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Nickel Supply Chain Integration for Electric Vehicle Battery Production

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Abstract

The global transition toward clean energy has positioned electric vehicles (EVs) as a cornerstone of low-carbon transportation, driving unprecedented demand for nickel a critical component of lithium-ion battery chemistries including Nickel-Manganese-Cobalt (NMC) and Nickel-Cobalt-Aluminum (NCA). As the world's largest nickel producer, Indonesia holds a strategically significant role in the global EV battery supply chain, yet the adequacy of its nickel supply for domestic EV development and the contribution of battery recycling as a secondary source remain insufficiently examined.This study analyzes strategies for fulfilling Indonesia's nickel demand for EV battery production over 2025–2030 through an integrated assessment of primary production capacity, battery recycling potential, and stakeholder roles, focusing on the Morowali industrial corridor in Central Sulawesi. Employing a descriptive qualitative method supported by quantitative data analysis including supply chain analysis and SWOT evaluation the study finds that Central Sulawesi's planned smelter capacity of approximately 3.99 million tonnes per year is structurally sufficient to meet projected domestic battery-grade nickel demand, contingent on accelerated deployment of High-Pressure Acid Leach (HPAL) technology. The study's principal contribution is the proposition and economic evaluation of a Localized Circular Economy model, co-locating battery recycling facilities with primary HPAL infrastructure in Morowali. This approach is projected to reduce logistics costs by up to 50% and generate national savings of approximately USD 4.1 million per year at a processing volume of 10,000 tonnes of spent batteries annually by 2030, while reducing carbon intensity and strengthening Indonesia's ESG credentials in global battery markets.

Introduction

The global imperative to transition away from fossil fuels has catalyzed an unprecedented expansion in the electric vehicle (EV) industry (Xu et al., 2020; Udendhran et al., 2025; Obando et al., 2024). Central to the performance and viability of modern EVs is the lithium-ion battery particularly chemistries based on NMC and NCA in which nickel plays an indispensable role by enhancing energy density, extending driving range, and improving cycle durability (Pandyaswargo et al., 2021; Xu et al., 2020). Global demand for nickel destined for EV batteries is projected to reach approximately 2.6 million tonnes by 2040, representing a dramatic increase from current consumption levels (Dunn et al., 2021; Wei et al., 2025; Sharma et al., 2025).

Indonesia occupies a uniquely strategic position in this supply chain. As the world's largest nickel producer accounting for more than one-third of global primary nickel mine production in 2021 Indonesia holds approximately 22.4% of total global nickel resources, predominantly

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in laterite deposits concentrated in Sulawesi and the North Maluku archipelago (Fatimah et al., 2023; Heijlen & Duhayon, 2024). The Indonesian government has pursued an aggressive downstream industrialization policy (hilirisasi), enforcing an export ban on unprocessed nickel ore since 2020 to stimulate domestic value-added processing, attracting major investments from battery manufacturers including CATL and LG and catalyzing the development of HPAL smelters in the Morowali Industrial Park (IMIP) (Maghfiroh et al., 2021; Pandyaswargo et al., 2021). Domestically, Presidential Regulation No. 55/2019 updated by No. 79/2023 targets 2 million electric four-wheeled vehicles (E4W) and 13 million electric two-wheeled vehicles (E2W) on Indonesian roads by 2030, requiring up to 1.2 million tonnes of nickel per year by 2040 (Pandyaswargo et al., 2021; Utami et al., 2020).

However, a singular reliance on primary extraction presents significant challenges: Indonesia's low-grade laterite ores require complex HPAL technology with limited operational facilities; the environmental costs of mining in the ecologically sensitive Wallacea biodiversity zone are substantial; and battery recycling infrastructure remains nearly absent, despite spent battery volumes projected to reach 10,000 tonnes per year by 2030 (Oetomo et al., 2025). Prior studies have examined nickel supply chains, EV adoption in Indonesia, and hydrometallurgical recycling, but no study has integrated primary production adequacy with a localized recycling strategy tailored to Indonesia's processing centers (Pandyaswargo et al., 2021; Rachmadhani & Priyono, 2023).

This study addresses that gap by evaluating a Localized Circular Economy framework centered on Morowali, Central Sulawesi. Co-locating battery recycling facilities adjacent to HPAL infrastructure is projected to reduce logistics costs by up to 50% given that transportation costs constitute approximately 41% of total recycling operational expenditure and generate national savings of approximately USD 4.1 million annually at a 10,000-tonne processing volume (Islam & Iyer-Raniga, 2022). This paper pursues three objectives: (1) to analyze strategies for fulfilling nickel demand through primary production and recycling over 2025–2030; (2) to identify key factors influencing nickel supply adequacy for the EV sector; and (3) to examine stakeholder roles in enabling a sustainable nickel-to-battery value chain in Indonesia (Islam & Iyer-Raniga, 2022).

