

REVIEW ARTICLE

Processing the Energy Transition: Emissions, Land and Governance in Indonesian Nickel Downstreaming

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Received 26 April 2025 | Revised 23 May 2025 | Accepted 15 June 2025

Abstract—The energy transition requires nickel, and Indonesia has restructured its nickel sector to supply it by banning raw ore exports and compelling domestic processing. This study asks where the environmental outcome of that restructuring is actually determined, and finds that it is determined at decision points which are not environmental decisions. The method combines a structured review of research published between 2017 and 2024 with a comparative synthesis of published life-cycle intensities across processing routes. Three findings follow. Processing route dominates the carbon outcome: published assessments give roughly 14 tonnes of carbon dioxide equivalent per tonne of contained nickel for nickel metal, 18 for ferronickel and about 69 for nickel pig iron, against approximately 36.8 for battery-grade nickel sulphate produced from Indonesian laterite by high-pressure acid leaching, so a fourfold difference follows from a metallurgical choice. Electricity is the dominant driver within routes, accounting for 41 per cent of global warming potential and 56 per cent of cumulative energy demand in the leaching case, which makes the smelter cluster's power source the second decisive variable. And the land consequences are measured: across 7,721 Sulawesi villages between 2011 and 2018, forest loss doubled in nickel mining villages, with environmental conditions continuing to deteriorate in later mining stages. The study concludes that both decisive variables are settled through investment approval rather than environmental permitting, and specifies what a route-and-power-inclusive assessment would require.

Index Terms—nickel laterite; downstreaming; life-cycle emissions; critical minerals; environmental governance

Abstrak—Transisi energi membutuhkan nikel, dan Indonesia telah menata ulang sektor nikelnya untuk memasok kebutuhan itu dengan melarang ekspor bijih mentah serta mewajibkan pengolahan di dalam negeri. Penelitian ini menanyakan di titik mana sesungguhnya hasil lingkungan dari penataan itu ditentukan, dan menemukan bahwa penentuannya berada pada titik-titik keputusan yang bukan keputusan lingkungan. Metodenya memadukan telaah terstruktur riset terbitan 2017 hingga 2024 dengan sintesis pembandingan atas intensitas daur hidup yang telah dipublikasikan pada berbagai jalur pengolahan. Tiga temuan mengikutinya. Jalur pengolahan mendominasi hasil karbon: kajian terbit memberi angka sekitar 14 ton setara karbon dioksida per ton nikel terkandung untuk logam nikel, 18 untuk feronikel, dan sekitar 69 untuk nikel pig iron, berhadapan dengan sekitar 36,8 untuk nikel sulfat kualitas baterai dari laterit Indonesia melalui pelindian asam bertekanan tinggi, sehingga selisih empat kali lipat lahir dari satu pilihan metalurgi. Listrik adalah pendorong utama di dalam setiap jalur, menyumbang 41 persen potensi pemanasan global dan 56 persen permintaan energi kumulatif pada kasus pelindian, sehingga sumber daya listrik kawasan peleburan menjadi variabel penentu kedua. Dampak lahannya pun terukur: pada 7.721 desa di Sulawesi antara 2011 dan 2018, kehilangan hutan berlipat dua di desa-desa pertambangan nikel, dengan kondisi lingkungan yang terus memburuk pada tahap penambangan lanjut. Penelitian menyimpulkan bahwa kedua variabel penentu tersebut diputuskan melalui persetujuan investasi alih-alih perizinan lingkungan, dan merinci apa yang dibutuhkan oleh penilaian yang mencakup jalur dan sumber daya listrik.

Kata kunci—laterit nikel; hilirisasi; emisi daur hidup; mineral kritis; tata kelola lingkungan

I. INTRODUCTION

Decarbonising transport and electricity requires metals that must be mined and processed, and the processing is not clean. This is the transition's structural awkwardness: the

technologies that reduce emissions at the point of use depend on materials whose production increases them elsewhere, and the elsewhere is usually a different country from the one counting the reduction.

Nickel sits at the centre of this. Sonter et al. (2020) find that 82 per cent of mining areas globally target materials needed for renewable energy production, and that mining potentially influences 50 million square kilometres of the earth's land surface, with 8 per cent coinciding with protected areas, 7 per cent with key biodiversity areas and 16 per cent with remaining wilderness. Demand projections make the pressure concrete: Xu et al. (2020) estimate that automotive battery nickel demand could rise by a factor of 28 to 31 between 2020 and 2050 under a nickel-manganese-cobalt dominant scenario, from 0.13 million tonnes to between 1.5 and 3.7 million tonnes.

