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Feasibility Study for the Construction of a 2 Million TPYAlumina Refinery Plant in Mempawah Industrial Area, West Kalimantan

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ABSTRACT

Indonesia holds among the world's largest bauxite reserves, yet for decades most of this resource was exported as low value-added raw ore, generating limited economic benefit for the country. The government's mineral downstreaming policy, culminating in a nationwide ban on raw bauxite exports since June 2023, has created an urgent need for domestic alumina refining capacity, while the very large capital requirements and volatile raw-material prices involved make such investment decisions highly uncertain. This study assesses the investment feasibility of constructing an alumina refinery plant with a production capacity of 2 million tons per year in the Mempawah Industrial Area, West Kalimantan, Indonesia, driven by this policy context and by growing global demand for aluminum-based products. A quantitative approach was used, comprising demand forecasting with the Moving Average method (m = 3), estimation of capital expenditure (CAPEX) and operating expenditure (OPEX), and evaluation of financial feasibility through Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP), followed by a scenario-based sensitivity analysis on bauxite and caustic soda (NaOH) prices. The demand forecast indicates a stable long-term national alumina consumption of approximately 5.17 million tons per year, supporting the plant's 2-million-ton-per-year capacity. Results show a required investment of approximately IDR 22.44 trillion, dominated by production machinery and equipment (44%). The financial evaluation yields a positive NPV of approximately IDR 3.49 trillion, an IRR of 12.93% (above the 10% Minimum Attractive Rate of Return), and a payback period of 7 years and 306 days, indicating that the project is financially feasible. Sensitivity analysis reveals that bauxite price is the most influential variable, followed by caustic soda price; the project remains feasible as long as IRR stays above the MARR and NPV remains positive. Compared with earlier alumina/SGA plant studies, which addressed either technical process design or financial feasibility in isolation, this study integrates both dimensions with a raw-material price-sensitivity analysis, offering a more complete decision-making basis for large-scale alumina refinery investment in Indonesia.

INTRODUCTION

Indonesia possesses substantial mineral resources, and bauxite the primary raw material for alumina production used in the aluminum industry is among its most

strategic commodities. According to the Ministry of Energy and Mineral Resources (ESDM), Indonesia's bauxite resources are recorded at 7.79 billion tons with reserves of 2.86 billion tons, concentrated mainly in West Kalimantan, Riau Islands, and Central Kalimantan. The United States Geological Survey (USGS) also ranks Indonesia among the world's top four countries in terms of bauxite reserves. Spatial studies mapping the distribution of Al2O3 and reactive silica (RSiO2) content in bauxite laterite deposits further support the characterization of ore quality across these reserves [1].

For years, however, Indonesia's bauxite has largely been exported as low value-added raw ore. Processing bauxite into Smelter Grade Alumina (SGA) raises its value from around USD 50/ton to USD 300-500/ton, and further processing into aluminum can raise the value to about USD 2,900/ton [2], [3]. To capture this added value, the Indonesian government enacted a mineral downstreaming policy under Law No. 3 of 2020 on Mineral and Coal Mining, which requires domestic processing and refining of minerals prior to export. A ban on raw bauxite ore exports has been in force since 10 June 2023, directly increasing the urgency of building domestic alumina refineries, a policy shift whose environmental and economic implications have also been examined in recent studies [4].

Following this policy, several smelter and alumina refinery projects have begun operating or are under development, and Indonesia's alumina export performance improved significantly in 2025 in both volume and value (TradeMap data). Nevertheless, Indonesia still imports alumina to meet domestic industrial needs, indicating that domestic production capacity has not yet fully met national demand, while domestic alumina consumption declined in 2025 due to slower growth among downstream aluminum users and a shift in production orientation toward export markets. At the same time, global demand for aluminum-based products particularly for electric vehicles, renewable energy, infrastructure, and manufacturing continues to expand, keeping the export market opportunity open.

