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How Indonesia's Mining Sector Can Support a Just and Sustainable Energy Transition Through an Integrated Sustainability Framework

Muhammad Rizki Aflahul Muzhidin[1,2*], Sahat Hutajulu[1], Yos Sunitiyoso[1], Pri Hermawan[1]

[1] School of Business and Management, Bandung Institute of Technology, 40132 Bandung, Indonesia
[2] Manufacturing Engineering, Bandung Polythecnic of Manufacturing, 40135 Bandung, Indonesia

[*] Correspondence: Muhammad Rizki Aflahul Muzhidin (rizkiaflahulm@gmail.com)

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Abstract: Indonesia occupies a strategically important position in the global energy transition because it is both a major producer of transition minerals and a country pursuing domestic decarbonization. This article develops an integrated sustainability framework to examine how Indonesia's mining sector can contribute to a just and sustainable energy transition without reproducing carbon-intensive, socially uneven, and weakly governed development pathways. The study adopts a mixed-method design that combines a targeted literature review, policy analysis, and triangulation of secondary data from official and authoritative sources on mineral production, electricity generation, national energy planning, and climate commitments. The results identify four interdependent sustainability tensions that shape the sector's transition role: value-added industrialization versus decarbonization, investment acceleration versus governance quality, export competitiveness versus ecological integrity, and national strategic gains versus local distributive justice. In response, the article proposes an integrated framework structured around four pillars: environmental integrity, social justice and inclusion, economic transformation, and adaptive governance. The framework is translated into five policy pathways: decarbonizing mine and smelter power supply, strengthening environmental, social, and governance (ESG)-linked permitting and monitoring, expanding local value capture and community safeguards, aligning mineral strategy with electricity and climate planning, and institutionalizing transition metrics for accountability. The article concludes that Indonesia's mining sector should not be evaluated solely through output growth or downstream investment, but through its capacity to deliver low-carbon industrial value, equitable development, and credible environmental stewardship. The framework contributes a policy-relevant tool for governments, firms, and researchers seeking to govern critical-mineral expansion in ways that support long-term sustainability and a just transition.

Keywords: Energy transitions; Mining sustainability; Critical minerals; Mining governance; Sustainable mining framework; Sustainability governance; Environmental integrity; ESG

1. Introduction

1.1 The Global Transition-Mineral Context

The global energy transition has increased the strategic importance of countries that supply minerals required for batteries, electric vehicles, transmission infrastructure, and other low-carbon technologies (Carr-Wilson et al., 2024; Sovacool et al., 2020). At the same time, the expansion of transition-mineral extraction introduces new environmental, social, and governance (ESG) challenges, meaning that mining cannot be assessed only through output growth or supply-security metrics, but must also be evaluated through its wider sustainability implications (Lèbre et al., 2020; Marín & Goya, 2021). The primary objective of this article is to develop an integrated sustainability framework that can evaluate whether Indonesia's mining sector is contributing to a just and sustainable energy transition in systemic rather than sectoral terms. In this study, a just transition in a mining context refers to governance arrangements that protect environmental health and livelihoods, ensure meaningful local participation, benefit-sharing, and grievance mechanisms, and distribute the risks and benefits of mining

more fairly across actors and territories (Lo et al., 2024; Owen et al., 2022; Rosada, 2025). This framing is consistent with recent sustainability research that emphasizes the need for integrated analytical frameworks capable of linking environmental, social, economic, and governance dimensions rather than treating them in isolation (Chang et al., 2024; Ha et al., 2026).

1.2 Indonesia's Strategic Paradox

Indonesia occupies a particularly important position in this debate. The country is the world's leading nickel producer, with the U.S. Geological Survey (USGS) reporting estimated nickel mine production of 2.6 million metric tons in 2025 and reserves of 62 million metric tons, placing Indonesia at the center of global supply chains for transition minerals (USGS, 2026). At the same time, Indonesia is pursuing domestic decarbonization through national climate and energy planning. The Second Nationally Determined Contribution reaffirms the country's commitment to achieving net-zero emissions by 2060 or sooner (Republic of Indonesia, 2025), while the 2025–2034 Electricity Supply Business Plan targets 69.5 GW of additional power capacity, of which about 76% is planned to come from renewable energy and storage (Ministry of Energy & Mineral Resources, 2025). These conditions make Indonesia a critical case for examining whether mineral-based industrialization can genuinely support sustainability rather than deepen carbon lock-in and socio-ecological pressures. At the same time, mining is a major source of greenhouse gas emissions, pollution and socio-environmental conflict, creating a tension between its enabling role and its sustainability footprint (Ali & Kim, 2024; Lèbre et al., 2020).

Recent scholarship suggests that this tension is empirically evident. Lo et al. (2024) found that nickel mining in Indonesia reduced forest cover and produced mixed well-being outcomes, indicating that mineral expansion can generate uneven local consequences. Wahyono et al. (2024) further showed that Indonesia's critical mineral mining and processing industries may create substantial environmental and human health impacts, with electricity use and carbon emissions emerging as major contributing factors. In parallel, Rosada (2025) argued that environmental governance reforms in Indonesia's nickel sector have often been reactive and face implementation challenges in practice. Together, these studies suggest that the sustainability implications of Indonesia's mining boom extend far beyond extraction economics and require closer attention to governance quality, ecological protection, and distributive justice. Recent studies highlight the need for integrated rather than fragmented approaches to transition analysis. In Vietnam, Ha et al. (2026) argued that an integrated analytical framework is needed to evaluate energy transition, energy intensity, economic growth, and financial development simultaneously rather than in isolation. Similarly, Chang et al. (2024) showed that broad sustainability and Sustainable Development Goal (SDG) objectives often require a more operational evaluation tool, and that ESG-based frameworks can provide a more comparable basis for policymaking and resource allocation. Taken together, these insights suggest that Indonesia's mining sector should be assessed through a framework that connects decarbonization, industrial transformation, social outcomes, and governance, rather than through single indicators alone.

1.3 Research Gap and Objectives

At the same time, existing studies remain fragmented. Some focus on environmental and health burdens, others on mineral security, industrial policy, or downstreaming strategy. For example, Aisyah et al. (2024) proposed a critical mineral security index for Indonesia that encompasses ESG dimensions, demonstrating that policy evaluation is already moving toward a multidimensional assessment. However, the literature still lacks an integrated framework that connects mining expansion, sustainability performance, and just transition objectives in a single analytical structure. As a result, policymakers and industry actors still have limited guidance on how to evaluate whether Indonesia's mining sector is contributing to a sustainable energy transition in systemic rather than sectoral terms. Indonesia exemplifies this dual role; the country has committed to achieving net-zero emissions by 2060, while remaining one of the world's largest producers and exporters of coal and a leading supplier of critical minerals such as nickel, copper and bauxite (Heijlen & Duhayon, 2024). In 2023, the mining sector contributed approximately 2.2 quadrillion Indonesian rupiah to the national GDP and attracted USD 7.46 billion in investment, underscoring its macroeconomic significance. According to the latest USGS estimate, Indonesia held approximately 62 million metric tons of nickel reserves in 2025 (USGS, 2026).

Existing studies remain fragmented. Some focus on environmental and health burdens, others on mineral security, industrial policy, downstreaming strategy, or local well-being. This fragmentation is problematic because policymakers and industry actors cannot evaluate whether mining contributes to sustainability in systemic rather than sectoral terms when the relevant evidence is dispersed across separate debates. Recent studies similarly advocate or a holistic approach to transition analysis, highlighting that sustainability evaluations are more effective when environmental, social, economic, and governance factors are considered together (Chang et al., 2024; Ha et al., 2026).