Methods

This study employs a descriptive qualitative research design supported by quantitative data analysis, a mixed-methods approach particularly suited to complex resource policy systems (Pandyaswargo et al., 2021). The study is geographically focused on Morowali Regency, Central Sulawesi, selected for its role as the host of the Indonesia Morowali Industrial Park (IMIP) one of the world's largest integrated nickel processing complexes. Geologically, the nickel deposits in this region comprise near-surface laterite profiles with a saprolite horizon as the primary commercial extraction target (Heijlen & Duhayon, 2024).

To ensure the reliability and relevance of the information analyzed, secondary data sources were selected based on several criteria. First, the data had to originate from authoritative institutions, including government agencies, internationally recognized organizations, and peer-reviewed academic publications. Second, the sources were required to provide information directly related to nickel resources, nickel processing, electric vehicle development, battery recycling, or related policy frameworks in Indonesia. Third, priority was given to the most recent publications and datasets available during the study period to ensure data relevance and consistency with current industrial developments.

The study relies exclusively on secondary data compiled from authoritative sources that are widely recognized within the Indonesian mining, energy, and industrial sectors. These sources were selected because they provide official statistics, policy information, and industry projections that are directly relevant to the objectives of this research. Nickel resource and

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reserve data were obtained from the Indonesian Geological Agency (GAI, 2022). EV adoption figures and national targets were drawn from the Institute for Essential Services Reform (IESR, 2023), the Indonesian Ministry of Industry, and Indonesia's NDC submissions. Nickel demand projections were sourced from peer-reviewed literature including Shang (2023) and Dilshara et al. (2024), while recycling efficiency and logistics cost data were obtained from Haynes et al. (2023), Kumar et al. (2023), and Bhagaskara et al. (2024). Policy data were sourced from Presidential Regulations No. 55/2019 and No. 79/2023, and Mining Law No. 3/2020.

To improve data reliability, a validation process was conducted through cross-referencing information obtained from multiple sources. Statistical data related to nickel resources, production capacity, EV adoption, and recycling projections were compared with government reports, academic publications, and industry reports where available. This triangulation approach was applied to reduce potential inconsistencies and improve the robustness of the analysis.

In cases where different sources reported varying figures for the same indicator, priority was given to the most recent official government data and peer-reviewed publications. Where discrepancies remained, the values were interpreted within their respective contexts and used to identify general trends rather than relying solely on a single numerical estimate.

To ensure comparability, all quantitative information was harmonized according to common measurement units and reporting periods whenever possible. Nickel-related data were standardized in tonnes or tonne-equivalent units, while EV adoption and production data were reported in vehicle units and battery capacity indicators. This harmonization facilitated integrated analysis across different segments of the nickel-to-battery supply chain.

Three analytical frameworks were applied: (1) descriptive statistical analysis to characterize production, EV demand, and recycling capacity trends across 2020–2030; (2) supply chain analysis to map nickel flows from laterite ore to battery cell and identify structural bottlenecks, tracing value addition from raw ore (USD 1,100–1,700/tonne) through to battery cells (USD 90,000–150,000/tonne nickel-equivalent); and (3) SWOT analysis to evaluate the strengths, weaknesses, opportunities, and threats of Indonesia's integrated nickel and EV battery sector, synthesized across regulatory, technological, and stakeholder (Pandyaswargo et al., 2021).

Results and Discussion

Nickel Resources, Reserves, and Smelter Capacity

Indonesia's nickel endowment is exclusively concentrated in near-surface laterite deposits across Sulawesi and the North Maluku archipelago. Based on data from the Indonesian Geological Agency (GAI, 2022), national nickel resources stand at 17,685.74 million wet metric tonnes (wmt) with reserves of 5,243.53 million wmt, containing 177.81 and 57.11 million tonnes of metal content respectively (Table 1). These figures represent approximately 22.4% of total known global nickel resources, though not all data have been independently verified under KCMI standards. Indonesia has undergone a twenty-fold increase in primary nickel production between 2000 and 2020, with processing facilities expanding from two to approximately 32 by 2022, and a further expansion to 44 projected by 2026 (Heijlen & Duhayon, 2024).