Against this background, the construction of an alumina refinery plant becomes a strategic alternative to support Indonesia's mineral downstreaming program, increase the added value of bauxite, reduce dependence on raw material exports, and strengthen the domestic aluminum industry. However, such a project requires very large capital investment and carries considerable risk, covering process facilities, utilities, supporting infrastructure, technology procurement, and operating costs. Prior to project realization, an investment feasibility analysis is therefore required, commonly evaluated through Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) indicators [3], [5].

Beyond financial indicators, production cost is a critical factor in alumina refinery investment. In the Bayer Process used for alumina production, bauxite ore and caustic soda (NaOH) are the main cost drivers, and both commodities are subject to global market price fluctuations that can significantly affect operating costs, profitability, and overall investment feasibility. A sensitivity analysis is therefore necessary to determine the extent to which changes in bauxite and caustic soda prices affect investment feasibility indicators, and to support risk-mitigation strategies in the plant's development.

A review of prior studies indicates a clear research gap that this study aims to fill. Technical engineering studies on alumina/SGA plant design using the Bayer Process, such as those for capacities of 440,000 and 1,000,000 tons per year [12], [13], focus primarily on process design and equipment sizing without a full financial feasibility assessment. Conversely, financial feasibility studies on other Indonesian

mineral- and energy-downstreaming projects such as Smelter Grade Alumina at PT. X [3], an electric-motorcycle battery plant [5], and a copper cathode factory [17] apply NPV, IRR, and PP analysis but do not incorporate a systematic sensitivity analysis of raw material price fluctuations specific to the Bayer Process. No prior study has combined a technical Bayer Process basis, full financial feasibility analysis, and a raw-material price-scenario sensitivity analysis for a large-scale (2-million-ton-per-year) alumina refinery in the Mempawah Industrial Area. This study addresses that gap and, in doing so, contributes to the field of industrial engineering and investment planning by offering an integrated technical-financial-sensitivity evaluation framework that can serve as a practical reference for investors, policymakers, and future researchers assessing similar mineral-downstreaming investments.

The plant in this study is planned for the Mempawah Industrial Area, West Kalimantan, a location chosen for its proximity to bauxite reserves, port access, industrial infrastructure support, and its role within the government-driven mineral downstreaming corridor. Despite the progress of the downstreaming policy, uncertainty remains regarding the investment feasibility of alumina refinery construction, particularly amid fluctuating raw material prices and dynamic domestic and global alumina market conditions. This study therefore analyzes the investment feasibility of constructing a 2-million-ton-per-year alumina refinery plant in the Mempawah Industrial Area, West Kalimantan, covering demand potential, raw material requirements, CAPEX and OPEX estimation, financial feasibility (NPV, IRR, PP), and sensitivity to bauxite and caustic soda price changes.

MATERIALS AND METHODS

This research applies a quantitative approach, characterized by a systematic and structured research design from data collection through analysis and reporting [6]. The quantitative approach was selected because the study involves numerical data processing, financial calculations, and model-based analysis, comprising investment feasibility analysis (NPV, IRR, Payback Period), cost analysis (Capital Expenditure and Operating Expenditure), and sensitivity analysis of raw material price changes. Investment feasibility indicators (NPV, IRR, and Payback Period) were computed following standard engineering-economics formulations [7], [8]. In addition, a scenario-based sensitivity analysis was carried out by recalculating these feasibility indicators under a series of bauxite and caustic soda price scenarios to observe their impact on investment feasibility.

The study was conducted as a case study on the planned construction of an alumina refinery plant in the Mempawah Industrial Area, West Kalimantan. The location was selected based on its proximity to bauxite raw material sources, availability of industrial land, access to logistics infrastructure (port and transportation), and its support for the development of mineral downstreaming industry. The research was carried out from January 2026 to June 2026, covering data collection, data processing, analysis, and report preparation.

The independent variables in this study consist of bauxite price (USD/ton), caustic soda (NaOH) price (USD/ton), initial investment cost (CAPEX), operating cost (OPEX), production capacity (ton/year), and alumina selling price (USD/ton). The dependent variables are Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP), consistent with the variable structure used in comparable alumina plant engineering studies [9].