To address this gap, the study develops an integrated sustainability framework organized around four

interdependent dimensions: environmental integrity, social justice and inclusion, economic transformation, and adaptive governance. This framework is intended to function as a systemic evaluation tool for Indonesia's mining–energy transition nexus and as a decision-oriented structure that can translate evidence into policy pathways. In line with recent research showing that policy instruments become more effective when paired with measurable indicators and adapted to context (Patil et al., 2025; Thirakulwanich et al., 2025), the framework is designed to support both analytical interpretation and practical governance.

As illustrated in Figure 1, these research questions directly target the complex relationships among mining, ESG pressures, stakeholders, energy systems, and net-zero objectives. First, what major sustainability tensions currently shape the role of Indonesia's mining sector in the energy transition? Second, how can these tensions be synthesized into an integrated sustainability framework organized around environmental, social, economic, and governance dimensions? Third, what policy pathways are needed to align mining development with just transition objectives in Indonesia? Together, these questions guide the movement from evidence to tensions, from tensions to pillars, and from pillars to policy pathways.

To clarify the system boundaries and interrelationships examined in this study, Figure 1 presents a modular conceptual map of the mining–energy transition nexus in Indonesia. The figure groups the analysis into three linked modules—inputs and drivers, the mining–energy transition nexus, and sustainability outcomes—to show that the pathway from mining-based development to net-zero emissions is mediated by regulatory conditions, investment, technological capability, institutional actors, and environmental-social constraints.

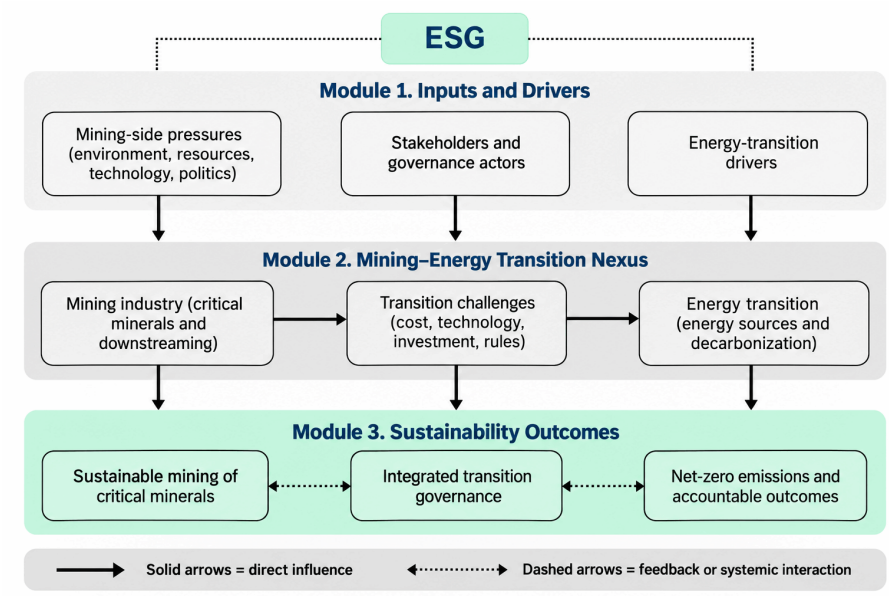

Figure 1. Conceptual relationship between Indonesia's mining industry, sustainability, and the energy transition
Note: ESG, environmental, social, and governance.

2. Methodology

2.1 Research Design

Methodologically, this study uses integrated analytical structures to connect multiple sustainability drivers within a single evaluative model. Rather than isolating a single variable or performance dimension, the present study synthesizes evidence from environmental, social, economic, and governance domains to generate a policy-relevant framework for transition-oriented decision-making (Chang et al., 2024; Ha et al., 2026).

Rather than testing a single causal hypothesis, the study aimed to build an integrated sustainability framework grounded in evidence from multiple sources. The qualitative component was used to identify recurring themes, governance tensions, and transition dilemmas in the Indonesian mining sector, while the quantitative component was used to situate those themes within observable sectoral trends such as mineral production, trade, electricity planning, and climate policy direction. This whole-system orientation is consistent with mining scholarship showing that ESG risks, social legitimacy, and operational decisions are dynamically interconnected and should be incorporated into strategic mine planning rather than treated as separate compliance issues (Verrier et al., 2022). The approach is also appropriate for framework-oriented sustainability research because it supports both analytical depth and policy relevance.

2.2 Evidence-Based and Source Selection

Table 1 provides an overview of the core evidence used in this study. The evidence base consisted of three complementary streams. The first stream was scholarly literature identified through Scopus and Google Scholar. Scopus was selected because it is a comprehensive abstract and citation database curated through an independent content-selection process, while Google Scholar was used to broaden coverage across interdisciplinary and policy-relevant scholarly materials. The search process focused on keyword combinations such as Indonesia, mining, nickel, critical minerals, energy transition, sustainability, ESG, just transition, downstreaming, and governance. The literature search prioritized peer-reviewed journal articles, review papers, and high-quality conference or policy-relevant academic outputs published in English.

Table 1. Evidence synthesis from literature, policy, and secondary data

Sources	Type of Source	Main Focus	Sustainability Dimension	Relevance to Framework Construction
Berg et al. (2022); Mancini & Sala (2018)	Journal literature	Transparent ESG measurement and mining social-impact indicators	Social justice and inclusion; Adaptive governance	Supports the design of credible transition metrics and dashboards
Ha et al. (2026); Lèbre et al. (2020); Marín & Goya (2021)	Journal literature	Mining as a sustainability-governance issue in the energy transition	Environmental integrity; Economic transformation; Adaptive governance	Establishes the global conceptual rationale
Lo et al. (2024); Wahyono et al. (2024)	Journal literature	Forest loss, pollution, health burdens, and mixed local well-being outcomes	Environmental integrity; Social justice and inclusion	Grounds the framework in empirical socio-ecological evidence
Aisyah et al. (2024); Chang et al. (2024)	Journal literature	ESG-linked and multidimensional sustainability assessment	Adaptive governance; Economic transformation	Supports the need for integrated evaluation
Ali & Kim (2024); Lahadalia et al. (2024)	Journal literature	Downstreaming, value-added industrialization, and strategic positioning	Economic transformation; Adaptive governance	Supports the opportunity side of transition-mineral development
Ministry of Energy & Mineral Resources (2025); Republic of Indonesia (2025); Rosada (2025)	Journal literature + policy documents	Governance gaps, regulatory response, and planning alignment	Adaptive governance; Environmental integrity	Supports the governance pillar and policy-pathway design
Lo et al. (2024); van der Zwaan et al. (2019)	Journal literature	Participation, local legitimacy, and fair distribution of risks and benefits	Social justice and inclusion; Adaptive governance	Supports mining-specific just transition logic
BPS-Statistics Indonesia (2025a); BPS-Statistics Indonesia (2025b); UNECE (2024); USGS (2026)	Official statistics and sectoral datasets	Nickel production, reserves, GDP, exports, and strategic national position	Economic transformation; Social justice and inclusion	Anchors the framework in descriptive sector evidence
58 core studies screened from Scopus and Google Scholar	Scholarly evidence base	Broad thematic support across mining, sustainability, governance, transition, and downstreaming	All four dimensions	Basis for evidence → tensions → pillars → pathways

Note: ESG, environmental, social, and governance.

