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# **Aluminum Downstream Decarbonization Strategy: Fostering a Just and Competitive Transition**



## Our Mission

To build reliable, equitable, and sustainable financing alternative for Indonesia's energy transition

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## Executive Summary

Indonesia has significant potential in the aluminum industry with bauxite reserves estimated at 2,8 billion tons or around 10% of the world's total reserves. With such reserves, Indonesia is ranked among the top four globally. In terms of output, it is the world's fifth-largest bauxite producer.

However, Indonesia's role in the aluminum value chain remains largely dominated by the export of raw bauxite. Its downstream capacity—particularly in refining (alumina) and smelting (primary aluminum)—remains limited compared to major producers such as China, Australia, and Brazil.

Global trends point to significant shift in the aluminum industry landscape. The European Union has implemented the Carbon Border Adjustment Mechanism (CBAM), imposing tariffs on aluminum products with high carbon footprints. Leading producers such as Canada and Norway have long utilized renewable hydropower to produce low-carbon aluminum (with carbon intensities below 4 tons Co<sub>2</sub> per ton of aluminum). Meanwhile, China—the world's largest aluminum producer—has, since 2020, begun relocating its smelters to regions powered by hydropower. These shifts present both opportunities and pressures for Indonesia to develop a sustainable aluminum downstreaming strategy without sacrificing competitiveness.

To identify the optimal strategy, we apply the “Market Dominance and Rigidity” (MDR) framework. This analysis helps align decarbonization goals with efforts to enhance economic value-added, while maintaining market viability. The market dominance analysis shows that Indonesia is not a dominant player in either reserves or primary aluminum production. On the other hand, market rigidity analysis reveals that global aluminum demand is relatively inelastic to price changes—suggesting there is room to increase production costs (e.g., due to decarbonization investments) without substantial risk of losing market share.

Based on this analysis, an overly aggressive strategy may risk undermining Indonesia's competitiveness, while an overly passive approach could leave the country behind in the global energy transition. We recommend a “moderate-conservative” strategy that strikes a balance between enhancing national economic value-added and meeting global decarbonization standards—without sacrificing competitiveness.

The core principles of this strategy include:

1. *Be the follower, not frontrunner.* Indonesia can align with decarbonization policies already adopted by advanced economies or dominant players like China, without taking on risks of being a first mover.
2. *Leverage premium market opportunities.* By complying with standards such as the EU's Carbon Border Adjustment Mechanism (CBAM), Indonesia can avoid carbon tariffs while gaining access to higher-value market.
3. *Focus on proven technologies.* The adoption of captive or grid-based renewable energy, energy efficiency improvements, and aluminum recycling, will help strengthen the foundation of a more resilient and sustainable aluminum industry.

Some of the key policy recommendations include:

- *Withdrawal of tax holiday incentive* currently granted to new aluminum smelters. Tax holidays reduce potential state revenues and may also trigger accusations of dumping, as seen in the case of nickel. For comparison, in 2024, the Chinese government revoked its 13% VAT rebate for aluminum exports to avoid similar sanctions from Western countries.
- *Banning the development of coal-fired captive power plants* for new aluminum smelters. This policy would align with China's approach, which only permits new smelters to operate on clean energy or be connected to the national grid.
- *Gradually raising ESG standards.* Indonesia enjoys competitive production costs (Quadrant 1 according to Wood MacKenzie), providing room to improve environmental standards and labor welfare to match those of key competitors.
- *Engaging with the international community.* Indonesia could take the lead in initiating a global aluminum producers' alliance to help stabilize the market and accelerate collective decarbonization—similar to OPEC in the energy sector.

This moderate-conservative strategy is expected to support a sustainable aluminum downstreaming agenda in Indonesia, enhance state revenue, strengthen the country's position in the global value chain, and fulfil national decarbonization commitments—all without compromising competitiveness.

# 1 Introduction

The downstreaming of natural resources has become a key pillar of Indonesia's economic development strategy over the past decade. Through downstreaming, the government aims to strengthen domestic value-added, increase state revenue, and expand employment opportunities. However, the current downstreaming program still relies heavily on coal as its primary energy source, contributing significantly to the rise in Indonesia's emissions. To ensure that the downstreaming agenda does not undermine national decarbonization goals and the 2060 net-zero emissions target, the government must develop a comprehensive plan for the decarbonization of the aluminum downstreaming sector.

The aluminum industry is the second-largest emitter within the global metals and minerals sector after steel, accounting for approximately 10% of the sector's total emissions. Out of the sector's estimated 7.2 GtCO<sub>2</sub>e emissions in 2023, aluminum production is projected to have contributed around 720 MtCO<sub>2</sub>e (0.72 GtCO<sub>2</sub>e). As such, decarbonizing the aluminum industry is a critical step toward reducing global emissions (McKinsey, 2024).

Indonesia possesses substantial bauxite reserves and ranks among the world's top five bauxite producers. However, its refining (alumina) and smelting (primary aluminum) capacities remain limited. Globally, the aluminum market is dominated by China, which accounts for over 55% of primary aluminum production, followed by other major producers such as India, Russia, Canada, and Australia. In this context, an overly aggressive downstreaming strategy could pose risks to the competitiveness of Indonesia's domestic industry—especially if production costs rise due to the implementation of strict ESG (environmental, social, and governance) standards and increased levies. Conversely, if decarbonization proceeds too slowly, Indonesia also risks losing competitiveness by failing

to meet the higher standards required to access key global markets. Given these global dynamics, a well-calibrated strategy is essential.

