

Aluminium Downstreaming Business Development in Indonesia: a PESTEL and Stakeholder Mapping Approach

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ABSTRACT

Background: Downstreaming is an industrial strategy to increase value added from natural resources, and in Indonesia aluminium has strong potential due to large bauxite reserves and rising global demand, yet its downstream development remains constrained by limited alumina capacity and low diversification into higher value-added products.

Purpose: The study aims to provide a comprehensive understanding of how Indonesia's aluminium business model can be strengthened by analyzing external factors influencing downstreaming development and mapping the roles of key stakeholders within the aluminium value chain.

Design/methodology/approach: The study employs a qualitative analytical approach by integrating PESTEL analysis to assess key political, economic, social, technological, environmental, and legal factors influencing aluminium downstreaming, alongside stakeholder mapping to identify actor roles, interests, and interrelationships within the industry ecosystem. Data are collected through desk studies, FGDs, and in-depth interviews, with findings synthesized to inform strategic and policy recommendations for strengthening Indonesia's aluminium industry.

Findings/Result: The results show that government downstreaming policies, increasing global aluminium demand, and domestic bauxite availability support industry development. However, major constraints include high energy requirements, technological dependence, environmental compliance, and regulatory complexity. Stakeholder mapping indicates that effective coordination among government institutions, energy providers, investors, and local communities is essential.

Conclusion: This study concludes that integrated industrial planning, clean energy utilization, regulatory clarity, and stakeholder coordination are required to support sustainable aluminium downstreaming in Indonesia.

Originality/value (State of the art): This study applies an integrated approach combining PESTEL analysis and stakeholder mapping to provide a comprehensive assessment of external factors and actor interactions, offering a framework for policy and collaborative governance in Indonesia's aluminium downstream industry.

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INTRODUCTION

Downstream is an industrial development strategy that aims to increase value added from natural resources through advanced processes, deepened production processes, and expanded domestic manufacturing activities. Aluminium, which is a product of bauxite downstreaming, plays an important role as a strategic material in various high-tech and renewable energy industries, such as electric vehicles, solar panels, electricity transmission networks, and the manufacture of electronic components and construction (Pratiwi, 2025).

Indonesia has a strategic position in downstreaming aluminium product, because it has primary bauxite reserves of around 1.2 billion tonnes, or 4% of the world's reserves (Putri, 2022). The potential of these resources provides a foundation for the development of an integrated aluminium industry from upstream to downstream. In terms of opportunities, the development of aluminium downstreaming is also becoming more open in line with global and national demand growth. Global aluminium consumption is increasing by around 3-4 per cent per year, mainly driven by the electrification of transportation, the expansion of renewable energy, and the need for lightweight materials in manufacturing.

However, Indonesia currently still has been facing various serious challenges in developing aluminium downstream industries. These challenges include Indonesia's dependence on large quantities of imported alumina due to the limited domestic alumina capacity, which currently stands at 2 million tonnes per year (Wahyudi, 2025). In addition, another challenge lies in the low diversification of downstream aluminium products in Indonesia. This is evident in the fact that Indonesia is still focused on the production of basic products such as ingots, billets, and sheets, while high value-added products such as aluminium tubes, alloy forgings, LED components, and sapphire glass have not been developed adequately.

Through these various barriers to downstreaming, this article aims to provide a more comprehensive understanding of how the aluminium business model in Indonesia can be strengthened, given that downstreaming development is also influenced by various external factors, such as global market dynamics, technological developments, sustainability demands, economic conditions, and policy changes, all of which affect the direction and pace of industry growth. On the other hand, the success of downstreaming is also largely determined by the involvement and alignment of the roles of stakeholders, ranging from the central and regional governments, state-owned enterprises, industry players, to private investors. Therefore, refining the aluminium downstreaming business model is an important step so that the development of this industry can be more focused, adaptive, and sustainable.