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sustainability, ESG, just transition, downstreaming, and governance. The literature search prioritized peer-reviewed journal articles, review papers, and high-quality conference or policy-relevant academic outputs published in English.

The second stream comprised policy and institutional documents obtained from official and authoritative public repositories. These included Indonesia's Second Nationally Determined Contribution from the United Nations Framework Convention on Climate Change (UNFCCC) repository, the Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik, RUPTL) of the State Electricity Company (Perusahaan Listrik Negara, PLN) for 2025–2034 policy announcement and associated materials from the Ministry of Energy and Mineral Resources, and official statistical publications from BPS-Statistics Indonesia on exports and gross domestic product. These documents were selected because they provide the formal policy baseline against which the sustainability role of mining can be assessed, especially in relation to climate commitments, power-sector planning, macroeconomic performance, and trade structure (BPS-Statistics Indonesia, 2025a; BPS-Statistics Indonesia, 2025b; Ministry of Energy & Mineral Resources, 2025; Republic of Indonesia, 2025).

The third stream consisted of sectoral and commodity-level reference data, particularly on nickel, obtained from the USGS. These data were used to position Indonesia's mining sector within the broader global transition-mineral landscape and to support descriptive interpretation of the country's strategic role in mineral supply chains (USGS, 2026). Taken together, the three evidence streams allowed the study to connect academic debates, policy commitments, and sectoral indicators within one analytical design.

2.3 Inclusion Criteria and Analytical Boundaries

To keep the analysis focused, the literature and documents included in this study had to meet two conditions. First, they had to relate directly to Indonesia's mining sector, with particular attention to nickel and other transition-relevant minerals. Second, they had to engage at least one of the following dimensions: environmental sustainability, social impacts, governance, industrial transformation, energy transition, or just transition. Studies dealing exclusively with geological exploration, mineral processing chemistry, or plant-level engineering performance were excluded when they did not connect their findings to wider sustainability or policy questions.

The study covered materials published mainly in the last decade, while allowing the inclusion of earlier seminal works when necessary for conceptual grounding. This time boundary was chosen to capture the period in which Indonesia's downstreaming agenda, transition-mineral debates, and climate-policy commitments became more prominent in both scholarship and policy practice. Because the aim was framework development rather than exhaustive meta-analysis, the review was designed as a targeted and transparent evidence synthesis, informed by the reporting logic of PRISMA 2020 but not limited to a full systematic review protocol (Page et al., 2021). Instead, a PRISMA-lite logic was used, evidence was identified across the three source streams, screened for Indonesia relevance and sustainability content, and then retained only when it could contribute directly to framework construction. The primary database search in Scopus yielded 678 records, which were screened for relevance to Indonesia's mining sector, transition minerals, and sustainability governance. After title, abstract, and eligibility screening, 356 records were retained for closer relevance assessment, 105 studies were selected for deeper analytical review, and 58 core studies were used in the final structured evidence synthesis. Google Scholar was used as a supplementary search source to broaden interdisciplinary coverage and to identify additional policy-relevant and cross-referenced studies not always captured through Scopus. Because Google Scholar was used mainly for supplementary retrieval and verification rather than as the primary reproducible search database, its results were not treated as a separate final evidence pool in the same way as the Scopus records.

2.4 Analytical Procedure

The analysis was conducted in four stages. In the first stage, the collected literature, policy documents, and statistical sources were systematically reviewed and organized in a structured extraction matrix. For each source, bibliographic information, document type, institutional origin, analytical focus, and relevance to the mining–energy transition nexus were recorded. This stage created an auditable evidence base and reduced the risk of relying on isolated or uncontextualized findings.

In the second stage, the study applied document analysis as a systematic procedure for reviewing, evaluating, and synthesizing textual materials. Bowen (2009) defined document analysis as a systematic procedure for reviewing or evaluating both printed and electronic materials, with the purpose of eliciting meaning, gaining understanding, and developing empirical knowledge. This method was suitable because the present study relied substantially on policy documents, institutional reports, statistical publications, and prior research rather than on interviews or surveys.

In the third stage, the study used thematic analysis to identify recurrent patterns across the evidence base. Following Braun & Clarke (2006), coding proceeded through familiarization with the data, generation of initial codes, clustering of related codes into candidate themes, reviewing and refining themes, defining and naming

themes, and then integrating them into the final analytical narrative. The coding process was partly deductive, because it began with four provisional sustainability dimensions—environmental integrity, social justice and inclusion, economic transformation, and adaptive governance—and partly inductive, because additional tensions and policy issues were allowed to emerge from the data itself. This combination helped preserve conceptual direction without suppressing context-specific findings.

In the fourth stage, the study conducted descriptive secondary data triangulation. Quantitative indicators were not used for causal econometric estimation, but rather to verify and contextualize the qualitative findings. The indicators included, where available, trends in mineral production and reserves, export structure, gross domestic product, electricity planning, and national climate-policy direction, using data from USGS, BPS, Ministry of Energy & Mineral Resources, and the UNFCCC repository (BPS-Statistics Indonesia, 2025a; BPS-Statistics Indonesia, 2025b; Ministry of Energy & Mineral Resources, 2025; Republic of Indonesia, 2025; USGS, 2026). Cross-source comparison was used to check consistency, and priority was given to the most recent primary or official source where multiple figures existed.

2.5 Framework Development

Framework construction followed a transparent three-step logic. First, recurrent coded patterns from the evidence base were consolidated into four sustainability tensions that captured the most persistent contradictions shaping Indonesia's mining–energy transition nexus. Second, these tensions were reorganized into four evaluative pillars: environmental integrity, social justice and inclusion, economic transformation, and adaptive governance, when the underlying coded issues clustered around a recurring sustainability dimension. Third, the pillars were translated into policy pathways when a governance response addressed one or more tensions, involved more than one pillar, and showed direct relevance to current Indonesian transition debates.

Figure 2 summarizes this staged process from evidence identification and screening to coding, triangulation, and framework construction. The figure is included to make the analytical chain explicit: evidence informs tensions, tensions inform pillars, and pillars are operationalized through policy pathways.

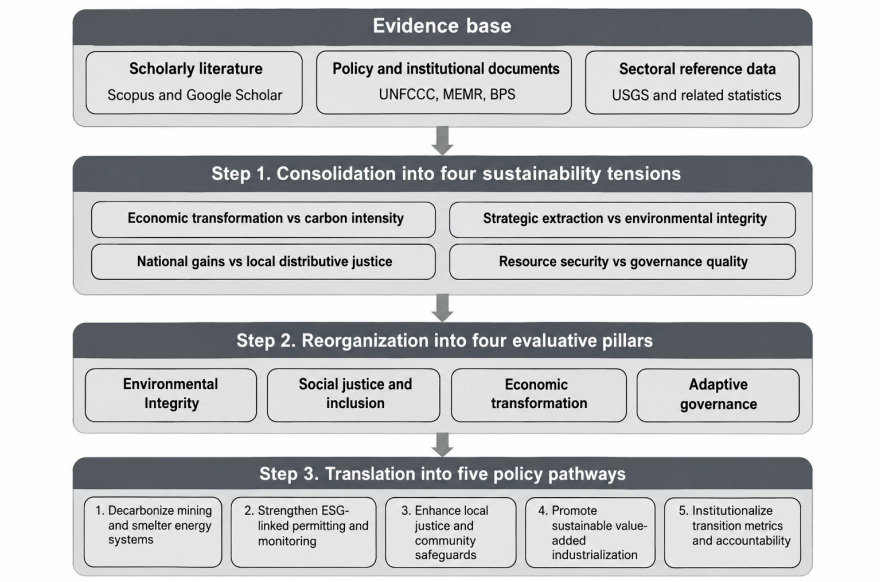

Figure 2. Evidence-selection and framework-construction process
Note: UNFCCC, United Nations Framework Convention on Climate Change; MEMR, Ministry of Energy and Mineral Resources; BPS, Badan Pusat Statistik (Statistics Indonesia); ESG, environmental, social, and governance.