At the same time, the global aluminum market is increasingly shaped by the energy transition and decarbonization agenda. The European Union has implemented the Carbon Border Adjustment Mechanism (CBAM), which will impose carbon tariffs on aluminum imports with high environmental footprints. Leading producers such as Canada and Norway are already ahead in producing low-carbon aluminum using renewable energy, while China is gradually relocating its smelters to regions with clean energy potential, such as Yunnan and Sichuan. These shifts indicate that global demand for low-carbon aluminum will continue to grow, pushing producers to adapt or risk losing access to premium markets.

This paper presents the “Market Dominance and Rigidity” (MDR) framework to evaluate Indonesia’s position within the global aluminum industry and define an optimal strategy. MDR examines two key dimensions: (1) the extent of Indonesia’s dominance in the global bauxite, alumina, and primary aluminum market; and (2) the price elasticity of global aluminum demand. The analysis finds that Indonesia falls into the non-dominant quadrant of a relatively inelastic market. This means Indonesia lacks the leverage to influence market prices and must tread carefully to ensure that downstreaming policies do not erode the competitiveness of its aluminum industry.

Based on this analysis, we recommend a “moderate-conservative” strategy, meaning Indonesia should follow the lead of market holders and dominant players in progressively raising environmental standards, without attempting to act as a pioneer. A gradual increase in ESG standards would allow Indonesia to access premium markets such as the EU while mitigating the risk of carbon-related tariffs. This strategy also includes a ban on the construction of new coal-fired captive power plants for aluminum smelters, and the withdrawal of tax holiday incentives—which have reduced state revenues and may expose Indonesia dumping allegations.

In addition, this paper explores the potential for Indonesia to strengthen its international role through collaboration with major aluminum-producing countries such as China, Australia, Canada, and Russia. The establishment of a global cooperation forum—similar to OPEC, but for the aluminum sector—could serve as a platform to help maintain market balance and accelerate the collective transition toward low-carbon aluminum production.

Through such a model, Indonesia' aluminum downstreaming agenda is expected not only to enhance national economic value-added, but also align with the country's decarbonization commitments and sustain industrial competitiveness in an increasingly demanding global market.

## 2 Aluminum Decarbonation Technologies and Their Application

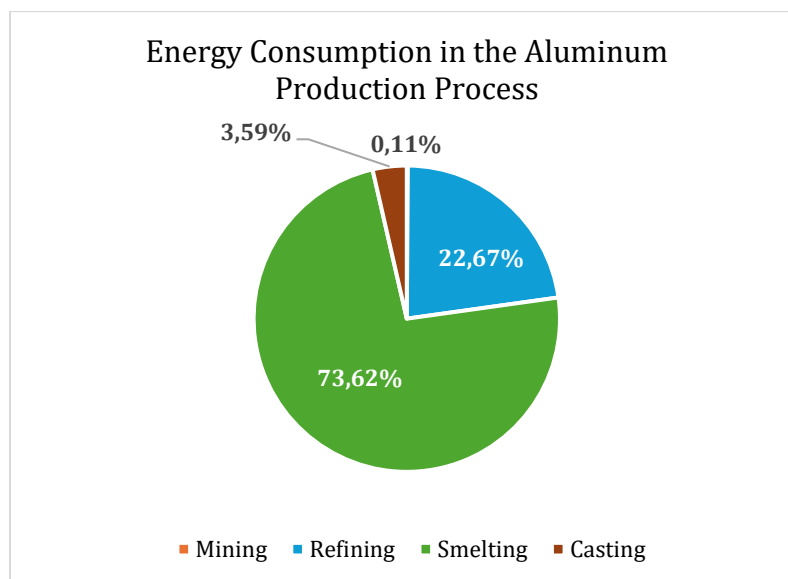
Aluminum decarbonization depends on the availability of proven and deployable technologies, some of which have already been adopted by one or more countries around the world. This section reviews low-carbon aluminum processing technologies as well as relevant practices implemented in other countries.

### 2.1 Technology

The primary aluminum production process generally consists of four main stages:

- **Mining:** Bauxite extraction from the earth's crust, with an energy consumption of approximately 23.5 MJ/kg → accounting for around 0.11% of the total.
- **Refining:** Refining bauxite into alumina ( $\text{Al}_2\text{O}_3$ ), with an energy consumption of approximately 4,772.70 MJ/kg → accounting for around 22.67% of the total.

- **Smelting:** Smelting alumina into aluminum through electrolysis, with an energy consumption of approximately 15,497.50 MJ/kg → accounting for around 73.62% of the total.
- **Casting:** Casting aluminum into ingots, with an energy consumption of approximately 755.80 MJ/kg → accounting for around 3.59% of the total.



*Figure 1 Energy Consumption in the Aluminum Production Process*

According to [Gautam, Pandey, & Agrawal \(2018\)](#), the highest energy consumption in aluminum production occurs during the smelting stage, amounting to 15,497.50 MJ/kg or approximately 73.62% of total energy use. Decarbonizing this entire process is therefore key to ensuring the sustainability of the aluminum industry.