Given the nature of these questions, this study adopts a qualitative, exploratory-analytical design rather than a hypothesis-testing approach. It does not seek to statistically test causal relationships or estimate the magnitude of individual factors; instead, it aims to systematically identify, categorize, and interpret the external factors and actor relationships that shape aluminium downstreaming, drawing on document analysis, focus group discussions, and in-depth interviews. Accordingly, the study is guided by two research questions rather than formal hypotheses: (1) which political, economic, social, technological, environmental, and legal factors enable or constrain the development of aluminium downstreaming businesses in Indonesia; and (2) which stakeholders hold the greatest power and interest in this process, and how should they be engaged? The expected outputs are an external factor map of the aluminium downstreaming ecosystem and a stakeholder engagement framework, which together inform the business model discussion and policy recommendations.

METHODS

The data collection method in this study is systematically designed to ensure that the data obtained is comprehensive, valid and able to describe the complexity of external factors in downstream policy making of the aluminium industry. The study used a multi-source qualitative approach that triangulated desk studies, focus group discussions (FGDs), and in-depth interviews. The FGDs and in-depth interviews convened relevant key stakeholders, including representatives from government ministries, the private sector, associations,

and other parties involved in related issues. This approach was chosen to understand the interests, perceptions, and interactions among actors involved in the downstream development of the aluminium industry.

The research begins with the preparation and formulation stages of the study focus which aims to determine the scope, analysis objectives and policy focus for the aluminium industry to be studied. At this stage, the output *included the* initial framework of the study, and a list of indicators of external factors as well as a mapping of potential actor groups. The main activities carried out include: (1) the preparation of the conceptual framework and the main indicators of each dimension of PESTEL, and (2) the formulation of research questions and expected outputs. In addition, this stage is carried out to strengthen the data collection process through a mixed method that combines secondary studies; desk studies, focus group discussions, and field visits through in-depth interviews.

The next stage focuses on collecting initial data to identify external factors through a literature review and policy documents. This data collection technique is through a literature study on sectoral policies, national agency reports, international institution reports and academic publications to obtain information and an overview of the development practices of the aluminium industry in other countries, as well as mapping government regulations and policies on the industry. The expected output or targeted output includes: (1) a list of external factors on the six dimensions of PESTEL, and (2) an initial identification of the relevant actors on each PESTEL factor.

After data collection through several relevant sources, output processing is carried out using PESTEL to obtain the linkage of external factors that affect industrial policies through: (1) categorization of factors into six dimensions of PESTEL, (2) analysis of the relationship between factors to obtain causal linkages and find leverage points, (3) synthesis of PESTEL results to determine opportunities, risks, and strategic obstacles for industrial development. The processing of PESTEL data that has been carried out continues to the validation stage, through Focus Group Discussions (FGD) and in-depth interviews to identify and map actors who play a role in the policy system and industrial ecosystem. The FGDs were conducted in December 2025 with representatives from government and industry, with the aim of validating the PESTEL results, identifying actors and their roles, and exploring views on opportunities and obstacles to collaboration in the aluminium industry. Meanwhile, to strengthen the results of PESTEL, field visits and in-depth interviews were conducted to explore the readiness of the industry and the potential of mapping the network of industry players through empirical evidence. Field visits and interviews were conducted with a representative aluminium industry company to understand on-the-ground conditions and to strengthen the collection of information related to actor networks and cross-sector relationships, including collaboration flows and policy-making that affect the aluminium industry. The results of all data desk studies, FGDs, and in-depth interviews will be analyzed simultaneously to ensure the consistency and validity of the information which

is then synthesized into a map of the relationship between external factors and industry policy actors so that it can produce the output of a sustainable aluminium industry business policy model.

Pestel Analysis

This study adopts a PESTEL (Political, Economic, Social, Technological, Environmental, Legal) analysis approach to examine and evaluate macro external factors that have the potential to affect the formulation of strategies, sustainability and competitiveness of the Aluminium industry. Through this method, PESTEL analysis plays an important role in identifying external environments such as policies, global economies, social trends, technological developments, environment and legal aspects that can influence the direction and strategy of the development of the Aluminium industry sector (Olayiwola et al., 2025). The same thing was conveyed by Huda et al. (2024) who stated that PESTEL analysis has advantages over SWOT analysis because it is able to identify aspects broadly and recognize the right dimensional components in influencing an industry.