The final framework was developed by synthesizing the coded themes and triangulated indicators into a structured analytical model. The synthesis focused on identifying:

(1) the main sustainability tensions shaping Indonesia's mining sector in the energy transition;
(2) the interactions among environmental, social, economic, and governance dimensions; and
(3) the policy pathways needed to align sectoral development with just transition objectives.

A theme or policy issue was retained in the framework only when it met three criteria: relevance, meaning that it appeared consistently across more than one evidence stream; policy salience, meaning that it had direct implications for current Indonesian transition debates; and integrative value, meaning that it helped connect more than one sustainability dimension. This procedure ensured that the framework was not merely descriptive, but analytically selective and practically useful.

2.6 Research Quality, Ethics, and Limitations

To strengthen research quality, the study relied on source triangulation across academic literature, official policy documents, and public statistical datasets. This improves credibility by reducing dependence on any single type of evidence and by allowing sector narratives to be checked against formal policy and statistical baselines. The methodological emphasis on transparent procedure and documentation is consistent with broader calls in sustainability science for rigorous and well-documented research designs when addressing wicked and transition-related problems (von Wehrden et al., 2019).

Because the study used only publicly available secondary data and published documents, no human participants were involved, and formal ethical approval was not required. The methodological limitation, however, is that this design is stronger for framework development and policy interpretation than for establishing causal relationships. The findings, therefore, should be interpreted as an evidence-based integrative assessment rather than as a causal impact evaluation. Even so, the approach is well-suited to the objective of this article, which is to produce a practical sustainability framework for guiding decision-making in Indonesia's mining sector. To improve transparency in source selection and analytical grounding, the main literature, policy, and secondary data inputs used to construct the framework are summarized in Table 1.

3. Results

3.1 Indonesia's Mining Sector Occupies a Dual Strategic Position in the Energy Transition

The triangulated evidence shows that Indonesia's mining sector occupies a dual strategic position in the energy transition. On the one hand, Indonesia is a globally significant supplier of transition minerals, especially nickel. The USGS reported that Indonesia's nickel mine production reached 2.6 million metric tons in 2025 and that the country held 62 million metric tons of nickel reserves, making it the dominant actor in global nickel supply. On the other hand, Indonesia is simultaneously under pressure to decarbonize its own development pathway. The government's 2025–2034 Electricity Supply Business Plan targets 69.5 GW of additional generating capacity, around 76% of which is planned to come from renewable energy and storage, while the Second Nationally Determined Contribution maintains a net-zero emissions target by 2060 or sooner and expects national emissions to peak by 2030 (Ministry of Energy & Mineral Resources, 2025; Republic of Indonesia, 2025; USGS, 2026). These findings indicate that Indonesia is not merely a supplier for other countries' transitions; it is also a country whose own energy system, industrial structure, and environmental governance must transition at the same time.

This dual position creates a structural paradox. The same mining sector that is expected to support decarbonization through critical-mineral supply is also embedded in a national economy still managing carbon-intensive infrastructure, industrial expansion, and uneven governance capacity. As a result, the role of mining in Indonesia's energy transition cannot be understood through output growth alone. The results of the evidence synthesis instead show that the sector's transition contribution is mediated by four interconnected tensions: economic transformation versus carbon intensity, strategic extraction versus environmental integrity, national gains versus local justice, and resource security versus governance quality. These four tensions emerged consistently across the literature, policy documents, and sectoral reference data reviewed in the study. Figure 3 visually anchors Indonesia's strategic importance by comparing its nickel production and reserves with those of other major producing countries.

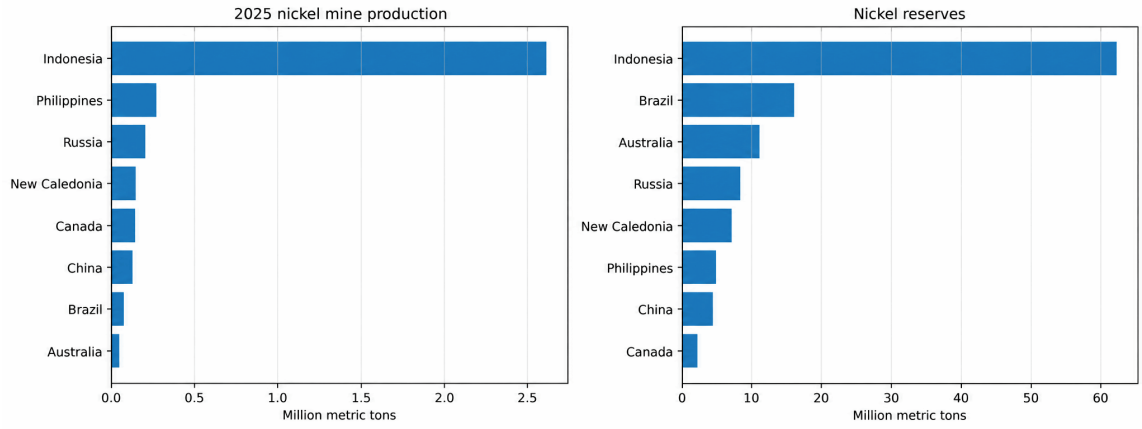

Figure 3. Indonesia's strategic importance in the global nickel supply compared with other major producing countries

Source: U.S. Geological Survey, Mineral Commodlity Summaries 2026 (2025 production: reserves).

3.2 Four Major Sustainability Tensions Shape the Mining–Energy Transition Nexus

The first major tension identified is economic transformation versus carbon intensity. The reviewed literature shows that Indonesia's downstreaming strategy has been framed as a pathway toward higher domestic value-added, stronger industrial capability, and deeper participation in the electric-vehicle and battery supply chain. Lahadalia et al. (2024) described Indonesia's nickel downstreaming strategy as a form of sustainable industrial policy intended not only to stimulate economic growth but also to support the energy transition and reduce inequality in eastern Indonesia. However, the environmental evidence points to a countervailing risk: Wahyono et al. (2024) found that Indonesia's critical-mineral mining and processing industries may generate significant environmental and human-health burdens through pollutant releases, material use, and energy consumption. The result is that industrial upgrading and sustainability do not automatically move together; without low-carbon energy inputs and tighter environmental controls, downstreaming may increase value capture while still reproducing high-emission and high-pollution development patterns. Recent global evidence further indicates that biomass-carbon losses associated with vegetation clearance at nickel mines are frequently omitted from corporate reporting and may be material relative to the operational emissions of nickel extraction and processing (Mervine et al., 2025).