### 2.1.1 Use of Renewable Energy

Most aluminum smelters today still rely on electricity generated from fossil fuel-based power plants, particularly coal. However, several countries and companies have successfully integrated low-carbon energy sources:

### *Hydropower*

In Canada, Norway, and Iceland, the majority of electricity supplied to aluminum smelters comes from hydropower. For example, the Alcoa Fjarðaál smelter in Iceland is fully powered by Kárahnjúkar hydropower plant, resulting in a carbon footprint of less than 4 tons of CO<sub>2</sub>, per ton of aluminum—significantly lower than that of coal-powered smelters (You, 2025; Home, 2020).

### *Solar and Wind Power*

Many companies are now using solar and wind power as part of their energy diversification strategies. By integrating renewable energy into their electricity supply, they are able to significantly reduce emissions. For instance, investors in Europe and North America have installed solar panels and wind turbines to partially meet the energy demands of their aluminum smelters.

### *Renewable Energy from the Grid*

Emirates Global Aluminum (EGA) purchased electricity certificates totaling 1.1 million MWh from Noor Abu Dhabi's solar power facility. EGA uses this solar-based electricity to produce low-carbon aluminum under its "CelstiAL" brand. Through this model, EGA claims to reduce carbon intensity by up to 60% per ton of aluminum produced (EGA, 2022).

#### **2.1.2 Anode Inert Technology**

The aluminum smelting process most commonly used today—known as the Hall-Héroult process—still relies on carbon-based anodes. During this process, the carbon anode reacts with oxygen from alumina (Al<sub>2</sub>O<sub>3</sub>), releasing carbon dioxide (CO<sub>2</sub>) as a by-product. This chemical reaction alone can generate approximately 2 to 3 tons of CO<sub>2</sub> for every 1 ton of aluminum produced independent of emissions from energy use. These process-related emissions are estimated to account for around 15% of total carbon emissions in primary aluminum productions.

In recent decades, experts have developed a new technology known as “inert anode” to replace conventional carbon anodes with non-reactive materials, such as heat-resistant metals or advanced ceramics. Unlike carbon anodes, these inert materials do not produce CO<sub>2</sub> during the smelting process—instead, they release pure oxygen. This breakthrough has the potential to significantly reduce carbon emissions from aluminum production.

In 2013, Russia-based UC RUSAL conducted a pilot test of inert anode technology at its Krasnoyarsk smelter ([Reverdy & Potocnik, 2020](#)). Later, in 2021, a joint venture between Rio Tinto and Alcoa began construction of the world’s first commercial-scale prototype at the Alma smelter in Quebec, Canada, under the name “Elysis Project” ([Rio Tinto, 2021](#)). Today, inert anode technology is widely regarded as a critical step toward low-carbon, environmentally friendly aluminum production.

According to the Climate Technology Centre & Network (CTCN), retrofitting existing smelters with inert anode technology requires an additional capital investment of around USD 1–2 million per pot, or approximately USD 1–2 billion for a new facility. Despite the high upfront costs, this technology can reduce operating expenses by roughly 3% and increase return on investment (ROI) by about 2% in new installations ([CTCN, n.d.](#)). A techno-economic study by the Royal Society of Chemistry (RSC) indicates that inert anodes can boost cell productivity by up to 15% while lowering operating costs by around 15%, primarily due to reduced anode replacement frequency and lower maintenance costs ([Boudreau, Johnson, & Bergthorson, 2024](#)). Furthermore, analysis by IOP Science suggests that when combined with complementary technologies, such as wettable cathodes, inert anodes could cut energy consumption by as much as 30% ([Padamata, Singh, Haarberg, & Saevarsdottir, 2023](#)). Overall, inert anode technology requires higher capital investment but offers significant reductions in both operating costs and carbon emissions.

When integrated with renewable energy sources, this technology presents a compelling opportunity to produce ultra-low-carbon aluminum in the future. When

combined with the use of renewable energy, inert anode technology creates the potential for (ultra) low-carbon aluminum in the future.

### 2.1.3 Energy Efficiency and Digitalization

The aluminum industry is increasingly adopting advanced technologies to improve energy efficiency and maintain optimal plant performance. Some of the key innovations include:

- **Process optimization using control system and *machine learning*.** Aluminum smelter operations can now be monitored in real time through sensors and AI algorithms to ensure optimal temperature and electric current level. This technology can improve production efficiency by 20–25% and reduce energy consumption by 10–15% (Elkamehr, 2024).
- **Heat conservation and improved current efficiency.** Smelting processes often generate excess heat that used to be wasted. Today, several plants have adopted heat recovery systems and operational optimizations, allowing current efficiency to exceed 95%. Through heat conservation and reduced electrical losses, less energy is wasted during the electrolysis process (Elkamehr, 2024).
- **Predictive maintenance.** This technology utilizes data from sensors—such as vibration, temperature, and acoustics—to predict equipment failures before they occur. A study by Rio Tinto shows that predictive maintenance can reduce unexpected downtime by 30%, lower maintenance costs by 20%, and extend equipment lifespan by up to 15% (Lee, 2025).

### 2.1.4 Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) is a technology designed to capture CO<sub>2</sub> emissions from industrial processes—such as aluminum smelting—and either store it underground or repurpose it into usable products. CCS holds potential as a short-term solution for smelters that are not yet able to fully transition to clean energy sources.