Secondary data were used in this study, comprising technical data (alumina production process/Bayer Process, raw and supporting material requirements, plant production capacity), economic and financial data (bauxite price, caustic soda price, alumina selling price, CAPEX and OPEX data), and supporting data (alumina export-import data from TradeMap, national alumina production data, and mineral downstreaming policy documents).

The overall research procedure is summarized in the flowchart in Figure 1.

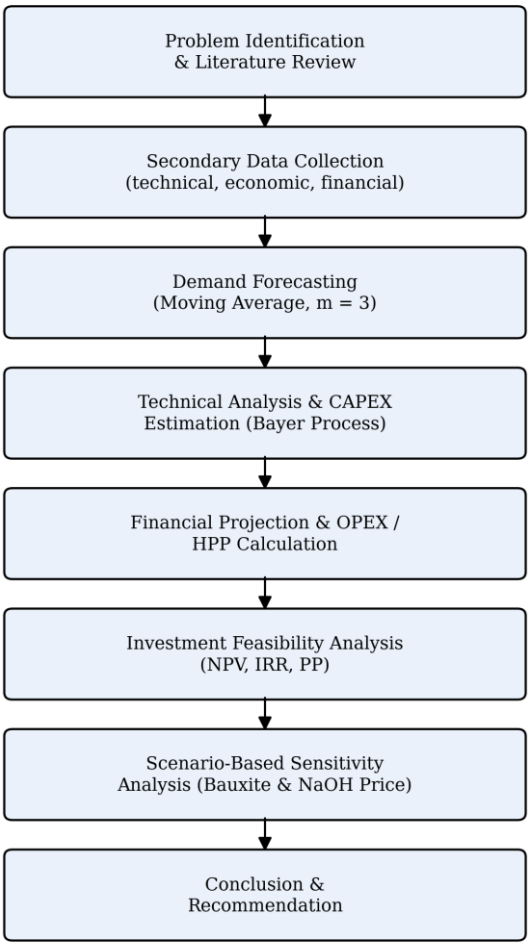


Figure 1. Research Methodology Flowchart

As illustrated in Figure 1, the research procedure began with problem identification and formulation, followed by a literature review of relevant journals, books, and prior studies to strengthen the theoretical basis and determine the appropriate methods. Data collection was followed by demand assessment using the Moving Average method to project future alumina demand and determine optimal production capacity. Technical analysis covering location planning, technology selection, process design, and plant layout was then used as the basis for estimating initial investment requirements (CAPEX), followed by the preparation of financial projections (income statement, cash flow, and balance sheet), operating cost (OPEX) calculation, and cost of goods manufactured (HPP), consistent with the financial-projection structure used in comparable feasibility studies [10], [11]. A loan repayment scheme was also formulated for the financing structure. The plant's process design and equipment sizing refer to the Bayer Process technology basis established in comparable alumina/SGA refinery engineering studies with capacities ranging from 440,000 to 1,000,000 tons per year

[12], [13], as well as established Bayer Process industry practices [14]. All results were then used in the investment feasibility analysis (NPV, IRR, PP), reinforced by a scenario-based sensitivity analysis that recalculated NPV, IRR, and PP under five bauxite and caustic soda price scenarios (-20%, -10%, 0%, +10%, and +20% relative to the base case) to examine their effect on project feasibility, prior to drawing conclusions and recommendations.