Indonesia has responded to that demand with an industrial policy rather than an extractive one. By banning exports of raw nickel ore it compelled foreign buyers to build processing capacity domestically, producing rapid industrial expansion and regional growth that Warburton (2024) finds substantially outpacing national averages. The policy is widely read as a success on its own terms, and this study does not dispute that reading.

It asks a different question. Downstreaming does not reduce environmental impact; it relocates it, moving the dominant share from the mine site to the smelter. Once that relocation has occurred, the environmental outcome depends on two things: which metallurgical route the processor chose, and what generates the electricity that route consumes. Neither is an environmental question in the administrative sense. Both are settled when an investment is approved and a plant is designed.

Three questions organise the analysis. First, how large is the difference between processing routes, and what does the published evidence establish about it? Second, what proportion of impact is attributable to the energy input, and what does that imply about where the decisive choice lies? Third, what are the measured land and community consequences in the producing regions, and what would an assessment framework that reached the decisive variables have to include?

II. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Demand and the resource base

Xu et al. (2020) model future material demand for automotive lithium-based batteries across fleet and chemistry scenarios including second use and recycling, finding demand increases by factors of 18 to 20 for lithium, 17 to 19 for cobalt and 28 to 31 for nickel between 2020 and 2050 under a nickel-manganese-cobalt dominant pathway. Baars et al. (2021), analysing circular economy strategies for electric vehicle batteries, find that technology-driven cobalt substitution is the most promising strategy but produces burden shifting in the form of increased nickel demand — a result that makes nickel's trajectory partly a consequence of efforts to reduce reliance on another metal.

Liang et al. (2023), modelling critical material demand under a net-zero emissions scenario, add that secondary supply cannot substitute for primary production at current recycling rates, contributing less than one per cent for rare earth elements by 2050 and rising to 35 per cent only under aggressive recycling assumptions. Their findings concern rare earths and photovoltaic metals rather than battery metals, and are cited here only for that general point.

Mudd and Jowitt (2022) provide the geoscience baseline. Their global assessment identifies 627 nickel deposits with reported resources or reserves, comprising 148 laterite and 248 magmatic sulphide deposits, with in-ground resources of 350.2 million tonnes of contained nickel — 190.2 million tonnes in laterites, 124.1 million in magmatic sulphides and 35.4 million in hydrothermal deposits — and reserves of 47.12 million tonnes. Laterites therefore hold the majority of the resource, and the distinction matters technically: laterite is an oxide ore requiring either high-temperature smelting or acid leaching, whereas sulphide ores are concentrated by flotation at far lower energy cost.

Processing route and energy intensity

Wei et al. (2020) construct a process model based on mass and energy balances rather than aggregated life-cycle inventory, and report energy consumption and greenhouse gas emissions for four nickel products. Expressed per tonne of contained nickel, their results give 174 gigajoules and 14 tonnes of carbon dioxide equivalent for nickel metal, 309 gigajoules and 18 tonnes for ferronickel, 485 gigajoules and 40 tonnes for nickel oxide, and 598 gigajoules and 69 tonnes for nickel pig iron. The ordering is the finding: nickel pig iron, produced at low nickel content, carries by far the highest burden per unit of the metal actually delivered.

Bartzas and Komnitsas (2024) supply the hydrometallurgical counterpart and do so for the Indonesian case specifically. Their cradle-to-gate assessment of battery-grade nickel sulphate produced from low-grade Indonesian laterite through high-pressure acid leaching, with refining in China, reports a global warming potential of 36.8 kilograms of carbon dioxide equivalent per kilogram of nickel under mass allocation and 33.8 under economic allocation, with cumulative energy demand of 385 and 354 megajoules per kilogram respectively. Their contribution analysis is the more consequential result: feed preparation and leaching account for 35 per cent of global warming potential, purification for 25 per cent of it and 35 per cent of land-use impact, and electricity alone for 41 per cent of global warming potential and 56 per cent of cumulative energy demand. The authors note the absence of transparent industrial data for this supply chain.

Wahyono et al. (2024) assess Indonesian critical mineral mining and processing across nickel, gold, copper, tin and bauxite using life-cycle assessment, reporting 4.61×10^4 kilograms of carbon dioxide equivalent per tonne of nickel produced and 9.21×10^{-4} asthma person-years per tonne. They identify electricity consumption and carbon dioxide release as the principal drivers of global warming impact and

fuel oil and electricity as the drivers of respiratory health effects, recommending stack controls and improved governance of steam power facilities. The convergence with Bartzas and Komnitsas on electricity as the dominant contributor is the important point.