However, CCS faces significant challenges. The exhaust gases from aluminum smelting contain only about 1% CO<sub>2</sub>, making it technically difficult and costly to capture. In addition, CCS is a complex and capital-intensive technology that requires permanent storage infrastructure (Hydro, 2024). Various studies have also found that CCS has only managed to capture around 10% of carbon emissions over a 20-year period (Jacobson, 2019; Oreskes, 2024).

### 2.1.5 Increased Use of Recycled Aluminum

One of the most effective ways to reduce emissions is by increasing the use of recycled aluminum (secondary aluminum). Compared to primary aluminum, producing recycled aluminum requires only about 5% of the energy, significantly lowering carbon emissions (Gautam, Pandey, & Agrawal, 2018). Therefore, developing robust recycling infrastructure and improving the efficiency of scrap collection have become key priorities for decarbonizing Indonesia's aluminum industry.

**Conclusion:** The combination of clean energy, innovative anode technologies, operational efficiency, and the use of recycled aluminum, forms the foundation for low-carbon aluminum production.

## 2.2 Application in Developed and Leading Countries

Several developed countries and leading global aluminum producers have emerged as pioneers in low-carbon aluminum production. Their practices can serve as important references for decarbonization strategies in Indonesia.

### 2.2.1 Canada

Canada has become one of the world's most environmentally friendly aluminum producers, as nearly all of its smelters rely on hydropower. This enables the production of aluminum with a carbon intensity of around 4 tons of CO<sub>2</sub> per ton of aluminum—among the

lowest globally and well below the industry average of 12 to 13 tons of CO<sub>2</sub> per ton ([ING, 2024](#)).

Canada is also a pioneer in decarbonization technology through the ELYSIS project in Quebec—a collaboration between Rio Tinto and Alcoa, supported by the Canadian government, Apple, and the U.S. government. As previously mentioned, the project employs inert anode technology, which uses non-carbon electrodes that release oxygen instead of CO<sub>2</sub>, effectively eliminating direct emissions from the smelting process ([You, 2025](#)).

In Canada, this technology is claimed to reduce greenhouse gas emissions by up to 7 million tons of CO<sub>2</sub> per year—equivalent to removing around 1.8 million cars from the road. In addition, the next-generation inert anodes developed through the project are estimated to last over 30 times longer than traditional carbon anodes ([ELYSIS, 2024](#)).

### 2.2.2 Norway

Norway is a global pioneer in low-carbon aluminum production, led by Hydro Aluminum, which introduced its Hydro REDUXA product. This aluminum has a carbon footprint of less than 4 tons of CO<sub>2</sub> per ton of aluminum ([Hydro, 2020](#)), well below the global average. This achievement is primarily enabled by the use of hydropower. Additionally, the company has adopted advanced digitalization technologies to monitor and optimize energy use, streamline production processes, and minimize waste. As part of its global marketing strategy, Hydro has implemented a carbon traceability system across its supply chain, allowing customers to track emissions at every stage of production. This model enhances transparency and aligns with the growing consumer demand for environmentally responsible products ([Hydro, 2023](#)).

### 2.2.3 European Union

The European Union has set an ambitious target through the European Green Deal, aiming to reduce industrial greenhouse gas emissions by 55% by 2030 compared to 1990 levels. This target has been legally mandated under the “Fit for 55” policy package, as part of

the EU's broader commitment to achieving carbon neutrality by 2050 ([European Commission, 2023](#)).

As part of its broader strategy, the European Union will implement the Carbon Border Adjustment Mechanism (CBAM) starting in 2026. This scheme will impose a carbon tariff on imported aluminum from countries that do not meet the EU's environmental standards. The initiative aims to prevent carbon leakage—where carbon-intensive production shifts to countries with laxer regulations—while also safeguarding the competitiveness of low-carbon manufacturing industries within Europe. The EU will become the first major economic bloc to introduce a “green tariff” on imported goods. Countries that fail to decarbonize their industries will be subject to carbon taxes.

In response, Western European smelters are increasingly focusing on using recycled aluminum and integrating clean energy, particularly from renewable sources. According to European Aluminum, the majority of aluminum produced in the EU already has a lower carbon footprint—6.3 kg CO<sub>2</sub> per kg of aluminum—compared to the global average. However, Europe's high electricity costs—two to three times higher than in the United States—combined with stringent environmental regulations, have forced several large-scale smelters to cut their operational capacity by half ([European Aluminium, 2025](#)).

#### **2.2.4 The United States of America**

The United States is accelerating the decarbonization of its aluminum industry through the Inflation Reduction Act (IRA), enacted in August 2022. The IRA provides substantial fiscal incentives—particularly through the Section 45X tax credit—for a wide range of industrial products, including low-carbon alumina and aluminum produced using clean energy and advanced technologies. Under the IRA, a 10% tax credit is available to offset production costs, including electricity, labor, and other inputs ([Esmen, 2023](#)).

Through the Department of Energy, the U.S. government has awarded a \$500 million subsidy grant under the Industrial Demonstration Program (IDP) to Century Aluminum to

establish the first green primary aluminum smelter in the United States. This smelter is designed to be significantly more energy-efficient and powered by renewable energy sources, with estimated CO<sub>2</sub> emissions at just 25% of those from conventional smelters. Once completed, the facility could potentially double the nation's primary aluminum production capacity ([Home, 2024](#)). The IDP has also allocated funding to support aluminum recycling initiatives. Among them is a zero-carbon casting facility in Virginia, funded with \$75 million, as well as technology upgrades for Golden Aluminum and Real Alloy aimed at reducing energy consumption and enhancing aluminum recycling capacity ([Aluminum Association, 2024](#)).