The second tension is strategic extraction versus environmental integrity. Across the reviewed evidence, environmental pressure emerges not as a peripheral concern but as a central feature of current mining expansion. Lo et al. (2024) found that deforestation in nickel-mining villages in Sulawesi nearly doubled between 2011 and 2018, and that environmental well-being continued to deteriorate in later stages of mining production. Their findings suggest that the physical expansion of nickel mining is occurring in ecologically sensitive landscapes, with biodiversity and land-cover implications that are difficult to reconcile with strong sustainability claims. Rosada (2025) similarly argued that environmental governance reforms in Indonesia's nickel sector have often been reactive and remain constrained by implementation challenges. The combined result is that industrial expansion is moving faster than the institutional consolidation needed to ensure ecological integrity. Figure 4 illustrates the spatial concentration of major nickel mining and smelting hubs relevant to these tensions in eastern Indonesia.

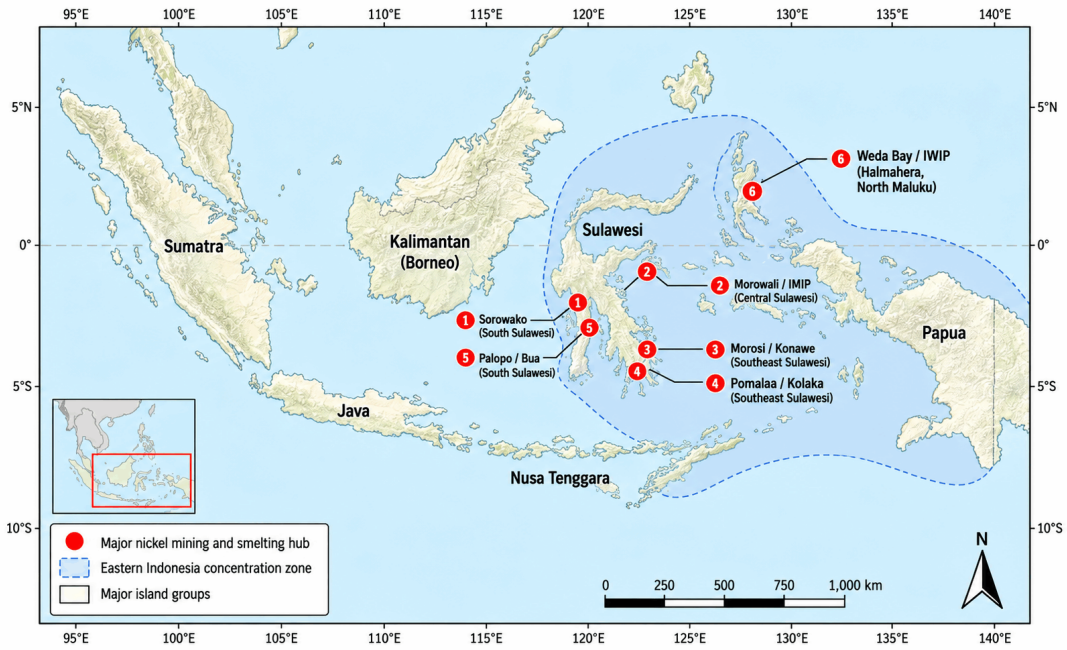

Figure 4. Schematic location of major nickel mining and smelting hubs relevant to Indonesia's spatial sustainability tensions

The third tension is national strategic gains versus local distributive justice. The evidence does not support a simple conclusion that mining-led transition development automatically improves local welfare. Lo et al. (2024) showed that nickel mining produced mixed well-being outcomes: some villages experienced improvements in infrastructure, health, or living standards, but these gains were offset by worsening environmental conditions and uneven social effects, especially in poorer areas. This means that local communities may bear disproportionate environmental and social costs even when national indicators point to successful investment attraction or industrial expansion. The results, therefore, indicate that a just transition in the mining sector cannot be inferred solely from macroeconomic performance. It must be assessed through how benefits, risks, and decision-making power are

distributed across localities, social groups, and stages of the mineral value chain.

The fourth tension is resource security versus governance quality. Aisyah et al. (2024) proposed a national Critical Mineral Security Index for Indonesia built around four dimensions: availability, accessibility, technology-efficiency, and ESG. Their study is important because it shows that resource-security thinking in Indonesia already requires sustainability variables to be part of the assessment framework. At the same time, their results assign the greatest weight to availability, suggesting that supply security remains the dominant policy lens. When read alongside assessment by Rosada (2025) of reactive environmental governance, this indicates that Indonesia's critical-mineral strategy still risks prioritizing scale and access over institutional robustness and sustainability performance. In other words, governance is recognized as necessary, but not yet fully positioned as the organizing principle of transition-mineral development. The four tensions identified in the analysis are synthesized in Table 2, together with their supporting evidence, main sustainability implications, and related framework pillars.

Table 2. Major sustainability tensions in Indonesia's mining sector

Tension	Description	Supporting Evidence	Main Sustainability Implication	Related Framework Pillar(s)
Economic transformation vs. carbon intensity	Downstreaming and mineral processing can increase domestic value-added and industrial capability, but may also increase energy demand, emissions, and pollution when powered by carbon-intensive systems	Lahadalia et al. (2024); Ministry of Energy & Mineral Resources (2025); Wahyono et al. (2024)	Industrial upgrading does not automatically deliver low-carbon development	Economic transformation; Environmental integrity
Strategic extraction vs. environmental integrity	Expansion of nickel mining contributes to global transition supply chains, but can intensify deforestation, biodiversity loss, pollution, and land-use pressure	Lo et al. (2024); Rosada (2025)	Transition-mineral extraction can undermine ecological sustainability if safeguards are weak	Environmental integrity; Adaptive governance
National gains vs. local distributive justice	National export growth, investment, and industrial policy gains may not be evenly shared at the local level, where communities bear environmental and social costs	Lo et al. (2024)	Just transition requires distributional fairness, participation, and local protection	Social justice and inclusion; Economic transformation
Resource security vs. governance quality	Critical-mineral strategy often prioritizes resource availability and industrial access, while governance systems for ESG performance, monitoring, and enforcement lag behind	Aisyah et al. (2024); Rosada (2025)	Supply security without strong governance increases sustainability risk	Adaptive governance; Environmental integrity; Social justice and inclusion

Note: ESG, environmental, social, and governance.

3.3 The Evidence Converges on a Four-Pillar Integrated Sustainability Framework

The structure of this framework is also consistent with recent studies on sustainability evaluation systems. Chang et al. (2024) demonstrated that framework-based sustainability assessment becomes more useful for policy when it offers a comparable basis for evaluation and helps guide resource allocation, while Thirakulwanich et al. (2025) showed that policy instruments become more meaningful when paired with indicators such as technology adoption and environmental impact. In this article, the four pillars and five policy pathways therefore function not

only as a conceptual model but also as a practical basis for future monitoring of mining transition performance in Indonesia. The first pillar, environmental integrity, captures issues related to land-use change, biodiversity, pollution, waste, water stress, emissions, and the carbon intensity of mining and processing. The second pillar, social justice and inclusion, encompasses community well-being, labor conditions, participation, benefit-sharing, health impacts, and unequal exposure to environmental harm. The third pillar, economic transformation, captures downstream value-added, industrial capability, employment potential, export positioning, and resilience to changes in global technology and mineral markets. The fourth pillar, adaptive governance, captures licensing quality, inter-ministerial policy alignment, data transparency, ESG monitoring, institutional learning, and accountability mechanisms. These pillars did not emerge as isolated categories; rather, they repeatedly appeared in the evidence as interacting determinants of whether mining expansion contributes to sustainable transition outcomes.