In its application, PESTEL analysis plays a role in detecting opportunities, threats, and external trends that also affect the industrial sector (Nurfauziya & Khalid 2024), identifying barriers that determine the success of implementing industrial innovation policies (Olayiwola et al. 2025), and determining the main factors that open up opportunities for the development of an industry in the context of national (political) policy support, macroeconomic stability, and technology readiness and environmental awareness (Rosyadi & Belgiawan 2022). In this study, PESTEL analysis was used to identify external factors that also affect the downstream development of the aluminium industry. Each dimension of PESTEL will be systematically analyzed to capture opportunities, challenges and risks that can affect the formulation of strategies and program implementation.

The stages in the PESTEL analysis used in mapping the downstream business model of the Aluminium industry are as follows:

Identify External Factors

External factors that also affect the downstream of the aluminium industry are identified through data collection sourced from previous literature reviews, energy policy reports relevant to the aluminium industry, official documents of the Ministry (Energy and Mineral Resources, Industry, Environment and others), as well as scientific publications that discuss the policies and development of the aluminium industry.

PESTEL Six-Dimensional Factor Category

Politics Mapping of government policy support and direction for the bauxite-aluminium industry. Economy Mapping investment costs, access to financing, price fluctuations, and international market demand. Social Mapping of public revenue, and workforce readiness. Technology Mapping of technology innovations, production and technology transfer. Environment Standardization mapping of the environment, opportunities and risks for industry Legal Mapping of regulations, technical standards, product certification, and export regulations (Table 1).

Analysis of Relationships Between Factors

This analysis was conducted to qualitatively examine the interrelationships between factors, as identified through the literature and validated by stakeholders, to help uncover the mechanisms that underpin the success of aluminium industry strategies. Analysis of the relationship between factors is carried out to identify leverage points that are important for formulating policy interventions. In addition, an analysis of the relationship between factors is carried out to minimize policy overlap and ensure that each intervention can target the root causes (Pan, et al., 2019; Nurfauziyah & Khalid, 2024).

Synthesis of Results

The results of PESTEL were then developed into an external strategy map of the industry which became the basis for the preparation of policy recommendations for the development of the aluminium industry business ecosystem.

Table 1. PESTEL Method Categories

Dimension	Code	Description
Political	(P)	Mapping government support and policy direction toward the bauxite-aluminium industry, clean energy, and green industrial development
Economic	(E)	Mapping investment costs, access to financing, price fluctuations, and international market demand.
Social	(S)	Mapping public acceptance, workforce readiness, and perceptions of the energy transition.
Technological	(T)	Mapping production technology innovation and technology transfer.
Environmental	(E)	Mapping energy efficiency, carbon footprint, and industrial waste management.
Legal	(L)	Mapping regulations, technical standards, green product certification, and export regulations.

RESULTS

Pestel Analysis

In the development of aluminium downstreaming in Indonesia, the government plays a crucial role in shaping the direction of the industry. The government encourages bauxite not to be sold merely as a raw material, but to be processed domestically into higher value-added products. To support this objective, various regulations have been introduced, including the ban on raw material exports, aimed at fostering the growth of processing industries such as alumina refineries and aluminium smelters within the country (Kirana & Triantama, 2024; Shinta & Wikarya, 2024). However, political conditions also create uncertainty for business actors. Policies may change with shifts in government, and coordination among sectors such as energy, industry, and the environment has not always been optimal. Moreover, Indonesia's downstreaming policy may trigger trade tensions with other countries, potentially affecting market access and investor interest (Krustiyati & Gea, 2023; Syahrudi & Wahbi, 2025).

Overall, economic conditions indicate that the development of aluminium downstreaming businesses in Indonesia offers substantial opportunities. Growing global aluminium demand through 2029, upward price trends, and abundant domestic bauxite reserves provide a strong foundation for developing aluminium processing industries domestically (Zahara & Mussry, 2025). In addition, relatively affordable labor costs further enhance Indonesia's attractiveness as a manufacturing location (Wulansari, 2021). Nevertheless, these opportunities are accompanied by several challenges, including continued dependence on imported semi-finished products, the impact of a strengthening US dollar on the cost of imported machinery, and intense competition with major global producers. Therefore, aluminium downstreaming business models must be carefully designed to maximize opportunities while minimizing risks.