In general, through a combination of fiscal incentives under the Inflation Reduction Act (IRA), subsidy support from DOE programs, and a new paradigm in technology—such as inert anodes and wettable cathodes—the United States is working to revive its low-carbon domestic primary aluminum industry.

### 2.2.5 China

China is the world's largest producer of primary aluminum, accounting for over 55% of total global output. However, the country's aluminum industry remains heavily reliant on coal-based energy. More than 80% of China's smelting capacity is powered by coal-fired electricity, whether through captive power plants or the public grid. According to Wood Mackenzie (2021), the average carbon intensity of Chinese aluminum production is estimated at 12.36 tons of CO<sub>2</sub> per ton of aluminum ([Wood Mackenzie, 2021](#)).

Since 2020, the Chinese government has promoted the relocation of aluminum smelters from coal-dominated northern regions to the southwest—particularly Yunnan and Sichuan—which have greater access to clean hydropower. This relocation involved the transfer of over 5.9 million tons of capacity by 2022 and accounted for approximately 62% of new capacity growth in those areas. However, some facilities have experienced production declines due to limited hydropower supply and unpredictable weather patterns, resulting in system disruptions and output reductions of 10–40% at certain smelters ([Cilive, 2023](#)).

According to the China Nonferrous Metals Industry Association (CNMIA), the country's aluminum sector has committed to peaking carbon emissions by 2030 and achieving carbon neutrality by no later than 2060 (Zhu & Jin, 2025). China's smelting capacity has now reached its ceiling, and the government has begun to impose strict limitations: new smelters are only permitted if they replace existing ones, utilize renewable energy, or are connected to the public power grid. The construction of new coal-fired captive power smelters is no longer allowed. In response to global pressure over alleged dumping practices, China has also withdrawn the 13% value-added tax (VAT) rebate for aluminum exports (Home, 2025).

Overall, China remains the dominant player as the world's largest aluminum producer, contributing more than half of global output. However, this dominance is overshadowed by a heavy reliance on coal, making the aluminum sector one of the largest industrial sources of carbon emissions. Nevertheless, China has demonstrated a strong commitment to accelerating the transition toward low-carbon aluminum production. Strategic measures such as relocating smelters to regions with renewable energy sources, limiting the expansion of new capacity, investing in energy-efficient technologies, and setting national targets for peak emissions and carbon neutrality reflect the country's determination to transform its industry toward greater sustainability.

### 3 Defining a Downstreaming Strategy

In designing strategies for downstream development of natural resources, governments face a fundamental trade-off between maximizing national economic value added and enhancing or maintaining global competitiveness. In many cases, it is not possible to achieve both simultaneously, as one option often comes at the expense of the other.

The more a government pursues national economic gains—such as through increased taxation, higher labor wages, stricter environmental and ESG standards—the greater the potential national value added. This value added may manifest in increased state revenues,

job creation, higher worker incomes, strengthening of domestic industries, reduction of environmental damage, and other benefits.

On the other hand, any increase in production costs carries the risk of reducing the competitiveness of Indonesian products in international markets. Higher-priced products tend to be abandoned by global buyers who have many alternatives, especially in open and highly competitive markets. As a result, an overly aggressive downstream strategy focused on national gains may backfire, leading to loss of market share, declining exports, and even premature deindustrialization.

Conversely, if the government places too much emphasis on price competitiveness—such as by offering tax holidays and other incentives, subsidizing fossil energy, maintaining low labor wages, and relaxing environmental regulations—Indonesian products will be cheaper and potentially highly competitive globally. However, this situation results in minimal value added from downstream activities, limited benefits to the national economy, increased environmental damage, and at some point, can trigger a "race to the bottom." In such a race, competing countries adopt similar strategies, leading to cutthroat competition, wage suppression, and environmental degradation, ultimately causing losses for all producing nations involved.

### **3.1.1 MDR Analysis**

Therefore, an analytical framework is needed that can balance two major objectives simultaneously: (1) maximizing national benefits from natural resource downstreaming, and (2) maintaining Indonesia's competitiveness in the global market. We have developed the Market Dominance and Rigidity (MDR) analysis to achieve an optimal strategy. The MDR analytical framework consists of two main pillars:

### **3.1.2 Market Dominance**

This analysis measures Indonesia's level of dominance in the global market for a given commodity, based on the ratio of reserves and production to the global total. If Indonesia

holds a dominant position, a more progressive downstream strategy can be pursued. Conversely, if Indonesia’s position is not dominant, the strategy should be more conservative.

### 3.1.3 Market Rigidity

This analysis assesses a product’s bargaining power by measuring the global price elasticity of demand. If demand is inelastic (meaning the market has difficulty finding substitutes or alternatives), Indonesia has greater policy space to adopt a more progressive strategy without fearing significant market share loss. Conversely, if the commodity’s demand is price elastic, policy space is limited as higher prices would significantly reduce demand.

By analyzing these two aspects simultaneously, the MDR model helps determine whether the most appropriate downstream strategy is progressive, moderate, or conservative. The more dominant Indonesia’s position and the more inelastic the market demand, the more progressive the strategy can be. Conversely, the smaller Indonesia’s market share and the more elastic the demand, the more conservative the strategy should be.