Golroudbary et al. (2023) model the nickel supply chain dynamically across primary and secondary production and both metallurgical routes, forecasting primary production of 4.3 million tonnes by 2030 with 13 per cent directed to batteries, and 58 per cent growth in battery-sector nickel consumption between 2010 and 2030. Their most striking result is negative: energy consumption and water use grow at the same rate as nickel mass flows over the period, indicating no efficiency improvement.

Land, biodiversity and community outcomes

Sonter et al. (2020) establish the global overlap between mining and conservation priorities described above, and note that areas targeting energy-transition materials which overlap protected areas and wilderness have a greater density of mines than those that do not. Lèbre et al. (2020), developing composite environmental, social and governance indicators across 20 metal commodities, find 84 per cent of platinum resources and 70 per cent of cobalt resources situated in high-risk contexts, establishing that transition-metal supply is systematically concentrated where governance is weakest.

For Indonesia the decisive empirical study is Lo et al. (2024). Using counterfactual analysis across 7,721 villages in Sulawesi between 2011 and 2018, they find forest loss doubled in nickel mining villages. Their well-being results are mixed rather than uniformly negative: in early mining stages environmental well-being, living standards and educational outcomes declined while health, infrastructure and social cohesion improved, but in later stages environmental conditions continued to deteriorate substantially, disproportionately affecting economically disadvantaged communities. The authors call for enhanced oversight.

Stauber et al. (2022) address a disposal method of particular relevance to Indonesian processing. Their generic risk assessment framework for deep-sea tailings placement scores 246 causal pathways across eight impact zones, identifying 11 as high risk and 18 as very high risk, all in benthic zones, with smothering of benthic biota extending beyond predicted deposition zones and recovery timescales that are slow. Their test case is a copper-gold operation rather than a nickel one, and the framework rather than the case is what transfers.

Downstreaming as industrial policy

Camba et al. (2022) compare Indonesian and Malaysian pathways for mobilising Chinese capital in mineral processing, characterising Indonesia's approach as a leading-sector strategy that built domestic nickel capacity and reduced raw-export reliance, with the Morowali industrial park constructed to house smelters and Chinese capital functioning as intermediate investment maximising forward and backward linkages. Malaysia's dual-economy strategy, by

contrast, impaired domestic steelmaking and inhibited smelting.

Warburton (2024) assesses the outcome critically, arguing that the export ban produced nationalist enclaves: industrial parks satisfying demands for higher-value extraction while perpetuating extractive structures, with benefits concentrating among narrow networks of foreign and politically connected domestic capital while environmental degradation and community harms remain diffuse at production sites. The asymmetry between concentrated benefit and diffuse harm is a governance observation with a direct bearing on where assessment should attach.

Dou et al. (2024) situate this within the broader pattern, finding that energy-transition demand for copper, lithium, cobalt and nickel has intensified resource nationalism globally, with industrialised nations bearing greater absolute welfare losses while developing nations face higher price pressures. Andreucci et al. (2023), using nickel as their central case, develop the concept of decarbonisation by dispossession, arguing that capital-driven transitions expand mineral frontiers and create sacrifice zones of extraction and processing concentrated in formerly colonised countries.

Residues, closure and what happens afterwards

Processing generates residues, and the governance of those residues has its own literature with its own record of failure. Williams (2021), reviewing tailings dam failures across almost a century, finds that conventional slurry disposal carries risk roughly two orders of magnitude higher than comparable water infrastructure, with marginally stable facilities failing by liquefaction under seismic, foundation or extreme-rainfall triggers. He argues for whole-life costing in place of net present value accounting and for adoption of the international standard on tailings management.

Schafer et al. (2021) address the closure horizon that a processing investment implies but rarely budgets for, developing a failure modes and effects framework for long-term geotechnical risk that extends to a thousand years and covers drainage, foundations, dam body and landforms. Their risk matrix, combining seven likelihood and five consequence categories, is designed to support deregistration decisions — that is, the decision that a facility no longer requires active management, which is the point at which a public liability either ends or becomes permanent.