The development of aluminium downstreaming business models is also strongly influenced by social conditions in the surrounding regions, particularly the availability of skilled labor, local social stability, and community support. Limited local workforce skills require companies to invest in training programs (Andriani, 2021), while continuous industrial operations depend on a safe and conducive social environment. On the other hand, job creation and rising community income can strengthen public support for industrial activities. Community expectations regarding corporate social responsibility and the presence of external experts must be managed carefully to foster harmonious relationships (Anggoro et al., 2021; Rismawati et al., 2023). If opportunities such as workforce training, local government support, and equitable benefit-sharing are optimized, aluminium downstreaming development can proceed more smoothly and sustainably.

From a technological perspective, the development of aluminium downstreaming business models in Indonesia is heavily influenced by the availability and reliability of energy supply, infrastructure readiness, and the ability to adopt environmentally friendly technologies (Abdinagoro & Hamsal, 2022). The utilization of hydropower and recycled aluminium technologies presents opportunities to reduce energy costs and emissions in the long term, thereby enhancing product competitiveness in global markets. However, the industry continues to face significant challenges, including extremely high electricity demand, limited technological and supporting infrastructure, dependence on imported machinery and raw materials, and gaps in local human resource capabilities. Furthermore, the dominance of coal-based energy poses a risk to the transition toward cleaner and more sustainable aluminium production (Parapat & Hasan, 2023).

Environmental aspects of aluminium downstreaming business development present both significant challenges and opportunities. Aluminium production processes generate considerable pollution, particularly because many plants in Indonesia still rely on coal-based electricity (Kirana & Triantama, 2024; Rahman & Raphael, 2025). At the same time, the ban on bauxite exports has increased domestic industrial activity, which may negatively affect air, water, and land quality around industrial zones. These conditions require companies to take environmental management more seriously in order to maintain social acceptance and market access. Simultaneously, opportunities arise from the use of cleaner energy sources such as hydropower and the growing global demand for environmentally friendly aluminium products, although companies must still contend with increasingly stringent environmental regulations and high costs associated with cleaner technologies (Batubara et al., 2024; Fahmi, 2025).

From a legal perspective, the development of aluminium downstreaming business models involves corporate compliance with a wide range of regulations, including business and environmental permits, labor standards, factory site selection, product quality standards, and fair competition rules. These regulations provide legal certainty and security for companies, enhance investor confidence, and expand market opportunities. However, lengthy permitting processes, additional compliance costs, land limitations, and restrictions on cooperation schemes may slow project implementation and increase operational costs. As a result, these challenges must be managed carefully to ensure smooth business operations (Solihah & Mulyadi, 2025; Suroso et al., 2024).

Stakeholder Mapping

The stakeholder mapping presented in Figure 1 illustrates stakeholders involved in the development of aluminium downstreaming business models in Indonesia based on two main dimensions: level of power (vertical axis) and level of interest (horizontal axis). This mapping aims to identify key actors, establish stakeholder management priorities, and formulate appropriate engagement strategies for each group.