*Table 1 Dominance and Market Rigidity (MDR) Analysis Matrix*

MDR Analysis		Market Dominance	
		Dominant	Non Dominant
Market Rigidity	Rigid	Progressive	Moderate Conservative
	Elastic	Moderate Progressive	Conservative

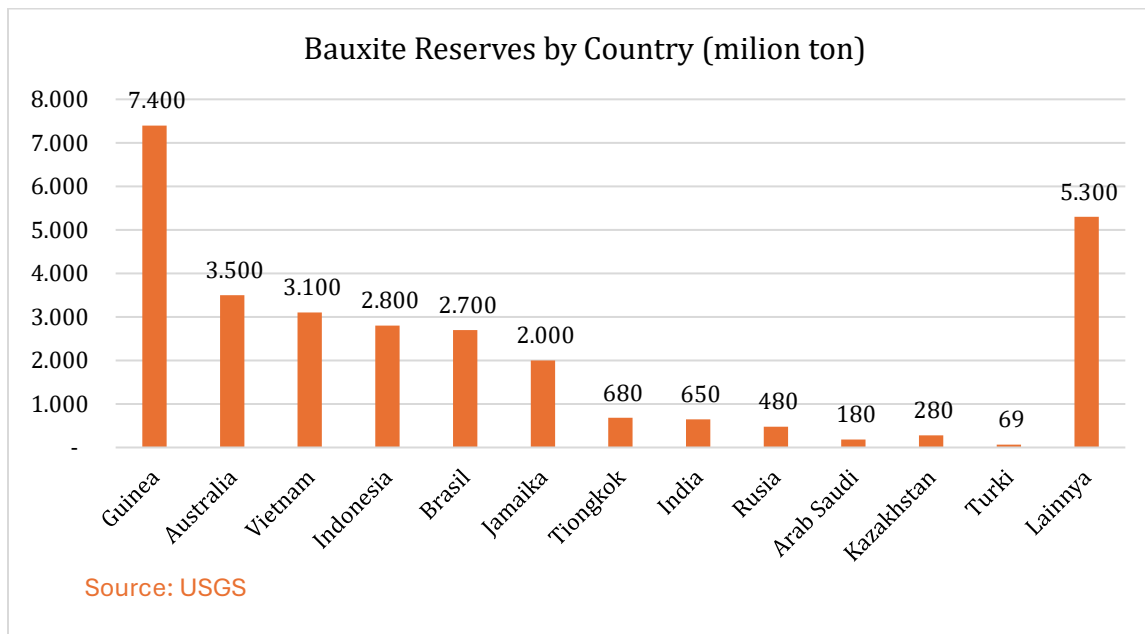
This analytical framework aims to ensure that the strategies developed maximize optimal benefits or value added to the domestic economy on one hand, without sacrificing international competitiveness on the other.

## 3.2 Market Dominance: Is Indonesia a Key Player?

Market dominance is measured using two main indicators: the ratio of Indonesia’s bauxite reserves and production relative to the global total.

### 3.2.1 Bauxite Reserves

According to the data of [USGS \(2025\)](#), the world’s total bauxite reserves are estimated at 29 billion tons. The six countries with the largest reserves are Guinea with 7.4 billion tons (25.4%), Australia 3.5 billion tons (12.0%), Vietnam 3.1 billion tons (10.6%), Indonesia 2.8 billion tons (9.6%), Brazil 2.7 billion tons (9.3%), and Jamaica 2 billion tons (6.9%). Together, these countries hold a total of 21.5 billion tons, accounting for 73.8% of the world’s bauxite reserves.



*Figure 2: Bauxite Reserves by Country (in million tons)*

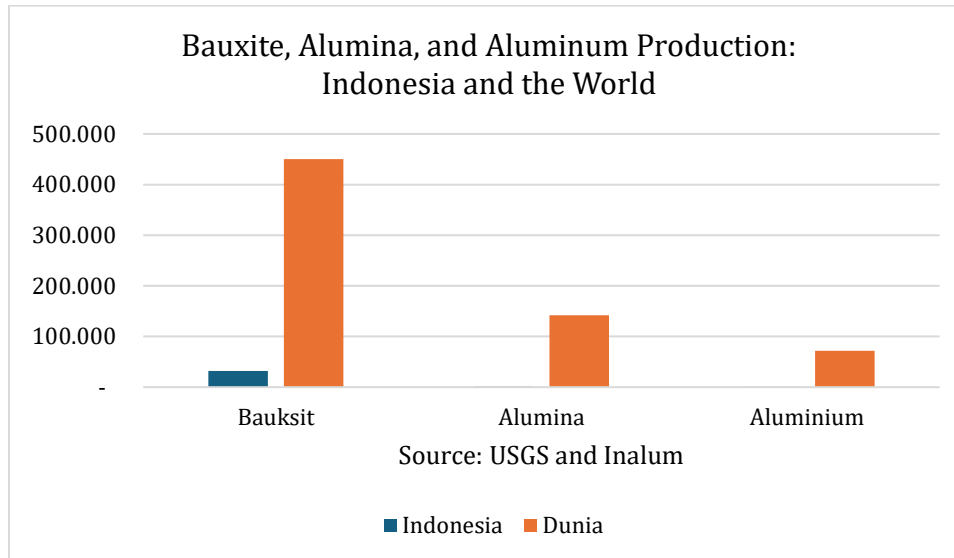
Indonesia ranks among the top six countries holding global bauxite reserves but accounts for less than 10%. While Indonesia is a significant player in terms of reserves, it is not a dominant holder.