Table 1. Indonesian Nickel Resources and Reserves, 2021

Indicator	Resources	Reserves
Raw ore (million wmt)	17,685.74	5,243.53
Metal content (million tonnes)	177.81	57.11

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Source: GAI, 2022

The ongoing smelter developments in Morowali represent the material foundation of Indonesia's downstream nickel strategy. Planned aggregate capacity in Central Sulawesi amounts to approximately 3,992,000 tonnes per year across multiple product categories (Table 2). Critically, only five of the planned facilities deploy HPAL technology the prerequisite for producing battery-grade nickel sulfate from Indonesia's low-grade laterite ore of which three are under active construction and two remain at the feasibility stage.

Table 2. Planned Nickel Smelter Development in Central Sulawesi

Company	Product	Est. Capacity (t/yr)	Location
PT QMB New Energy Material	Pure Nickel	50,000	Morowali
PT Huayue Nickel Cobalt	Pure Nickel	60,000	Morowali
PT Obsidian Stainless Steel	Stainless Steel	3,000,000	Morowali
PT Bukit Smelter Indonesia	NPI	150,000	Morowali
PT Lestari Smelter Indonesia	NPI	300,000	Morowali
PT Fajar & Teluk Metal Industry	Nickel Sulfide	120,000	Morowali
PT Walsin Nickel Industrial	Nickel Pig Iron	300,000	Morowali
PT Indonesia Puqing Recycling	Ni-Co-Mn Hydroxide	12,000	Morowali
Total		**3,992,000**	**Central Sulawesi**

Source: Ministry of ESDM, Indonesia.

EV Adoption, Nickel Demand, and Recycling Projections

Indonesia's EV market has expanded rapidly from a negligible base, surpassing 100,000 units by 2023, led by a 1,600% increase in E2W between 2021 and 2023 (IESR, 2023). The Ministry of Industry targets production of 6 million E2W and 400,000 E4W by 2025, rising to 9 million E2W and 600,000 E4W by 2030. However, current production capacity approximately 1.4 million E2W and 80,000 E4W annually falls far short of these targets, as does the current EV stock relative to NDC adoption commitments (Table 3). This divergence between policy ambition and market realization introduces significant uncertainty into demand-side nickel planning.

Table 3. EV Targets vs. Realization in Indonesia

Source	Target Year	E2W Target	E2W Realization	E4W Target
Ministry of Industry	2025	6 million units	~100,000 units	400,000 units
Ministry of Industry	2030	9 million units	—	600,000 units
NDC (Paris Agreement)	2025	1.8 million stock	85,838 stock	400,000 stock
NDC (Paris Agreement)	2030	13 million stock	—	2 million stock

Source: IESR, 2023; Ministry of Industry; NDC, 2022

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To illustrate the implications of this uncertainty, EV adoption can be viewed through three possible development pathways. A conservative pathway assumes that EV adoption continues to follow current market trends, resulting in lower battery demand and slower growth in domestic nickel consumption. A moderate pathway assumes gradual improvements in production capacity, charging infrastructure, and consumer acceptance, leading to a steady increase in battery demand. An optimistic pathway follows official government targets, generating substantially higher demand for battery-grade nickel and related processing capacity.

To better understand the implications of this uncertainty, EV adoption can be interpreted through several possible development pathways. Under a conservative pathway, EV adoption continues to follow current market trends, resulting in slower growth of battery demand and domestic nickel consumption. Under a moderate pathway, gradual improvements in production capacity, charging infrastructure, and policy support contribute to steady growth in EV adoption and battery demand. Under an optimistic pathway, government targets are achieved, leading to significantly higher demand for battery-grade nickel and related processing capacity. These alternative pathways demonstrate that future nickel demand is closely linked to actual EV market performance rather than policy ambitions alone.

Under all three pathways, domestic nickel demand is expected to increase over time. However, the scale and timing of that demand may vary significantly. Consequently, projections based solely on official targets may overestimate short-term domestic nickel absorption. This suggests that investment planning for HPAL facilities and nickel sulfate production should remain adaptive and responsive to actual EV market developments rather than relying exclusively on policy targets.