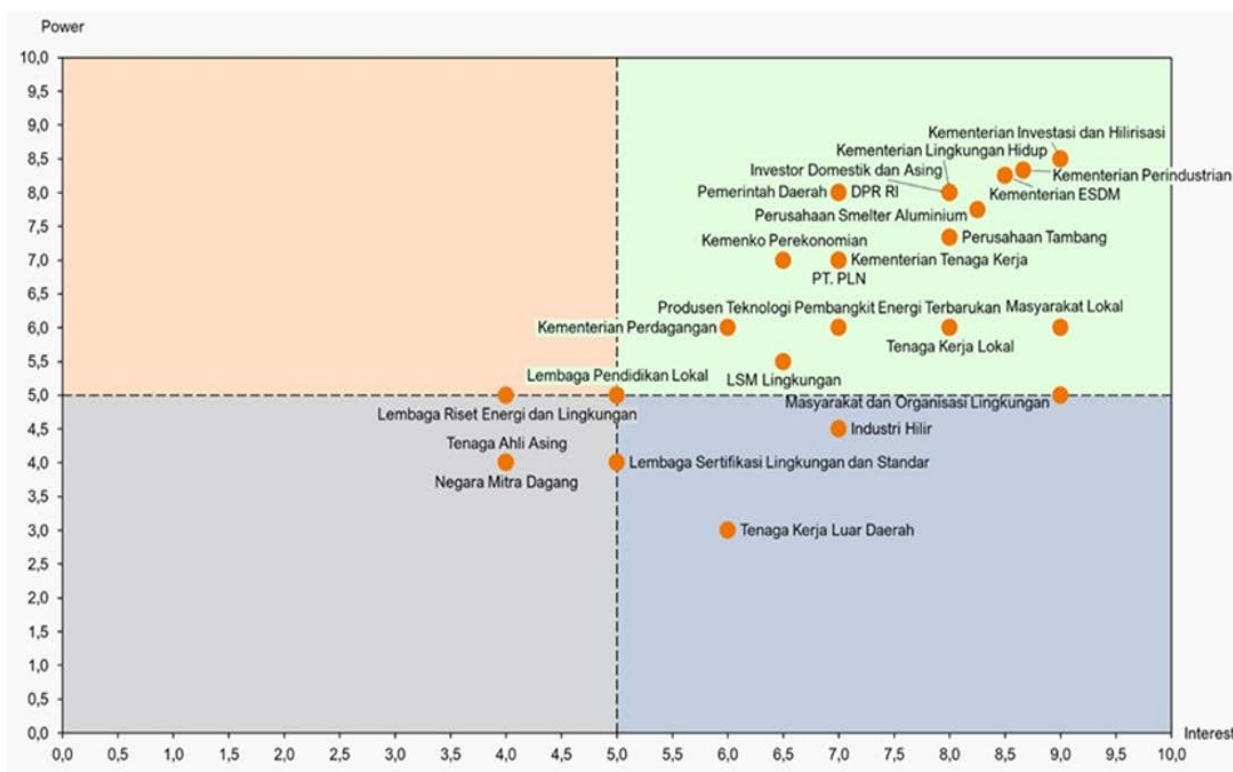


Figure 1. Stakeholder Mapping

High Power – High Interest (Key Players)

Stakeholders located in the upper-right quadrant possess both significant influence and high interest in the success of the project. This group includes the Ministry of Investment and Downstreaming, Ministry of Industry, Ministry of Environment, Ministry of Energy and Mineral Resources, Coordinating Ministry for Economic Affairs, Ministry of Manpower, Ministry of Trade, domestic and foreign investors, aluminium smelter companies, PT PLN, renewable energy technology providers, local communities, and local workers.

High Power – Moderate Interest (Keep Satisfied)

Stakeholders in the upper-left and partially upper-right quadrants have high institutional power but relatively moderate direct interest in the project. Based on the stakeholder mapping results, no stakeholders fall into this category.

Low/Moderate Power – High Interest (Keep Informed)

Stakeholders in the lower-right quadrant are highly affected by or concerned about the project but lack formal decision-making power. This group includes community and environmental organizations, environmental NGOs, non-local workers, and downstream industries.

Low/Moderate Power – Low/Moderate Interest (Monitor)

The lower-left quadrant includes energy and environmental research institutions, foreign experts, trading partner countries, environmental and product certification bodies,

and local educational institutions. These stakeholders do not have regulatory authority or direct involvement in the project's commercial success and are therefore categorized as monitor stakeholders with optional and situational engagement.

Business Model

Indonesia possesses substantial potential to develop its aluminium industry due to abundant bauxite reserves across several regions. With sufficient raw material availability, the development of integrated aluminium industrial zones can be carried out more effectively, encompassing mining, raw material processing, and the production of finished aluminium products for both domestic and global markets. This integration enables more efficient production processes, simplified logistics, reduced transportation costs, and improved coordination across production stages (Zeng, 2016). By optimizing local resource utilization, Indonesia has the opportunity to build a self-sufficient and sustainable aluminium industrial ecosystem.

Government support is a key factor strengthening the prospects of Indonesia's aluminium industry. Policies promoting mineral downstreaming, including domestic processing of bauxite, aim to increase value added (Kirana & Triantama, 2024; Shinta & Wikarya, 2024). These regulations provide investors with long-term policy certainty, signaling the government's commitment to developing strategic industries rather than relying solely on raw material exports. Such policy clarity enables companies to plan long-term investments, including smelter and processing plant construction, with greater confidence and reduced regulatory risk.