### 3.2.2 Production of Bauxite, Alumina, and Aluminium

The aluminum production chain consists of three main stages: bauxite, alumina (aluminum oxide), and aluminum (metal). Each stage involves complex industrial processes and results in a reduction of volume from raw material to the next product.

One ton (1,000 kg) of bauxite produces approximately 400–600 kg of alumina, depending on ore quality and process efficiency, with a global average of about 500 kg of alumina per ton of bauxite. Then, 1,000 kg of alumina yields around 500 kg of aluminum metal through the Hall–Héroult electrolytic smelting process (USGS, 2023). Thus, 1,000 kg of bauxite produces roughly 500 kg of alumina, which in turn produces about 250 kg of aluminum.

To understand Indonesia's aluminum production capacity, it is necessary to consider the capacity across the entire production chain. The following chart shows Indonesia's production capacities of bauxite, alumina, and aluminum relative to the world. According to data published by USGS and Inalum, in 2024 Indonesia produced 32 million tons of bauxite, accounting for approximately 7.11% of the global production of 450 million tons. In the same year, Indonesia produced 1.3 million tons of alumina, or about 0.92% of the world's 142 million tons. Meanwhile, Indonesia's aluminum production reached 275 thousand tons, roughly 0.38% of the global output of 72 million tons.



*Figure 3: Bauxite, Alumina, and Aluminum Production in Indonesia and the World*

Looking at the production volume across the value chain, Indonesia is a fairly significant producer (though not dominant) only at the bauxite level, accounting for about 7%. For downstream products such as alumina and aluminum, production remains below 1%. While downstream processing can increase Indonesia's production volume at the downstream end, it is unlikely to surpass the volume of bauxite itself. Thus, in terms of production volume, Indonesia is not considered a dominant player.

### **3.3 Market Rigidity: Is Aluminum Demand Elastic?**

The second dimension in formulating downstreaming strategies is the rigidity of the global aluminum market, particularly the price elasticity of demand.

Price elasticity of demand measures how much demand changes in response to price fluctuations. If a price change causes a significant shift in demand, the commodity is considered elastic. Even a slight price increase can lead to a substantial reduction in consumption. Conversely, if price changes have little effect on demand, the commodity is inelastic, meaning price increases do not significantly reduce demand.

To measure the price elasticity of global aluminum demand, we require data on global production, consumption, and prices over a sufficient time span, typically 10 years or more. Since we could not find comprehensive global aluminum consumption data, we relied on third-party calculations.

[Fisher & Owen \(1981\)](#) estimated that the price elasticity of demand and consumption for aluminum is low, at -0.25 in the short term and -0.3 in the long term. This means a 10% increase in aluminum prices leads to a 2.5% decrease in consumption in the short term and a 3% decrease in the long term.

In addition to measuring demand for primary aluminum (aluminum extracted from natural resources), market rigidity can also be assessed through the price elasticity of supply for secondary aluminum (aluminum recycled from scrap). [Blomberg & Söderholm \(2009\)](#) found that the price elasticity of supply for scrap aluminum is 0.21. This indicates that a 10% price increase results in approximately a 2.1% increase in scrap supply. This suggests that secondary aluminum supply, which substitutes for primary aluminum, is also inelastic, limiting consumer options.

Furthermore, we conducted our own calculations of the global aluminum demand elasticity model. Based on various sources covering data from 2011 to 2024, the following results were observed:

*Table 2: Analysis of Aluminum Demand Elasticity with Respect to Price*

Dependent Variable: Ln Consumption	Model 1	Model 2
Constant	-0.7486 (0.3828)	-0.7318 (0.4092)
Ln Price	-0.0148 (0.0319)	-0.0106 (0.0392)
Ln Productoon	1.0777 (0.0331)	1.0731 (0.0414)

Dummy Years of Shock	No	Yes
Adj R2	0.9885	0.9874
F-stat	561.7386	341.8429

**Note:** Numbers in parentheses represent standard errors.

**Data sources:** Aluminum production data (USGS), Price data (Federal Reserve Economic Data (FRED), series PALUMUSDM), Consumption data (Department of Industry, Science, and Resources Australia).

The regression results indicate that the price elasticity of aluminum consumption is very low, ranging from approximately  $-0.01$  to  $-0.015$ . This means a 1% increase in price leads to only a 0.01% decrease in consumption. In contrast, the elasticity with respect to production is very high, around 1.07, indicating that consumption rises proportionally with increased production. These findings are consistent with [Fisher & Owen \(1981\)](#), who reported a short-term price elasticity of aluminum demand of  $-0.2$ .

The finding that aluminum consumption is insensitive to price suggests that market dynamics in this industry are driven more by supply factors and production capacity rather than price. Several other studies, including [Blomberg&Hellmer \(2000\)](#) and [InternationalAluminium.org \(Aljanabi, Carrere, & Cruz, 2022\)](#), also note that aluminum demand tends to be inelastic because its use is essential and not easily substituted in sectors such as construction, automotive, and packaging. Even under high price conditions, consumption remains stable.