Akhmaddhian et al. (2023) supply an Indonesian case of the alternative outcome. A village-owned enterprise approach adopted in 2016 rehabilitated a former mining site in West Java that now supports diverse flora and fauna, hosts several businesses and drew approximately 114,000 visitors in a single year while generating village revenue. The case is small and single, and is cited here for the institutional form rather than for generalisable outcomes: rehabilitation was organised through a village enterprise rather than through the licensee.

Measuring what the sector does to land

Nascimento et al. (2020) demonstrate that the land dimension of an extractive complex is measurable with available imagery, applying object-based image analysis to map revegetated area and quantify land-use change across open-cast mining complexes over a four-year period. The method requires no site access and produces a time series rather than a snapshot, which is the property a rehabilitation obligation needs if compliance is to be verified rather than asserted.

Lo et al. (2024) apply comparable reasoning to outcomes rather than to cover, finding through counterfactual analysis across 7,721 villages that deforestation doubled in nickel mining villages, with early-stage mining lowering environmental well-being, living standards and education while improving health, infrastructure and social relations, and later production stages producing substantial environmental deterioration concentrated in already-poor villages. The temporal asymmetry is the finding with design content: benefits appear early and costs accumulate late, so an assessment conducted at approval records the favourable half.

Research gap

Three gaps shape this study. Published life-cycle intensities for pyrometallurgical and hydrometallurgical nickel routes exist but have not been placed alongside the Indonesian downstream literature, so the environmental implication of the route actually chosen has not been stated. No verified peer-reviewed source quantifies captive power capacity at Indonesian smelter clusters; the available figures are grey literature and are not used here. And no verified 2017 to 2024 peer-reviewed source addresses occupational safety at these facilities or community outcomes in Maluku, so the empirical base for community effects is Sulawesi alone.

III. METHOD

The study is a structured review with a comparative synthesis of published quantities. It generates no primary data, conducts no new life-cycle assessment, and makes no estimate of Indonesian production volumes or installed capacity.

Source identification and verification

Peer-reviewed studies published between 2017 and 2024 on critical mineral demand, nickel resources, nickel processing life-cycle assessment, mining and biodiversity, tailings disposal and Indonesian downstream policy were identified and retained only where bibliographic details could be verified against a publisher page, a digital object identifier record, an indexing database record or an institutional repository. Sources whose findings could not be read directly were excluded even where their bibliographic details were confirmed. Works by authors holding office in the policy under evaluation were excluded on conflict-of-interest grounds.

Comparative synthesis of intensities

Life-cycle figures are reported per tonne of contained nickel, since comparison per tonne of product would misrepresent routes producing low-grade alloys. Values are taken as published from single identified sources and are not recalculated, recombined or averaged. Because the pyrometallurgical figures come from a process-model study and the hydrometallurgical figure from a cradle-to-gate assessment with a different system boundary and allocation basis, the comparison is treated as indicative of order of magnitude rather than as a like-for-like ranking, and this qualification is carried into the conclusions.

What is not reported

Three categories of figure are absent because they could not be verified in peer-reviewed sources within the review window: captive power generation capacity at smelter clusters, tailings volumes and disposal arrangements for Indonesian high-pressure acid leaching operations, and occupational injury or fatality counts. Figures on all three circulate in non-peer-reviewed reporting. They are not used, and their absence is treated as a finding about the evidence base rather than as an absence of the phenomena.

IV. RESULTS AND DISCUSSION

Demand establishes the pressure

Table 1. Verified demand and resource quantities

Source: compiled by the authors. Figures are reported as published and are not recalculated or combined across sources.

Two implications follow. Laterites hold 190.2 of 350.2 million tonnes of contained nickel resources, so the majority of the resource requires the energy-intensive processing routes examined below; the comparatively benign sulphide route cannot supply demand of the projected magnitude. And Baars et al. (2021) show that reducing cobalt dependence increases nickel demand, so the trajectory in the first row is partly driven by efforts to solve a different supply problem.

The route determines most of the outcome

Figure 1. Greenhouse gas intensity per tonne of contained nickel by processing route (sources: Wei et al., 2020; Bartzas & Komnitsas, 2024)

Table 2. Energy and emissions intensity per tonne of contained nickel

Source: compiled by the authors. The pyrometallurgical figures derive from a process model and the leaching figure from a cradle-to-gate assessment with a different system boundary and allocation basis; the comparison indicates order of magnitude rather than a like-for-like ranking.