These relationships are synthesized in Figure 5, which visually links the four major sustainability tensions to the four interdependent pillars and the five policy pathways proposed in this study. The framework shows that economic transformation through smelting and downstream processing may increase domestic value capture, but if the associated electricity supply remains carbon-intensive, environmental integrity is weakened. Likewise, investment growth can strengthen employment and infrastructure outcomes, but when governance is weak or public participation is limited, local social acceptance may decline. Conversely, stronger adaptive governance can improve the performance of the other three pillars by aligning industrial policy with environmental safeguards, social accountability, and long-term transition planning.

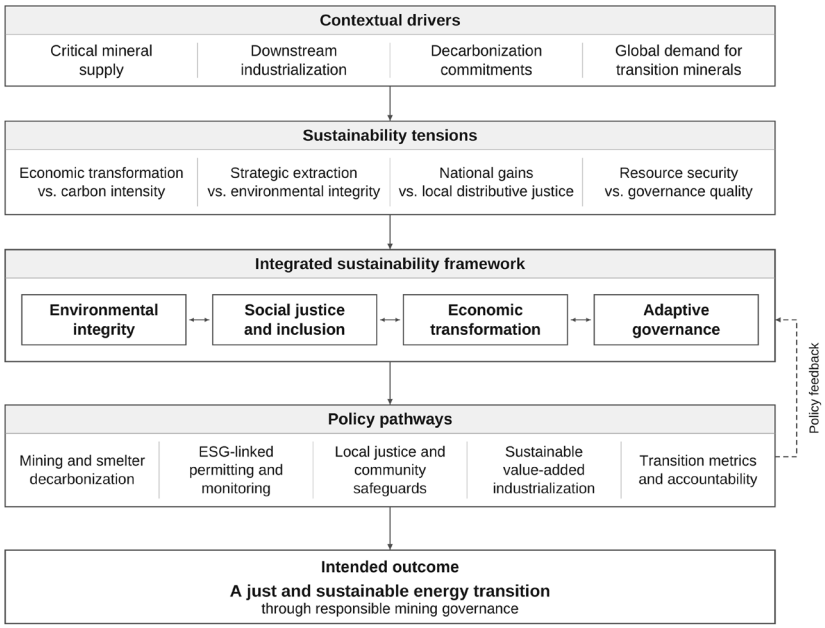

Figure 5. Integrated sustainability framework for Indonesia's mining sector in the energy transition

3.4 Five Policy Pathways Emerging from the Framework

From this framework, five policy pathways were identified. The first is the decarbonization of mining and smelter energy systems, especially through stronger alignment between mineral-industrial strategy and electricity-system transformation. This pathway emerged because the evidence consistently shows that mineral-based industrialization and clean-energy goals cannot be treated as separate agendas. An initial implementation entry point is to require mine and smelter energy plans to assess renewable-electricity integration, energy storage, operational load requirements and regulatory constraints during the project design and permitting stages (Igogo et al., 2021).

The second is ESG-linked permitting, monitoring, and disclosure, reflecting the recurring finding that environmental governance currently lags behind industrial acceleration. An initial entry point is to strengthen existing environmental impact assessment (EIA) requirements in Indonesia for nickel-smelter projects by incorporating explicit criteria for climate, cumulative impacts, social performance, public participation and post-approval monitoring (Kurniawan et al., 2020; Purnama, 2003).

The third is strengthening local justice and community safeguards, including more robust benefit-sharing, health protections, labor safeguards, and meaningful participation in mining-affected areas. An initial entry point is to

require transparent community feedback and grievance mechanisms and to incorporate affected community evaluations into EIA follow-up, corrective action, and compliance monitoring (Kurniawan et al., 2021; Owen et al., 2022).

The fourth is value-added transformation with sustainability conditions, meaning that downstreaming should be evaluated not only by export substitution or investment inflows but also by whether it meets environmental and social performance thresholds.

The fifth is institutionalization of transition metrics, including practical indicators or dashboards that allow governments and firms to assess mining performance across environmental, social, economic, and governance dimensions rather than through production and revenue measures alone.

Each pathway responds to one or more of the tensions identified in Section 3.2. Decarbonizing mining and smelter energy systems primarily addresses the tension between economic transformation and carbon intensity, ESG-linked permitting addresses resource security versus governance quality and supports environmental integrity, local justice and community safeguards respond directly to the tension between national gains and local distributive justice, sustainable value-added industrialization seeks to balance economic transformation with environmental and social conditions; and transition metrics and accountability cut across all four tensions by enabling more anticipatory and evidence-based governance. These pathways are summarized in Table 3, which also identifies the primary actors, indicative monitoring dimensions, and potential implementation barriers.

Table 3. Proposed policy pathways and practical implications

Policy Pathway	Objective	Key Actors	Expected Sustainability Benefit	Example Monitoring Indicators
Decarbonize mining and smelter energy systems	Reduce emissions from extraction and mineral processing by aligning mining growth with renewable electricity and cleaner industrial energy systems	Ministry of Energy and Mineral Resources, PLN, mining firms, smelter operators, investors	Lower carbon intensity, improved climate alignment, stronger global sustainability credibility	Share of renewable energy in mining/smelter operations; emissions intensity per ton of product
Strengthen ESG-linked permitting and monitoring	Integrate environmental, social, and governance performance into licensing, compliance, and reporting systems	Ministry of Energy and Mineral Resources, Ministry of Environment, local governments, mining firms	Better compliance, reduced environmental harm, improved accountability	ESG compliance scores; number of environmental violations; frequency of audits and disclosures
Enhance local justice and community safeguards	Ensure mining benefits are more equitably distributed and local communities are protected from adverse impacts	Local governments, firms, communities, civil society, labor institutions	Greater social legitimacy, reduced conflict, improved well-being and participation	Community development outcomes; grievance cases resolved; local employment share; health indicators
Promote sustainable value-added industrialization	Ensure downstreaming creates domestic value while meeting environmental and social performance standards	National government, industrial parks, mining firms, investors	Higher domestic value-added, more resilient industrial transformation, better long-term competitiveness	Domestic processing share; export value-added; green certification uptake; job creation quality
Institutionalize transition metrics and accountability	Develop measurable indicators to evaluate mining's contribution to a just and sustainable transition	Government agencies, statistical institutions, firms, researchers	More transparent decision-making, evidence-based policy, stronger sustainability governance	National mining sustainability dashboard; integrated ESG-transition index; periodic public reporting

Note: PLN, Perusahaan Listrik Negara (State Electricity Company); ESG, environmental, social, and governance.

Within Indonesia's current institutional context, each pathway also has a plausible initial entry point for implementation. For decarbonizing mining and smelter energy systems, an initial entry point is to integrate

renewable electricity procurement and low-carbon captive power planning into smelter licensing, industrial estate approvals and coordination between PLN and the Ministry of Energy and Mineral Resources under the RUPTL. For ESG-linked permitting and monitoring, an initial entry point is to revise EIA requirements for smelter and industrial-park projects so that climate, labor, and community-performance criteria are assessed explicitly. For local justice and community safeguards, an initial entry point is to strengthen consultation, grievance-redress, and community-development obligations through permit conditions and provincial or district oversight in mining-affected areas. For sustainable value-added industrialization, an initial entry point is to link downstreaming incentives and industrial estate approvals to measurable requirements for energy efficiency, emissions reporting, local employment, and workforce training. For transition metrics and accountability, an initial entry point is to develop a joint reporting dashboard across Ministry of Energy and Mineral Resources, BPS-Statistics Indonesia, and sectoral regulators to standardize periodic disclosure for major nickel mining and processing operations.