The forecasting and financial-feasibility formulas applied in this study are presented in Equations (1)-(7).

$$F_{t+1} = (A_t + A_{t-1} + A_{t-2} + \ldots + A_{t-n+1}) / n \quad (1)$$

where Ft+1 is the forecast for the next period, At is the actual data at period t, and n is the number of periods used in the moving average (n = 3 in this study).

$$Production\ Cost = Fixed\ Cost + Variable\ Cost \quad (2)$$

$$HPP = Total\ Production\ Cost / Total\ Units\ Produced \quad (3)$$

HPP (Harga Pokok Produksi) denotes the cost of goods manufactured per unit of output.

$$NPV = \Sigma_{t=0}^{n} [CF_t / (1 + r)^t] \quad (4)$$

where CFt is the net cash flow in year t, r is the discount rate (MARR), t is the time period, and n is the project's economic life.

$$0 = \Sigma_{t=0}^{n} [CF_t / (1 + IRR)^t] \quad (5)$$

IRR is the discount rate at which NPV equals zero; the project is feasible when IRR exceeds the MARR.

$$PP = Initial\ Investment / Annual\ Net\ Cash\ Flow \quad (6)$$

PP indicates the length of time required to recover the initial investment through the project's net cash flow.

$$BEP = Fixed\ Cost / (Selling\ Price\ per\ Unit - Variable\ Cost\ per\ Unit) \quad (7)$$

BEP represents the production volume at which total revenue equals total cost, used as a supporting indicator alongside NPV, IRR, and PP [7], [8].

RESULTS AND DISCUSSIONS

Results

Demand Projection. Alumina demand projection was carried out using international trade data from TradeMap for the 2021-2025 period as a representation of global market conditions and Indonesia's alumina export opportunities. Table 1 presents the export-import balance used as the basis for national consumption data.

Table 1. Alumina Export and Import Data (2021-2025)

Year	Export (Ton)	Import (Ton)
2021	1,292,647	359,930
2022	2,024,196	329,884
2023	2,153,522	711,056
2024	2,212,467	1,068,508
2025	5,267,938	1,089,914
Total	12,950,770	3,559,293

Source: TradeMap

As shown in Table 1, both export and import volumes trended upward over 2021-2025, with a sharp rise in exports in 2025 reflecting the increased alumina output following the bauxite export ban. National consumption, derived from this export-import balance, was forecast using the Moving Average method with a three-period moving average (m = 3), which was selected for its ability to smooth historical fluctuations and provide a representative demand estimate for production capacity planning, consistent with its established application in raw-material and product-demand forecasting [15], [16]. The forecast results are presented in Table 2.

Table 2. Alumina Demand Forecast Using Moving Average (m = 3), 2021-2043

Year	Actual Demand (Ton)	Forecast Ft (Ton)
2021	6,067,283	-
2022	5,305,689	-
2023	5,557,534	5,643,502
2024	5,856,041	5,573,088
2025	2,821,976	4,745,184
2026	-	5,320,591
2027	-	5,212,954
2028	-	5,092,910
2029	-	5,208,818
2030	-	5,171,561
2031	-	5,157,763
2032	-	5,179,381
2033	-	5,169,568
2034	-	5,168,904
2035	-	5,172,617
2036	-	5,170,363
2037	-	5,170,628
2038	-	5,171,203
2039	-	5,170,731
2040	-	5,170,854
2041	-	5,170,929
2042	-	5,170,838
2043	-	5,170,874

As presented in Table 2, national alumina demand converges to a stable long-term average of approximately 5.17 million tons per year from 2028 onward, after an initial adjustment in 2026-2027 following the sharp 2025 decline. This stable demand level, together with Indonesia's growing bauxite downstreaming needs, forms the basis for setting the plant's production capacity at 2 million tons per year, equivalent to roughly 39% of the projected national demand and leaving room for supply from other domestic producers as well as export opportunities.