The spread is the finding. Nickel pig iron carries approximately five times the greenhouse gas burden of refined nickel metal per tonne of the metal actually delivered, and roughly twice that of the high-pressure acid leaching route producing battery-grade sulphate. The reason is straightforward: the product contains little nickel, so the energy consumed in producing a tonne of alloy is divided

across a small quantity of the target metal. A policy that succeeds in raising domestic processing volumes while the volume is predominantly low-grade alloy has raised emissions per unit of nickel supplied to the world, whatever it has done for domestic value addition.

The sector-level Indonesian assessment by Wahyono et al. (2024), at 46.1 tonnes of carbon dioxide equivalent per tonne of nickel, sits between the ferronickel and nickel pig iron values, which is consistent with a production mix weighted toward pyrometallurgical routes. It should not be read as confirming either figure, since its system boundary differs from both.

Electricity is the variable within the route

Route choice sets the ceiling; the energy source determines where within it the operation falls. Bartzas and Komnitsas (2024) find electricity accounting for 41 per cent of global warming potential and 56 per cent of cumulative energy demand in their Indonesian leaching case. Wahyono et al. (2024) independently identify electricity consumption as a principal driver of global warming impact and, together with fuel oil, of respiratory health effects, recommending improved governance of steam power facilities.

Two studies converging on electricity from different methods is a robust enough basis for the design inference: the emissions performance of a smelter cluster is largely a question of what generates its power. This is where the analysis reaches the limit of the peer-reviewed record, since no verified source within the review window quantifies generation capacity or fuel mix at Indonesian nickel industrial parks. The inference that follows is therefore conditional and is stated as such: if electricity governs roughly half of impact, then the power-source decision governs roughly half of the environmental outcome, and any assessment that does not evaluate it is assessing the smaller half.

Golroudbary et al.'s (2023) finding that energy consumption and water use grew at the same rate as nickel mass flows between 2010 and 2030 sharpens this. If intensity is not improving through technical progress, then total impact scales with volume, and a policy that multiplies domestic processing volume multiplies impact proportionally unless the route or the power source changes.

Measured land and community consequences

Lo et al. (2024) provide the only verified counterfactual evidence for Indonesia, and their result is unambiguous on land: across 7,721 Sulawesi villages between 2011 and 2018, forest loss doubled in nickel mining villages. Their well-being findings resist simple summary and should not be simplified. Early mining stages brought declines in environmental well-being, living standards and educational outcomes alongside improvements in health, infrastructure and social cohesion; later stages saw environmental conditions deteriorate substantially, with the burden falling disproportionately on economically disadvantaged communities.

The temporal pattern is the policy-relevant part. If benefits appear early and environmental costs accumulate late, then

an assessment conducted at approval, or an evaluation conducted in the first years of operation, will record a more favourable balance than the operation will ultimately produce. This is a structural feature of the evidence, not a criticism of any particular assessment.

Warburton's (2024) characterisation aligns with this from the political-economy side: benefits concentrate among narrow networks while environmental degradation and community harms remain diffuse at production sites. Concentrated benefit and diffuse harm is the classic condition under which regulatory attention lags, because the beneficiaries are organised and the affected are not.

Where the decisive choices are made

Figure 2. Decisive environmental variables and the approval process that governs each (authors' construction)

Table 3. Decision points, share of outcome governed, and the approval that applies

Source: authors' analysis. Shares are inferred from the life-cycle contributions reported in Table 2 and by Bartzas and Komnitsas (2024); they are indicative rather than measured for any specific Indonesian facility.

The pattern in the final column is this study's central claim. The two variables that govern most of the environmental outcome are settled through investment approval and plant design, where the criteria are capital cost, feedstock grade, product specification and time to production. The variables that are assessed environmentally are real and matter, but they govern a smaller share. An environmental permitting system can therefore operate correctly and still leave most of the outcome undetermined by environmental considerations.

This is not an argument that route choice should be dictated by emissions alone. High-pressure acid leaching is capital-intensive, technically demanding and produces its own residues, and the peer-reviewed record on Indonesian leaching tailings is empty, so a route comparison conducted on carbon alone would be incomplete in a way this study cannot repair. The argument is that the comparison should be made explicitly and at the stage where the choice is live, rather than not made at all.

What a route-inclusive assessment would require

Four elements follow. First, emissions intensity per tonne of contained nickel, rather than per tonne of product, should be a declared parameter of any processing investment, since the per-product metric conceals precisely the difference that matters. Second, the power supply arrangement should be assessed as an environmental variable of the facility rather than as a separate commercial matter, given that it governs roughly half of impact. Third, assessment should be repeated in later operating stages, because Lo et al. (2024) show environmental deterioration continuing after the period in which benefits appear. Fourth, tailings and residue arrangements for leaching operations require a published evidence base before capacity expands further; Stauber et al.'s (2022) framework, which scored 246 causal pathways

and identified 29 as high or very high risk in benthic zones, indicates the level of specificity such an assessment can reach when the data exist.