In conclusion, aluminum demand is generally price inelastic. When prices rise, the industry continues to consume aluminum, with only a slight reduction in consumption. This is because aluminum is a fundamental industrial material with few substitutes. Additionally, scrap aluminum—the closest substitute—cannot fully offset price changes.

### 3.4 Strategy Matrix

Based on the two analyses above, we can develop an aluminum processing strategy matrix as shown in Table 1. According to the DKP analysis, Indonesia currently falls into Quadrant 1, where (1) Indonesia is not dominant in the market, and (2) global aluminum demand is relatively

rigid or inelastic. As a non-dominant player, Indonesia's aluminum processing industry remains vulnerable to changes in domestic production costs, making a progressive strategy unfeasible. The optimal approach is a conservative strategy—following the progress of advanced countries (which are the main markets) or dominant countries (which are the main competitors).

Indonesia's position is still somewhat supported by the generally inelastic nature of the global aluminum market. Therefore, Indonesia can adopt a strategy that is moderately conservative rather than overly cautious. This means Indonesia need not be overly concerned, as the market is relatively rigid.

Indonesia can still improve its overall ESG standards, including the use of renewable energy, but should remain behind advanced and dominant countries to avoid production cost increases beyond those of its competitors.

## 4 Recommended Strategy

As outlined earlier, Indonesia is positioned in Quadrant 1—as a non-dominant player in the global market with relatively inelastic demand. Based on the MDR matrix, the most appropriate strategy is “moderately conservative.”

### 4.1 Principles of Conservatives-Moderate Strategy

There are three main principles in the moderately conservative strategy.

#### **First, become a follower, not frontrunner.**

Indonesia does not need to position itself as a pioneer in implementing decarbonization policies or enhancing value addition in the aluminum industry. Instead, Indonesia can monitor the actions of advanced economies or dominant players such as China and Canada, then gradually adapt and follow their lead. This approach allows Indonesia to keep production costs competitive while still aligning with the global trend toward more environmentally friendly aluminum production.

### **Second, leverage opportunities arising from rising global standards.**

Every progressive policy adopted by advanced economies—such as the European Union’s Carbon Border Adjustment Mechanism (CBAM)—can present strategic opportunities for Indonesia. By aligning its production standards to meet these requirements, Indonesia can avoid carbon tariffs and gain access to premium markets in the EU. This principle also helps Indonesia steer clear of direct competition with low-cost, high-carbon aluminum producers such as China.

### **Third, focus on gradual efficiency improvements and the adoption of proven technologies.**

Another key principle is the adoption of technologies that have been proven effective and commercially viable, such as the use of available renewable energy and the expansion of recycled aluminum. More advanced decarbonization technologies, such as inert anodes, can be considered in the long term once they have matured at the global industrial level.

## **4.2 Recommended Strategy**

### **Withdrawal of Tax Holiday Incentives**

Tax holiday incentives currently granted to processing industries should be discontinued. This scheme has proven ineffective in the long term, as it reduces potential state revenue and diminishes overall economic value. In the nickel sector, for example, tax holidays led to extremely low production costs, triggering allegations of dumping. This ultimately resulted in China imposing a 20.2% anti-dumping tariff on Indonesian nickel products. For comparison, in 2024 the Chinese government also revoked a 13% rebate scheme for aluminum exports in response to dumping accusations from Western countries. These cases demonstrate that overly aggressive fiscal incentives not only harm domestic interests but also risk provoking international trade disputes.

### **Ban on the Construction of Captive Coal-Fired Power Plants**

Indonesia needs to adopt environmental standards that are slightly below or on par with those of advanced economies and dominant players such as China. Currently, new aluminum smelters in China no longer rely on captive coal-fired power plants, instead turning to renewable energy sources or electricity from the national grid. Indonesia should follow China's lead to remain competitive and meet global market expectations for low-carbon products. This policy is also aligned with the country's national commitment to achieving net zero emissions by 2060.

### **Enhancement of ESG Standards and Workforce Welfare**

Production cost analysis by Wood Mackenzie indicates that aluminum smelters in Indonesia—particularly Inalum—have competitive cash production costs and rank in quadrant 1 of the global cost curve, comparable to leading smelters in China. This favorable position provides the government with room to gradually raise ESG standards, including transitioning to renewable energy, tightening environmental regulations, and adjusting minimum wages to better align with Chinese standards. This approach will enhance domestic economic value added without significantly reducing global competitiveness.

Beyond maintaining competitiveness, improving ESG standards also creates opportunities to access premium markets in the European Union, which are becoming increasingly stringent following the implementation of the Carbon Border Adjustment Mechanism (CBAM). Indonesia can capitalize on this momentum by building a reputation as a high-standard green aluminum supplier. Enhancing ESG standards opens access to markets with higher price margins while strengthening Indonesia's position in the supply chains of the automotive and electronics industries in Europe, which increasingly demand low-carbon raw materials.

### **International Collaboration for Market Stability**

Although Indonesia is not a major global aluminum producer, its strategic role can be enhanced through economic diplomacy. The government could initiate the formation of an alliance or organization comprising key bauxite, alumina, and aluminum producing countries—such as China, Guinea, Australia, Brazil, India, Canada, and Russia—that functions similarly to OPEC. This collaboration would enable coordinated efforts to maintain the balance of global aluminum supply and demand, thereby stabilizing prices. Such coordination would also facilitate more progressive decarbonization efforts without triggering cost competition among producing countries.

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