Investment Requirements (CAPEX). The total investment required for the 2-million-ton-per-year alumina plant amounts to IDR 22,436,165,569,424, as detailed in Table 3

Table 3. Plant Investment Breakdown

Category	Cost (IDR)	Percentage
1. Land & Site Preparation	914,458,317,632	4%
2. Buildings & Civil Works	2,442,591,615,385	11%
3. Machinery & Equipment	9,842,976,000,000	44%
4. Utilities	1,629,040,000,000	7%
5. Infrastructure	3,578,848,000,000	16%
6. Instrumentation & Automation	679,280,000,000	3%
7. Engineering & Construction	933,993,576,923	4%
8. HSE (K3) & Environment	388,720,800,000	1.7%
9. Contingency	93,399,357,692	0.4%
10. Working Capital	1,932,857,901,792	9%
Total	22,436,165,569,424	100%

As shown in Table 3, the largest cost component is production machinery and equipment at IDR 9,842,976,000,000 (44% of total investment), reflecting the highly capital-intensive nature of alumina processing, particularly the Bayer Process stages of digestion, precipitation, and calcination, which require large-capacity, high-technology equipment. Significant investment is also required for infrastructure (16%), buildings and civil works (11%), and utilities (7%). Working capital amounts to IDR 1,932,857,901,792 (9% of total investment), while total annual depreciation and amortization expenses are IDR 914,084,696,651 and IDR 70,805,686,731, respectively.

Financial Feasibility (NPV, IRR, PP). Payback Period was calculated by comparing the initial investment of IDR 22,436,165,569,424 with the project's annual net cash flow (net profit after tax plus depreciation). The cumulative net cash flow turns positive between year 7 and year 8 of operation; interpolation gives a Payback Period of 7 years and 306 days, well within the 15-year project economic life.

NPV and IRR were computed from projected net cash flows over 15 years of operation, discounted at a Minimum Attractive Rate of Return (MARR) of 10%, with additional discount rates of 5% and 20% used to interpolate the IRR. As summarized in Table 4, the analysis yields a positive NPV of IDR 3,488,379,180,173 and an IRR of 12.93%, exceeding the 10% MARR. Since the NPV is positive and the IRR exceeds the MARR, the alumina refinery investment is classified as feasible.

Table 4. Summary of NPV and IRR Analysis

Category	Cost (IDR)
Initial Investment	IDR 22,436,157,769,520
MARR	10%
NPV	IDR 3,488,379,180,173
IRR	12.93%
NPV Criterion	Positive
IRR Criterion	IRR > MARR
Decision	Feasible

Discussions

The results confirm that alumina refinery investment in the Mempawah Industrial Area is financially feasible under current market assumptions, consistent with prior feasibility studies on similar mineral-processing projects in Indonesia. Rianto et al. [3] reported a comparable positive feasibility outcome for a Smelter Grade Alumina

project at PT. X, while Bahri et al. [17] and Oetomo [5] found similarly positive NPV and IRR results for copper cathode and electric-motorcycle battery plant investments, respectively. These findings collectively indicate that Indonesia's downstream mineral-processing projects, despite requiring very large capital investment, can generate returns above the investor's minimum required rate when demand and pricing conditions remain favorable, supporting the broader downstreaming policy objective of increasing the domestic value added of raw minerals. Table 5 summarizes how the present study compares with these and other related studies.

Table 5. Comparison with Previous Feasibility and Plant-Design Studies

Study	Object / Capacity	Method	Position Relative to This Study
Maulana Akbar et al. [12] (2022)	Alumina plant design, 440,000 TPY	Technical process design (Bayer)	Technical basis only, no financial feasibility; this study adds full NPV/IRR/PP analysis at larger scale
Dharmawan & Harahap [13] (2025)	SGA refinery design, 1,000,000 TPY	Technical process design (Bayer)	Technical basis only; this study doubles the capacity and adds financial and sensitivity analysis
Rianto et al. [3] (2023)	SGA plant feasibility, PT. X	NPV, IRR	Financial feasibility only; no raw-material price-sensitivity analysis
Oetomo [5] (2023)	EV battery plant, Gresik	NPV, IRR, PP	Different downstream sector; confirms consistent feasibility methodology
Bahri et al. [17] (2024)	Copper cathode factory, Central Kalimantan	NPV, IRR	Different mineral commodity; no sensitivity analysis on input prices
This Study (2026)	Alumina refinery, 2,000,000 TPY, Mempawah	NPV, IRR, PP + scenario-based price sensitivity	Integrates Bayer Process technical basis, full financial feasibility, and bauxite/NaOH price sensitivity analysis