Global nickel demand for EV batteries is projected to rise from 3% of total consumption (163,000 tonnes) in 2020 to 30% (1.2 million tonnes) by 2040 (Jiang et al., 2025; Rachmadani et al., 2022; Xu et al., 2020; Zhang et al., 2023). Domestically, approximately 30 GWh of battery demand is estimated, comprising 19 GWh for E4W, 5.3 GWh for E2W, and 1.8 GWh for ESS applications (IESR, 2021). Spent battery volumes are projected to increase from 600 tonnes currently to 10,000 tonnes per year by 2030. Hydrometallurgical leaching systems demonstrate nickel recovery rates consistently exceeding 90% across multiple leaching agent configurations (Shayakhmetova et al., 2025; Dickson et al., 2025; Faris et al., 2023), confirming the technical viability of secondary nickel recovery as a complement to primary production.

The relationship between EV adoption and nickel demand occurs through battery manufacturing requirements. As the number of electric vehicles increases, demand for lithium-ion batteries also expands, which subsequently increases the need for battery-grade nickel, particularly for nickel-rich battery chemistries such as NMC and NCA. Therefore, projections of future nickel demand are influenced not only by resource availability but also by the scale of battery production required to support EV deployment. This relationship highlights the strategic importance of ensuring adequate battery-grade nickel production capacity through HPAL processing and downstream refining facilities.

Supply Adequacy and the HPAL Bottleneck

Based on currently available projections, the planned smelter capacity of approximately 3.99 million tonnes per year in Central Sulawesi appears sufficient to support Indonesia's anticipated domestic demand for battery-grade nickel sulfate during the 2025–2030 period. However, the actual adequacy of this capacity will depend on future EV adoption rates, battery industry expansion, and the successful implementation of HPAL projects that are specifically designed to produce battery-grade materials (Octaviana Randrikasari et al., 2025; Sunuhadi et al., 2024; Tan, 2022). The government's target of 1 million tonnes of nickel sulfate

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production by 2030 is achievable on the basis of committed investment pipelines alone (Pandyaswargo et al., 2021). However, this potential remains contingent on the accelerated deployment of HPAL technology. Without a substantial expansion of HPAL capacity beyond the five projects currently in development, Indonesia's nickel output will predominantly serve conventional metallurgical applications stainless steel and nickel pig iron rather than battery-grade markets, limiting the domestic value chain's alignment with EV sector requirements (Barizi & Triarda, 2023; Heijlen & Duhayon, 2024). Concurrently, the significant gap between official EV adoption targets and market realization introduces material uncertainty into demand-side planning; overstated targets risk generating misallocated capital and stranded assets, underscoring the need for evidence-based, scenario-driven supply chain investment decisions (Yusgiantoro et al., 2021). These findings suggest that resource availability alone does not guarantee supply adequacy for the EV battery sector. The critical determinant is the ability of HPAL facilities to convert Indonesia's abundant laterite resources into battery-grade nickel products required by battery manufacturers. Therefore, future competitiveness will depend not only on mining capacity but also on technological readiness and refining capability within the domestic downstream industry (Nair et al., 2026; Aditya et al., 2025; SH Moerenhout & Jobet, 2026).

The Localized Circular Economy Model

Battery recycling constitutes an indispensable strategic complement to primary production (Islam & Iyer-Raniga, 2022). While Indonesia's projected end-of-life battery volume of 10,000 tonnes per year by 2030 is modest relative to primary production, establishing recycling infrastructure now is essential to building the institutional and technical capacity required when battery waste volumes increase substantially in the 2030s (Machala et al., 2025). The central contribution of this study is the economic and strategic evaluation of a Localized Circular Economy model, whereby battery recycling facilities are co-located with primary HPAL processing infrastructure in Morowali rather than being established near consumption centers.

This spatial strategy is grounded in a rigorous cost structure analysis. Transportation costs represent approximately 41% of total battery recycling operating expenditure equivalent to USD 820 per tonne under an average operating cost of USD 2,000 per tonne due to the hazardous waste (B3) classification of spent lithium-ion batteries under Indonesian environmental regulations (Machala et al., 2025; Neumann et al., 2022). By centralizing recycling at a single processing hub in Sulawesi, transportation costs can be reduced by up to 50%, yielding savings of approximately USD 410 per tonne. At a projected annual management volume of 10,000 tonnes by 2030, this translates to estimated national cost savings of USD 4.1 million per year approximately IDR 65 billion without changes to underlying recycling technology. Beyond direct cost savings, the model generates further efficiency gains through technological synergy: the hydrometallurgical leaching and metal purification circuits used in HPAL processing are chemically analogous to those employed in battery recycling, enabling black mass from spent batteries to be processed through existing HPAL infrastructure, eliminating greenfield capital expenditure (Rinne et al., 2021; Vieceli et al., 2021). The resulting nickel sulfate output can be directly reintroduced into the precursor manufacturing stream at the same industrial site, creating a genuinely closed-loop material cycle within the IMIP complex (Kinnunen et al., 2024). This integrated model also reduces the carbon intensity of battery-grade nickel output by up to 40% relative to pyrometallurgical alternatives, and strengthens Indonesia's ESG credentials in markets that increasingly apply lifecycle sustainability criteria to battery procurement (Islam & Iyer-Raniga, 2022; Machala et al., 2025).