The bauxite export ban is a strategic measure to secure raw material supply for domestic industries. This policy allows companies to focus on developing processing facilities without concern over supply shortages. Guaranteed raw material availability enhances investor interest in building smelters and alumina plants by reducing production disruption risks. Moreover, the export ban contributes to a more stable domestic market for bauxite and aluminium products, providing a stronger foundation for future production expansion.

Aluminium downstreaming has been designated as a national priority program, suggesting sustained government support over the long term. This support may take the form of fiscal incentives, simplified permitting, industrial land provision, and accelerated development of supporting infrastructure (Afida & Widodo, 2023). Such conditions increase the attractiveness of aluminium industrial zones for investors by ensuring regulatory protection and institutional backing. Consequently, companies can plan integrated upstream-to-downstream industrial development more effectively, creating a stable and sustainable aluminium production ecosystem.

Nevertheless, high energy demand remains a major challenge in aluminium industry development (Batubara et al., 2024; Tan et al., 2025). Aluminium smelting requires large and stable electricity supplies, making energy efficiency a critical determinant of industrial competitiveness. Although energy costs in Indonesia are relatively affordable compared to some countries, dependence on specific energy sources and supply fluctuation risks can still affect production costs. Therefore, aluminium industrial zones must be designed with efficient and sustainable energy strategies, such as hydropower and other renewable sources (Fahmi, 2025). Effective long-term energy management can reduce production costs while enhancing investment attractiveness and global competitiveness.

Uncertainty surrounding National Strategic Project (PSN) status may influence investment decisions. Projects lacking PSN designation often face obstacles related to permitting, land acquisition, and infrastructure provision, potentially delaying implementation and increasing development costs. Accordingly, ensuring PSN status is essential to strengthen the prospects of aluminium industrial zones by improving project certainty, cost control, and investment risk mitigation. Social factors also play a critical role in aluminium downstreaming business model development. Skilled labor availability remains limited in certain regions, requiring companies to implement training and skill development programs for local workers (Andriani, 2021). Establishing training centers within industrial zones can enhance workforce capabilities, gradually reducing reliance on external or foreign labor. This local human resource development improves productivity while expanding employment opportunities for surrounding communities.

Maintaining social stability around industrial zones is essential for uninterrupted operations. Social disturbances

such as conflicts, protests, or community dissatisfaction can disrupt production and cause significant losses. Therefore, companies must foster positive community relations through CSR programs, open dialogue, and equitable economic benefit-sharing (Kulshrestha et al., 2024). When communities experience tangible benefits from industrial activities, they are more likely to support operations and contribute to social stability.

Job creation represents a significant positive social impact of aluminium industrial zone development. Industrial presence increases household income, generates new business opportunities in logistics, services, and trade, and stimulates local economic growth. These impacts enhance community acceptance and support for downstreaming initiatives, reinforcing long-term investment sustainability.

The presence of foreign experts also provides opportunities for knowledge transfer (Rismawati et al., 2023). Local workers can learn advanced machine operation, processing techniques, and environmentally friendly technologies directly from experts, improving technical capacity and reducing long-term dependence on foreign expertise. This knowledge transfer strengthens the sustainability of industrial operations.

From an economic perspective, rising global aluminium demand over the coming years creates broad market opportunities for Indonesian products (Figure 2). Growing demand from electric vehicles, solar panels, and energy infrastructure sectors positions domestic aluminium production for both domestic and international markets. Meeting this demand enables companies to plan sustainable production expansion and strengthens Indonesia's role in the global aluminium supply chain. Upward aluminium price trends further enhance investment attractiveness (Zahara & Mussry, 2025). Higher selling prices increase profit potential, accelerate capital recovery, and encourage expansion of production facilities. Stable or rising prices support long-term strategic planning, including the development of integrated industrial zones spanning upstream and downstream activities.

Abundant national bauxite reserves constitute a strategic asset for integrated aluminium industry development. Sufficient reserves reduce reliance on foreign supplies, ensuring stable production. Concentrating industrial zones near bauxite-producing regions enables integrated production centers, lowers logistics costs, and improves supply chain efficiency.

