to industrial customers. To make the project bankable, long-term waste-supply, tipping fee, and steam-offtake agreements are required. The figure shows the main parties in the WtS project and their relationships.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study assessed the feasibility of developing a Waste-to-Steam (WtS) project in Banten Province by examining existing waste management conditions, technical and economic feasibility, potential environmental benefits, project structuring alternatives, and financial sensitivity under different operating scenarios. Based on the findings, several conclusions can be drawn regarding the project's potential, key constraints, and requirements for further development.

First, the existing waste management conditions in Indonesia and Banten Province indicate a continuing need to improve municipal solid waste treatment and resource recovery. The waste management system remains substantially dependent on landfill-based disposal, while increasing waste generation creates opportunities to recover energy from municipal solid waste. From a regulatory perspective, Presidential Regulation No. 109 of 2025 provides a policy basis for waste-to-energy development, particularly electricity generation. However, the regulation does not fully establish the arrangements required for direct steam transactions with industrial offtakers. Therefore, the development of a WtS project requires further clarification of the regulatory and contractual frameworks governing waste supply, tipping fee payments, steam offtake, and potential government support.

Second, the proposed WtS project is technically feasible at the business development and preliminary feasibility stages, considering the availability of municipal waste sources, estimated waste processing capacity, waste characteristics, and the potential demand for industrial steam. The proximity of industrial facilities requiring steam also provides a potential basis for direct energy utilization. Nevertheless, detailed engineering studies are required to confirm the plant configuration, equipment specifications, waste treatment capacity, steam pressure and quality, piping infrastructure, and site suitability. In particular, the reliability of the waste supply and the consistency of its lower heating value (LHV) must be validated because these factors directly influence energy recovery and steam production.

Third, the financial analysis indicates that the project demonstrates potential economic viability at the project level under the Base scenario, although its attractiveness to equity investors remains limited. The project records a Project IRR of 10.29%, slightly above the weighted average cost of capital (WACC) of 9.49%, and a positive Project NPV of approximately IDR 53.0 billion. However, the Equity IRR of 7.12% remains below the cost of equity of 13.42%, while Equity NPV is negative at approximately IDR 230.7 billion. These

results indicate that the project generates a positive net present value when assessed using the project-level discount rate but does not yet provide sufficient returns to meet equity investors' required rate of return under the current financing assumptions.

The sensitivity analysis further demonstrates that the project's financial performance is highly dependent on engineering and operating assumptions. Under the Pessimistic scenario, Project IRR decreases to 3.15% and Project NPV becomes negative at approximately IDR 362.9 billion. Equity IRR falls to -2.39%, while Equity NPV declines to approximately negative IDR 528.2 billion. Furthermore, the average Debt Service Coverage Ratio (DSCR) decreases to 0.76x, with a minimum DSCR of 0.50x, indicating substantial risks to debt-servicing capacity. These results highlight the project's vulnerability to unfavorable operating conditions and insufficient revenue generation.

Conversely, the Optimistic scenario produces a Project IRR of 19.74% and a positive Project NPV of approximately IDR 771.7 billion. Equity IRR increases to 20.71%, and Equity NPV reaches approximately IDR 283.5 billion. Average and minimum DSCR improve to 2.42x and 1.67x, respectively, indicating stronger investment returns and debt-servicing capacity. These improvements are associated with higher waste throughput, longer annual operating hours, higher waste LHV, improved boiler efficiency, and increased steam sales volume. In particular, annual steam sales increase from 353,390 tonnes in the Base scenario to 573,056 tonnes in the Optimistic scenario, while decreasing to 215,619 tonnes under pessimistic conditions.

The sensitivity results therefore emphasize that securing reliable long-term waste supply, maintaining plant availability, achieving efficient energy recovery, and obtaining firm industrial steam offtake commitments are essential to the project's financial sustainability. However, the Optimistic scenario assumes an increase in processing capacity from 600 to 837 tonnes per day while the financial model holds CAPEX and other non-revenue assumptions at Base levels. Accordingly, the projected upside should be treated as conditional until additional capital expenditure, operating costs, and financing requirements associated with the higher capacity are validated. Further sensitivity testing is also required to isolate the individual effects of waste availability, LHV, boiler efficiency, steam price, tipping fees, CAPEX, OPEX, interest rates, debt tenor, and government support on project returns.

Fourth, the Low-Carbon Carbon Network (LCCN) component is not yet suitable for immediate implementation within the proposed project. Although the LCCN concept may provide a future pathway for integrating municipal waste-derived energy into low-carbon industrial applications, the supporting hydrogen ecosystem and related infrastructure in

Indonesia remain at a preparatory stage. Therefore, integrating the WtS project with the LCCN concept should be considered a potential future development rather than a prerequisite for the initial project implementation. Any future integration should be supported by a separate assessment of technical readiness, infrastructure requirements, commercial viability, and potential environmental benefits.