4. Discussion

4.1 Mining Should be Understood as a Sustainability-Governance Issue, Not Only a Resource-Supply Issue

The results show that Indonesia's mining sector should not be assessed merely as a supplier of critical minerals for the global low-carbon transition. Instead, it should be understood as a sustainability-governance issue in which environmental integrity, social justice, economic transformation, and institutional capacity are inseparable. This interpretation is consistent with broader sustainability-transition scholarship, which emphasizes that transitions are not simply technological substitutions but socio-technical transformations shaped by policy, power, and distributional outcomes. In the Indonesian case, the evidence indicates that the strategic importance of nickel and downstreaming has outpaced the development of an equally integrated governance framework. As a result, the contribution of mining to the energy transition remains conditional rather than automatic.

This finding is relevant because public discourse may frame the supply of minerals for batteries and electric vehicles as inherently sustainable. However, the results of this study indicate that such an interpretation does not capture the environmental and social conditions associated with mineral extraction and processing. Lo et al. (2024) showed that nickel mining in Indonesia reduced forest cover while yielding mixed local well-being outcomes, and Wahyono et al. (2024) found that critical-mineral mining and processing can impose substantial environmental and human health burdens. These studies reinforce the argument that transition-mineral extraction may support decarbonization in one part of the value chain while generating new sustainability pressures in another. Therefore, the sustainability of Indonesia's mining sector depends not only on what minerals are produced, but on how production is governed, powered, and distributed across society.

4.2 The Indonesian Case Highlights a Central Contradiction in Transition-Mineral Development

This contradiction is consistent with broader findings of recent studies on transition dynamics in rapidly industrializing economies. Ha et al. (2026), for example, showed that in Vietnam, energy transition and economic growth may still contribute to rising emissions when renewable energy expansion fails to substitute effectively for fossil fuels and financial development is not sufficiently directed toward green investment. This insight is highly relevant to Indonesia, where mineral-based industrialization may improve value-added and global strategic positioning, yet still weaken transition credibility if smelting expansion remains tied to carbon-intensive electricity systems and poorly aligned financial incentives. Indonesia's downstreaming strategy has been promoted as a way to increase domestic value-added and strengthen industrial competitiveness in the battery and electric-vehicle supply chain. This is a rational development strategy from an economic standpoint, and recent policy-oriented scholarship has emphasized its role in industrial upgrading and national strategic positioning (Lahadalia et al., 2024). Nevertheless, the findings of the present study show that downstreaming cannot be equated with sustainability unless its environmental and social conditions are explicitly governed.

This contradiction is particularly visible in the relationship between mining industrialization and electricity systems. The expansion of mineral processing and smelting increases energy demand, and if that demand is met through carbon-intensive sources, the sector's climate contribution becomes more ambiguous. In that sense, Indonesia's mining strategy and Indonesia's energy transition strategy are deeply interdependent. The RUPTL 2025–2034 and the Second Nationally Determined Contribution show that decarbonization is now embedded in national planning (Ministry of Energy & Mineral Resources, 2025; Republic of Indonesia, 2025). Yet the results of this study suggest that mining policy, electricity planning, and ESG governance still need stronger operational alignment. Without that alignment, Indonesia risks achieving resource-based industrial success while weakening the environmental credibility of its transition narrative.

4.3 A Just Transition Lens is Essential for Evaluating Mining-Led Development

The justice dimension is also inseparable from social acceptance and stakeholder legitimacy. In their study of renewable energy in Kenya, van der Zwaan et al. (2019) showed that even broadly supported low-carbon development can face obstacles when local participation in planning and benefit-sharing is limited. They further argue that stakeholder engagement and public dialogue can help prevent perceived drawbacks from becoming barriers to broader uptake of the transition. Applied to Indonesia's mining sector, this suggests that a just transition requires more than compensation-oriented approaches; it requires early dialogue, transparent benefit-sharing, and meaningful community participation in planning, monitoring, and grievance mechanisms. The results show that macro-level benefits such as export growth, industrial investment, and strategic global positioning are not sufficient indicators of sustainability. Local communities in mining areas may experience environmental degradation, health risks, unequal access to benefits, and reduced influence over decisions that directly affect their livelihoods. Lo et al. (2024) provided clear evidence that local well-being outcomes from nickel mining are mixed rather than uniformly positive, which supports the argument that national transition gains can coexist with local injustices.

This implies that the concept of a just transition should not be limited to labor shifts in fossil-fuel sectors, as often discussed in international transition debates. In the Indonesian mining context, a just transition must also include questions of local participation, compensation, benefit sharing, environmental protection, and health security. A transition that is economically successful but socially uneven cannot be regarded as fully sustainable. The framework proposed in this study, therefore, extends the just transition perspective into the domain of transition-mineral governance by emphasizing that mining legitimacy depends on how risks and rewards are distributed.

4.4 The Integrated Sustainability Framework Offers a Practical Contribution to Policy and Assessment

The main analytical contribution of this article is the integrated sustainability framework developed from the results. Existing studies have generated important but fragmented insights into environmental damage, mineral security, industrial policy, and local welfare. The framework proposed here adds value by organizing those insights into four interdependent pillars: environmental integrity, social justice and inclusion, economic transformation, and adaptive governance. This is important because it creates a clearer basis for evaluating whether mining is genuinely supporting a sustainable energy transition rather than simply expanding output.

The framework also speaks directly to the type of policy-relevant, evaluative contribution that sustainability journals seek. Aisyah et al. (2024) already demonstrated that Indonesia's mineral security can be assessed through a multidimensional index that includes ESG aspects, but the present study goes further by integrating ESG concerns with transition governance, local justice, and low-carbon industrialization. In this sense, the framework is not only descriptive but also diagnostic. It can help policymakers identify where current mining development is becoming misaligned with long-term sustainability goals.

A particularly useful implication is that the framework can be translated into measurable tools, such as a mining transition scorecard, an ESG-linked licensing dashboard, or a regional sustainability monitoring framework. For example, environmental integrity can be tracked through emissions intensity, land disturbance, and water-management performance; social justice through local employment quality, grievance resolution, and health safeguards; economic transformation through domestic value-added and resilience indicators; and adaptive governance through disclosure quality, inter-agency coordination, and compliance performance. This makes the framework practical for state agencies, firms, and researchers. Because ESG assessments can produce divergent results when indicator scope, measurement methods, and weighting rules differ, any mining-transition dashboard should publish transparent definitions, data sources, normalization procedures, and aggregation rules (Berg et al., 2022). Social indicators should also capture health, human rights, employment quality, land-use impacts, and distributional outcomes rather than relying on a single community-development measure (Mancini & Sala, 2018).

4.5 Policy Implications for Indonesia

The findings suggest five major policy implications. First, mining and smelting decarbonization should be treated as a strategic priority rather than as a secondary environmental issue. If Indonesia aims to position its mining sector as a pillar of the energy transition, the sector's power supply and industrial energy systems must progressively align with cleaner electricity pathways. Otherwise, downstreaming may increase domestic value creation while reducing transition credibility.

Implementation capacity is equally critical. Qiu et al. (2024) identified limited institutional capacity, insufficient funding, and technological constraints as major barriers to low-carbon policy implementation in developing-country settings, and they recommend institutional capacity building, financing coordination, and context-appropriate technology development as core responses. This reinforces the Indonesian implication that transition-

mineral governance must be supported by stronger institutions, coordinated finance, and practical implementation capability, rather than by aspirational sustainability language alone.