As shown in Table 5, earlier alumina/SGA plant-design studies [12], [13] focused on technical process configuration without evaluating financial feasibility, while general feasibility studies on other Indonesian downstreaming projects [3], [5], [17] applied NPV/IRR/PP analysis but did not examine sensitivity to raw material price changes. This study fills that gap by combining a Bayer Process technical basis with a

complete financial feasibility analysis and a scenario-based sensitivity analysis specific to bauxite and caustic soda prices, providing a more comprehensive decision-making framework than any single prior study.

A scenario-based sensitivity analysis was conducted to evaluate the robustness of the investment against changes in bauxite and caustic soda (NaOH) prices, the two dominant cost drivers in the Bayer Process, under five price scenarios: -20% (optimistic), -10% (moderate), 0% (base case), +10% (pessimistic), and +20% (highly pessimistic) relative to the base case. Under each scenario, the cost of goods manufactured, net cash flow, NPV, IRR, and Payback Period were recalculated to trace the cause-and-effect relationship between raw material prices, production cost, company profit, and investment feasibility.

The results show that bauxite price has the most dominant influence on investment feasibility, owing to its larger contribution to direct material cost compared with caustic soda. An increase in bauxite price raises the cost of goods manufactured (HPP), reducing profit margin, NPV, and IRR, while extending the Payback Period; a price decrease has the opposite effect. Caustic soda price changes follow a similar but comparatively weaker pattern, since NaOH is used mainly in the digestion and evaporation stages. The project remains feasible as long as price increases in bauxite and caustic soda do not push the IRR below the 10% MARR or cause the NPV to turn negative, underscoring the importance of raw material price-risk mitigation strategies such as long-term supply contracts with bauxite suppliers and optimization of caustic soda consumption to sustain the plant's long-term financial viability.

CONCLUSION

Based on the investment feasibility analysis of the 2-million-ton-per-year Smelter Grade Alumina (SGA) plant in the Mempawah Industrial Area, several conclusions can be drawn, directly supported by the results and discussion above. First, demand potential for SGA in both national and global markets remains positive: the Moving Average forecast (Table 2) shows national alumina demand stabilizing at approximately 5.17 million tons per year from 2028 onward, driven by rising aluminum demand in transportation, construction, packaging, energy, and manufacturing, and supporting the plant's planned 2-million-ton-per-year capacity. Second, the main raw material requirement is bauxite ore, supported by caustic soda (NaOH), process water, fuel, and electricity, processed through the Bayer technology stages of crushing and grinding, digestion, clarification and filtration, precipitation, calcination, and material handling and storage, with bauxite and caustic soda contributing the largest share of production cost. Third, the total investment required is IDR 22,436,157,769,520 (Table 3), dominated by production machinery and equipment (approximately IDR 9,842,976,000,000, or 44% of total investment). Fourth, the project is financially feasible (Table 4), with a positive NPV of IDR 3,488,379,180,173, an IRR of 12.93% (above the 10% MARR), and a Payback Period of 7 years and 306 days. Fifth, the scenario-based sensitivity analysis shows that bauxite and caustic soda prices are the most influential variables on investment feasibility; price increases raise production cost and reduce NPV and IRR while lengthening the Payback Period, with bauxite price exhibiting greater sensitivity than caustic soda price due to its larger contribution to total production cost. Compared with previous alumina/SGA plant-design and feasibility studies (Table 5), which addressed either technical design or financial feasibility in isolation, this study's integration of technical, financial, and sensitivity analysis constitutes its principal contribution to the industrial engineering literature on mineral

downstreaming investment. Overall, considering the market, technical, investment, financial, and sensitivity analyses, the planned construction of the 2-million-ton-per-year SGA plant in the Mempawah Industrial Area is declared feasible for realization.

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