Technological challenges persist due to the complexity and high cost of aluminium production equipment. Most advanced technologies must still be imported, exposing companies to price fluctuations and supply risks (Batubara et al., 2024). Well-developed industrial zones must therefore be equipped with adequate technological infrastructure, including maintenance facilities and production control systems, to ensure efficient operations.



Figure 2. Global Primary Aluminium Supply-Demand (in thousand tons)

The use of clean energy sources such as hydropower presents opportunities to reduce costs and environmental impacts. Cleaner energy lowers long-term electricity expenses and produces aluminium products that are increasingly favored in global markets, particularly those emphasizing sustainability. This approach also helps companies respond to international pressure to reduce industrial emissions and enhance environmental reputation (Batubara et al., 2024).

Aluminium recycling represents an important strategy for energy efficiency. Recycled aluminium requires only a fraction of the energy needed for primary aluminium production from bauxite (Raabe et al., 2022). Integrating recycling processes into industrial zones can reduce production costs, lower carbon emissions, and strengthen environmental credentials while utilizing aluminium waste as a sustainable secondary raw material.

Environmental considerations are central to aluminium industrial zone development. Aluminium production, particularly when powered by coal-based electricity, generates significant emissions (Kirana & Triantama, 2024; Rahman & Raphael, 2025). Effective environmental management including waste treatment, emission control, and air and water quality monitoring is therefore essential. Environmentally responsible industrial zones are more socially acceptable, reduce conflict risks, and support long-term operational sustainability.

From a legal standpoint, certainty in business licensing, spatial planning, and product standards provides security for investors. Clear permitting processes and compliance with standards enable smooth operations and reduce legal risks (Solihah & Mulyadi, 2025). Regulatory compliance also expands market access, as aluminium products meeting national and international standards can reach broader export markets (Susanto, 2022). Nonetheless, compliance costs remain a challenge, requiring careful budgeting for workplace

safety, product standards, and environmental obligations. Thorough planning and effective cost management strategies are essential to maintaining profitability while ensuring regulatory compliance.

Overall, the development of aluminium downstreaming business models within integrated industrial zones offers highly promising prospects. With strong government support, abundant local raw materials, clean energy utilization, improved local human resources, sound social relations, and regulatory compliance, aluminium industrial zones can become key drivers of economic growth, job creation, and Indonesia's global competitiveness. With appropriate strategies, existing challenges can be transformed into opportunities to build a strong, self-reliant, and sustainable aluminium industry.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study shows that Indonesia's aluminium downstreaming is shaped by interconnected political, economic, social, technological, environmental, and legal factors, as well as stakeholder relationships. These findings indicate that these factors cannot operate independently in shaping aluminium downstreaming business development in Indonesia. The study demonstrates that industrial development is driven not only by external factors, but also by how these factors are interconnected and coordinated with one another. The findings are consistent with previous studies highlighting the importance of downstreaming policies, bauxite availability, energy supply, technology, and regulatory conditions (Kirana & Triantama, 2024; Shinta & Wikarya, 2024; Batubara et al., 2024; Tan et al., 2025). However, this study extends previous research by showing that these factors cannot be addressed independently. Energy reliability and affordability

must increasingly be considered alongside carbon intensity and environmental performance, while technology transfer depends on skilled labour and supporting infrastructure. Stakeholder mapping further demonstrates that coordination among government institutions, aluminium producers, energy providers, investors, and local communities is critical to implementation.

Recommendations

Theoretically, this study extends the application of PESTEL and stakeholder perspectives to industrial downstreaming by showing that external environmental factors and stakeholder relationships jointly shape industrial development. This suggests that the effectiveness of external conditions, such as policies, energy availability, technology, and regulations, depends not only on their individual characteristics but also on their interconnections and the capacity of relevant stakeholders to coordinate them. In this sense, the study broadens conventional PESTEL-based analysis from identifying external factors toward understanding their interdependencies within an industrial ecosystem. The study therefore recommends integrated industrial planning, reliable and cleaner energy supply, technology and workforce development, regulatory clarity, environmental management, and structured stakeholder engagement.

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