Second, ESG-linked permitting and monitoring should be strengthened. The evidence outlined in this study indicates that environmental governance has often been reactive rather than anticipatory (Rosada, 2025). Accordingly, permitting systems should not merely authorize industrial expansion but should also incorporate mechanisms for continuously monitoring environmental and social performance in a transparent and enforceable manner.

Third, local justice safeguards must be institutionalized. Mining governance needs to move beyond compensation-oriented logic and toward a broader framework of participation, health protection, local development quality, and grievance resolution. This is necessary to ensure that transition-mineral expansion does not deepen local vulnerabilities.

Fourth, value-added industrialization should be conditioned on sustainability performance. Downstreaming should continue to be recognized as an important economic strategy, but its success should be measured not only by investment size or export substitution. It should also be assessed according to environmental efficiency, energy source, labor conditions, and community outcomes.

Fifth, transition metrics should be institutionalized in national governance systems. A major weakness in transition governance is that success is often measured through output, revenue, or investment alone. The framework in this article suggests that Indonesia would benefit from a more integrated set of indicators capable of assessing whether mining development is simultaneously low-carbon, socially legitimate, economically resilient, and institutionally accountable.

In addition, recent work suggests that integrated transition governance should operate across multiple levels of decision-making. Patil et al. (2025) emphasized that sustainable energy strategies require coordinated action at local, state, and national levels, rather than fragmented or isolated interventions. For Indonesia, this means that the mining transition policy should connect national industrial and climate goals with provincial implementation capacity and site-level community realities.

These interconnections are synthesized in Figure 5, which presents the integrated sustainability framework developed in this study. The figure shows how four major sustainability tensions are translated into four interdependent pillars and five policy pathways for governing Indonesia's mining sector in support of a just and sustainable energy transition.

4.6 The Study's Limitations and Future Research Directions

This article has several limitations. First, it relies on secondary data and document-based analysis rather than primary fieldwork or stakeholder interviews. As a result, the framework is stronger as an integrative and policy-oriented assessment than as a direct test of local causal relationships. Second, the study focuses primarily on transition-oriented mining governance in Indonesia, with particular emphasis on nickel and downstreaming, so its conclusions should not be generalized uncritically to all mineral sectors or all producing countries.

However, these limitations also point to productive directions for future research. One next step would be to validate the framework through interviews with regulators, firms, local communities, and civil society organizations. Another would be to operationalize the framework into a measurable index or dashboard that could be applied across mining regions in Indonesia. A third avenue would be to compare Indonesia with other critical-mineral-producing countries in order to identify which governance arrangements are most effective in reconciling mineral development with just transition goals.

4.7 Overall Interpretation

Overall, the discussion confirms that Indonesia's mining sector can support a just and sustainable energy transition, but only under specific governance conditions. The sector's transition role is not determined solely by its mineral endowment or industrial ambition. It is determined by whether economic transformation is accompanied by ecological protection, social legitimacy, and adaptive institutional capacity. This is the central implication of the integrated sustainability framework developed in this study.

5. Conclusions

This article set out to examine how Indonesia's mining sector can support a just and sustainable energy transition through an integrated sustainability framework. The findings show that Indonesia occupies a unique and strategically important position in the global transition because it is simultaneously a major supplier of critical minerals, especially nickel, and a country pursuing its own long-term decarbonization agenda through national energy and climate policy. However, the study also shows that this strategic position does not automatically translate into sustainability. Rather, the role of mining in the energy transition depends on how environmental,

social, economic, and governance dimensions are managed together.

The analysis identified four major sustainability tensions that currently shape Indonesia's mining–energy transition nexus: economic transformation versus carbon intensity, strategic extraction versus environmental integrity, national gains versus local distributive justice, and resource security versus governance quality. These tensions reveal that the expansion of mining and downstream processing may generate industrial growth and global strategic relevance, while at the same time creating pressures related to emissions, ecological degradation, uneven benefit distribution, and institutional weakness. In this sense, the study confirms that transition-mineral development should not be assessed solely through production scale, export value, or investment attraction, but through its capacity to contribute to long-term ecological integrity, social legitimacy, and accountable governance.

Based on these findings, the article developed an integrated sustainability framework consisting of four interdependent pillars: environmental integrity, social justice and inclusion, economic transformation, and adaptive governance. The framework contributes to the literature by bringing together strands of research that are often treated separately, including critical mineral security, industrial policy, environmental sustainability, and just transition. More importantly, it provides a practical analytical structure for assessing whether mining expansion is aligned with broader sustainability goals. Instead of treating mining merely as a commodity-supply sector, the framework repositions it as a governance-intensive system whose legitimacy depends on balancing value creation, ecological limits, and social outcomes over time.

The study also translated the framework into five policy pathways. These include decarbonizing mining and smelter energy systems, strengthening ESG-linked permitting and monitoring, enhancing local justice and community safeguards, promoting sustainable value-added industrialization, and institutionalizing transition metrics and accountability. Together, these pathways suggest that Indonesia's mining sector can support the energy transition only when downstream industrialization is accompanied by cleaner energy use, stronger environmental oversight, more equitable social outcomes, and better policy coordination across institutions. This conclusion is particularly relevant in the Indonesian context, where mineral industrialization, electricity planning, and climate commitments are becoming increasingly interconnected.

From a theoretical perspective, this article contributes to sustainability scholarship by showing that mining-led transition development should be understood through an integrated framework rather than through isolated sectoral indicators. From a practical perspective, it offers a policy-relevant tool that can support decision-making by government agencies, firms, and researchers. The framework may also serve as a foundation for future assessment instruments, such as sustainability scorecards, ESG-linked mining dashboards, or regional transition monitoring systems.

This study has limitations. Because it relies on secondary data, policy documents, and literature-based synthesis, it is stronger as an integrative and interpretive assessment than as a causal evaluation of local outcomes. Future research should therefore validate and operationalize the framework through fieldwork, stakeholder interviews, regional case comparisons, or the development of measurable indicators that can be applied across mining areas in Indonesia.

In conclusion, Indonesia's mining sector can play a constructive role in a just and sustainable energy transition, but only if its development is governed through an integrated sustainability perspective. The critical issue is not whether mining is important to the energy transition, because it clearly is, but whether its expansion can be aligned with environmental integrity, social justice, economic resilience, and adaptive governance. The framework proposed in this article offers one pathway for making that alignment more visible, more assessable, and more actionable.

Author Contributions

Conceptualization, M.R.A.M. and S.H.; methodology, S.H.; software, M.R.A.M.; validation, S.H., Y.S., and P.H.; formal analysis, S.H.; investigation, Y.S.; resources, S.H.; data curation, Y.S.; writing—original draft preparation, M.R.A.M.; writing—review and editing, M.R.A.M.; visualization, M.R.A.M.; supervision, Y.S. and P.H.; project administration, M.R.A.M. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data supporting the findings of this study are publicly available from the sources cited in the manuscript, including the U.S. Geological Survey, the Ministry of Energy and Mineral Resources of the Republic of Indonesia, BPS-Statistics Indonesia, the UNFCCC repository, and the scholarly literature referenced in this article. Additional extracted and synthesized data supporting the research findings are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Declaration on the Use of Generative AI and AI-assisted Technologies

Generative AI and AI-assisted technologies were used in the preparation of this manuscript for language refinement, structural organization, and drafting support under the direction and supervision of the authors. All interpretations, arguments, verification of sources, and final editorial decisions were made by the authors. The authors take full responsibility for the content of the manuscript and confirm that generative AI was not used to fabricate data, results, or references.

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