Fifth, the proposed WtS project has the potential to deliver environmental benefits compared with conventional landfill-based waste management and fossil-fuel-based industrial steam production. By diverting suitable waste from landfills and utilizing its energy content to produce steam, the project could reduce landfill disposal requirements and potentially displace conventional fossil fuels. Nevertheless, the actual environmental benefits depend on the composition and characteristics of the waste processed, plant efficiency, auxiliary energy consumption, emissions control performance, and the type of conventional fuel displaced. A comprehensive environmental assessment, including greenhouse gas emissions analysis and comparison with the existing waste management baseline, is therefore required to establish the project's net environmental benefits.

Sixth, the recommended project structure involves the local government as the municipal waste supplier, a private project company as the project developer, and industrial facilities as steam offtakers. This arrangement could establish a coordinated framework for waste collection, treatment, energy recovery, and industrial steam utilization. However, its effectiveness depends on clearly defined contractual arrangements covering long-term waste supply, minimum waste quantities, waste quality, tipping fee mechanisms, steam pricing, steam quality, offtake commitments, and the allocation of operational and financial risks. Potential government support and appropriate financing mechanisms should also be explored to improve project bankability and reduce investment risks.

Overall, this study concludes that the Banten WtS project has promising technical potential and could contribute to improved municipal waste management and industrial energy utilization. Nevertheless, the project is not yet ready for investment or construction because its financial attractiveness, waste supply reliability, steam offtake commitments, and regulatory arrangements require further validation. The sensitivity analysis reinforces this conclusion by demonstrating that relatively substantial changes in operating assumptions can shift the project from positive project-level returns to significant financial losses and inadequate debt-servicing capacity.

Accordingly, a comprehensive feasibility study should be conducted before proceeding with investment and construction. The study should validate the technical design, waste

availability and quality, plant capacity, steam demand and pricing, environmental performance, CAPEX and OPEX, financing structure, contractual arrangements, regulatory requirements, and potential government support. It should also reassess the financial model under alternative operating and financing assumptions, particularly where improved performance requires additional capital investment. By addressing these requirements, the project can establish a more reliable basis for assessing its long-term economic viability, investment attractiveness, environmental contribution, and overall bankability.

5.2 Recommendations

The main recommendation is to conduct a comprehensive feasibility study, including detailed engineering.

The feasibility study should cover:

1. Quantity, quality and long-term availability of feedstock.
2. Estimated steam demand, market price, and off take possibility.
3. Waste to Steam capacity, project site and environmental parameter.
4. Estimated CAPEX, OPEX, financing structure, tipping fee, and steam-sales revenue.
5. Financial feasibility, investment feasibility and government affordability.
6. Required permits, land availability, waste supply and project structure

The plant design, equipment, steam pipeline, construction period, and more accurate project cost should be confirmed based on detailed engineering calculation.

The project should be developed under a PPP scheme with clear government commitments to improve project credibility and bankability.

The PPP scheme should cover:

1. **Waste supply guarantee**

   The local government should guarantee a minimum quantity and agreed quality of municipal solid waste throughout the project period.

2. **Tipping-fee and steam-payment guarantee**

   The project should have a reliable mechanism for payment of the tipping fee and steam-sales revenue. This is important to give confidence to lenders that the project will have stable and predictable cash flow.

3. **Regulation of tipping-fee amount and steam-sales price**

The government should provide a clear regulatory framework for determining, reviewing, and adjusting the tipping-fee amount and steam-sales price. The mechanism should consider inflation, operating costs, financing costs, and changes in market conditions.

4. **Government support, where available**

   The project should assess the availability of government guarantees, grants, viability gap funding (VGF), concessional financing, or other support mechanisms to improve financial feasibility.

A legal study of Perpres No. 109/2025 should be conducted. The results should be discussed and negotiated with local and central government to confirm the project structure, government support, and applicable regulations. The project should focus first on Waste-to-Steam. Hydrogen and LCCN can be considered later, after Indonesia's hydrogen infrastructure and market become more ready.

5.3 Contribution of the Study

This study provides an initial framework for a Waste-to-Steam project in Indonesia.

5.3.1 Theoretical Implications

The study shows that municipal waste may potentially be used to produce steam for industrial users. It also shows that a project can have a positive Project NPV but still provide low returns for investors. Therefore, financing structure is important.

5.3.2 Practical Implications

For local government, the study provides an initial option to reduce landfill waste.

For industry, the study provides an option for lower-carbon steam. For investors and developers, the study identifies the need to confirm costs, revenue, financing, regulations, and contracts before starting the project.

5.3.3 Directions for Future Research

Future research should conduct a detailed feasibility study using real data.

The next study should focus on waste sampling, steam-demand study, detailed engineering, financial sensitivity analysis, PPP structure, and regulatory analysis of Perpres No. 109/2025. Future research may also review hydrogen and LCCN opportunities when Indonesia's hydrogen infrastructure is more developed.

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