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Challenges, SWOT, and Stakeholder Roles

Despite the strategic logic of the proposed model, several constraints must be acknowledged. Environmental impacts of primary laterite mining remain severe: open-pit extraction in the Wallacea biodiversity zone generates deforestation, soil erosion, tailing runoff into the Coral Triangle marine ecosystem, and community displacement on indigenous lands (Heijlen & Duhayon, 2024). Technological limitations persist in the form of limited HPAL operational experience and nascent industrial-scale battery recycling capacity in Indonesia. Policy and infrastructure gaps particularly the absence of regulatory frameworks for hazardous battery waste logistics and dedicated recycling zones within industrial parks constrain private investment (Setiani et al., 2024). Finally, overstated EV adoption targets distort investment signals across the entire supply chain.

A SWOT synthesis of these findings identifies Indonesia's abundant nickel reserves, growing productive-age population, and strong political commitment to EV development as core strengths, while technology dependence on foreign partners, limited HPAL capacity, and low consumer willingness-to-pay represent key weaknesses. Opportunities center on international technology transfer, growing global battery-grade nickel demand, and the first-mover advantage of establishing an ESG-compliant circular battery economy in Southeast Asia. Threats include the WTO dispute over Indonesia's nickel ore export ban, competing battery chemistries that reduce nickel intensity (notably lithium iron phosphate), and reputational risks arising from environmental and human rights concerns in mining operations (Pandyaswargo et al., 2021).

Realizing the integrated supply chain vision requires coordinated action across three stakeholder groups (Nie et al., 2026; Rashid & Rasheed, 2025; Ghobakhloo et al., 2026). Government must provide regulatory certainty through specific provisions for battery waste logistics, fiscal incentives for HPAL investment and integrated recycling, and evidence-based recalibration of EV adoption targets (Heijlen & Duhayon, 2024; Setiani et al., 2024). Industry particularly nickel producers and battery manufacturers operating in Morowali must pioneer the co-location model, invest in indigenous technical capacity, and develop structured battery collection systems. Civil society and consumers must be engaged through subsidy schemes, charging infrastructure expansion, and public awareness campaigns on responsible battery disposal to ensure an adequate and reliable flow of end-of-life batteries to centralized facilities (Pandyaswargo et al., 2021; Ushakov et al., 2026; Munonye et al., 2026).

Conclusion

This study indicates that Indonesia possesses substantial nickel resources and expanding processing capacity that can potentially support domestic EV battery development during the 2025–2030 period. Nevertheless, the realization of this potential remains dependent on several factors, including actual EV adoption rates, the pace of battery industry development, investment realization, and the successful deployment of HPAL technology. Therefore, future nickel supply adequacy should be interpreted as conditional upon both market developments and industrial readiness rather than solely on policy targets.

The central novel contribution of this study lies in the proposition and evaluation of a Localized Circular Economy model, in which end-of-life battery recycling facilities are co-located with primary HPAL nickel processing infrastructure in Morowali rather than established near consumption centers. By co-locating these functions, transportation costs which constitute approximately 41% of total battery recycling operating expenditure can be reduced by up to 50%, generating estimated national logistics savings of USD 4.1 million per year at the projected 2030 processing volume of 10,000 tonnes of spent batteries annually. Beyond direct cost savings, the model leverages chemical and infrastructural synergies between HPAL processing and hydrometallurgical recycling, reduces the carbon intensity of

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battery-grade nickel output by up to 40%, and strengthens Indonesia's ESG credentials in an increasingly sustainability-sensitive global battery market. Realizing this vision will require the Indonesian government to establish specific regulatory frameworks for hazardous battery waste logistics, designate dedicated integrated recycling zones within existing industrial parks, and recalibrate EV adoption targets while industry and civil society play complementary roles in technology deployment, investment mobilization, and consumer engagement. Future research should extend this analysis through detailed techno-economic feasibility assessments of integrated HPAL-recycling facilities and full lifecycle carbon accounting under Indonesian operational conditions.

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