Limitations

Five limitations qualify this analysis. First, the intensity comparison combines a process-model study with a cradle-to-gate assessment using different boundaries and allocation bases, so the ranking is indicative rather than exact. Second, no verified peer-reviewed data on captive power capacity or fuel mix at Indonesian smelter clusters were available, so the power-source argument is conditional on the life-cycle contribution shares rather than grounded in facility data. Third, no verified source addresses tailings management for Indonesian leaching operations. Fourth, the community evidence is confined to Sulawesi, and no comparable verified study exists for Maluku. Fifth, no peer-reviewed source on occupational safety at these facilities was located within the review window, so that dimension is absent rather than assessed as unproblematic.

V. CONCLUSION

Indonesia's decision to process its nickel domestically rather than export it raw is an industrial policy that has achieved its industrial objectives. Its environmental consequences, however, are determined largely outside the environmental permitting system. The published life-cycle evidence gives approximately 14 tonnes of carbon dioxide equivalent per tonne of contained nickel for refined metal, 18 for ferronickel and about 69 for nickel pig iron, against roughly 36.8 for battery-grade sulphate from Indonesian laterite by high-pressure acid leaching. A choice made on capital cost and feedstock grade therefore moves the emissions outcome by a factor of up to five, and it is not made as an environmental choice.

Within any route, electricity dominates. Two independent assessments converge on this, one attributing 41 per cent of global warming potential and 56 per cent of cumulative energy demand to electricity in an Indonesian leaching case, the other identifying electricity as a principal driver of both warming and respiratory health impacts at sector level. The power source of a smelter cluster is thus the second decisive environmental variable, and it too is settled commercially. Meanwhile the land consequences are measured and substantial: forest loss doubled in nickel mining villages across 7,721 Sulawesi villages between 2011 and 2018, with environmental conditions continuing to deteriorate in later mining stages even where early-stage benefits appeared.

The implication is not that downstreaming should be reversed but that the assessment should reach the decisions that matter. Emissions per tonne of contained nickel should be a declared parameter of processing investment; the power supply arrangement should be assessed as an environmental feature of the plant; assessment should be repeated in later operating stages, when the evidence shows deterioration concentrating; and a published evidence base on leaching residues should precede further capacity. That

last point is also a statement about this study's own limits. No verified peer-reviewed source within the review window reports captive power capacity, leaching tailings volumes, or occupational injuries at these facilities. For an industry of this scale and strategic importance, that absence is itself a governance finding.

Declarations

Author contributions (CRediT)

Conceptualisation: Author 1. Methodology: Author 1. Formal analysis and investigation: Author 1. Writing — original draft preparation: Author 1. Writing — review and editing: Author 1. Supervision: Author 1. All named authors have read and approved the final manuscript and accept responsibility for its content.

Conflict of interest

The authors declare that they have no financial or non-financial conflict of interest in relation to the subject matter of this article. No author holds a position in, or receives support from, any organisation examined or evaluated in this study.

Data availability

This study generated no primary data. It draws exclusively on published peer-reviewed literature, publicly available legal instruments and publicly available official statistics, all of which are identified in the text and listed in the references. No confidential administrative record, individual taxpayer record, permit file or personal datum was accessed, and no individual person or business is identified. Every quantity reported was traced to a single identified public source and can be verified by any reader from that source.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Declaration on the use of artificial intelligence

In accordance with COPE, ICMJE and WAME positions, and with the RCP AI Use Declaration requirement, the authors disclose that generative artificial intelligence tools were used in preparing this manuscript, specifically to assist with literature identification, synthesis of the reviewed sources, and language editing of the draft. Artificial intelligence was not used to generate data, results or citations. Every reference in this article was verified by the authors against the publisher's own record, a digital object identifier record or an indexing database record before inclusion, and sources whose bibliographic details or indexing status could not be confirmed were excluded. No artificial intelligence tool is listed as an author. The authors take full responsibility for the accuracy, integrity and originality of the entire content of this article.

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How to cite: Afrizal Aqila Fathin (2025). *Processing the Energy Transition: Emissions, Land and Governance in Indonesian Nickel Downstreaming*. JEIG, 1(1), 9–15.