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A MINING–ENERGY–INDUSTRY FEEDBACK LOOP IN INDONESIA’S NICKEL SECTOR: STRUCTURE, BENEFITS, AND ENABLING CONDITIONS

Policy Concept Note

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Executive Summary

Indonesia's Nickel Opportunity and Project Background

Indonesia is the world's largest producer of nickel ore and intermediates, and it has used that position to drive an ambitious downstreaming agenda (*hilirisasi*). That agenda has so far been powered largely by captive coal: dedicated coal-fired generation at mines and smelters reached 11.2 GW in 2023 and is projected to grow by roughly a further 20 GW by 2032, concentrated in the nickel hubs of Sulawesi and North Maluku.

As part of the *Indonesia's Green Industrialization* project, developed by the Columbia Center on Sustainable Investment (CCSI) with support from Yayasan Visi Indonesia Raya Emisi Nol Bersih (ViriyaENB), this policy concept note outlines the structure of a **mining–energy–industry feedback loop** in Indonesia, with a focus on the nickel sector ([Section 1](#)), its **potential benefits** ([Section 2](#)), and its necessary enabling conditions, including **policy recommendations** to achieve them ([Section 3](#)). Companion publications in this project include a report on the [circular economy](#) in Indonesia's nickel sector, a paper on [financing](#) Indonesia's green industrialization, and a project [appendix](#) compiling contextual information on Indonesia's mineral and energy landscape.

The Mining–Energy–Industry Feedback Loop

Mining and mineral processing—large, predictable electricity buyers—provide the anchor demand that makes renewable power bankable and lowers offtaker risk. Reliable and increasingly renewable power then enables midstream processing and downstream industry. Those industries, particularly producers of clean energy technologies such as batteries, electric vehicles, and grid and solar equipment, become customers for domestic minerals and, as their capacity grows, drive technology costs down across the system. Each turn of the loop creates efficiencies that accelerate the next.

The loop rests on three structural elements. First, mining and energy are interdependent; both are unlocked by co-locating generation with demand and opening the shared use of power infrastructure. Second, domestic manufacturing of renewable energy technologies is paired with deployment at national and regional scale through interconnection under the ASEAN Regional Integrated Energy System. Third, the feedback loop logic extends beyond nickel to other minerals and sectors, such as aluminum, copper, tin, silicon, alloys, and grid equipment, broadening the industrial base and building resilience against shifts in battery chemistry and commodity prices.

Renewables Phase-in Rather than Coal Phaseout

Indonesia's captive coal fleet is young, the government treats coal as a domestic energy security resource and energy diversity as a source of competitive advantage, and forcing early retirement would be costly—retiring the fleet 15 years early would imply losses on the order of 1.1 percent of 2020 GDP—and is unlikely in the near term. Rather than a coal phaseout, this policy concept note supports a **renewables phase-in**: anchoring the next wave of mineral and industrial demand on newly built renewable systems so that renewables progressively displace coal at the margin of new capacity, allowing the coal share to decline as demand grows and the existing fleet ages. This framing aligns the transition with the Indonesian government's energy security and competitiveness objectives.

Coordination, Data, and Regulatory Constraints to the Feedback Loop

Intra-governmental coordination and data sharing are primary constraints that need to be unlocked for developing a mining–energy–industry feedback loop in Indonesia. Mineral processing permits are issued without reference to up-to-date reserve, resource, and energy data held elsewhere in

government, so capacity approvals can outrun both feedstock and power availability. Much of the captive power fleet is effectively invisible to the institutions responsible for energy planning, and the ministries that hold the relevant data operate separate information systems that do not interoperate; even where the mandate to coordinate exists, the underlying platforms may not fit together.

Another constraint is regulatory: captive generation is generally confined by law to a company's own concession, making surplus renewable power difficult to share with a neighboring smelter, community, or the grid; under the monopoly of PLN, the state electricity utility, a renewable independent power producer (IPP) cannot sell directly to an industrial offtaker. Furthermore, coal enjoys a supportive policy environment, and the pricing of alternative fuels can push firms back toward captive coal.

Potential Sustainability Co-Benefits of the Feedback Loop

The feedback loop would generate reinforcing economic, environmental, and social co-benefits (detailed in [Section 2](#)). **Economically**, it would deepen value addition beyond extraction and smelting into higher-value manufacturing, diversify the economy beyond nickel, and spread the high fixed cost of generation and transmission across many users through shared use and economies of scale. **Environmentally**, displacing coal at the margin would lower greenhouse gas emissions and improve air quality, support better land use—including siting solar on degraded or former mine land—and create room for circular economy practices. **Socially**, it would generate skilled employment and support a just transition in coal- and nickel-dependent regions, widen access to reliable clean energy, and reduce pollution-related illness and its fiscal burden. This policy concept note presents these potential co-benefits qualitatively and calls for Indonesia-specific studies to quantify them.

Recommendations for Indonesian Stakeholders

Achieving the loop depends on aligning three sets of enabling conditions (detailed in [Section 3](#)). The recommendations below emphasize concrete, near-term measures that would unlock the feedback loop, identifying the instruments and the institutions responsible.

1. Align planning, coordination, and shared-use infrastructure

- **Build a shared, cross-ministerial data and modeling foundation.** A georeferenced platform covering current and forecasted renewable energy generation, grids, and mining, energy, and industrial demand—built on the geospatial reserve and resource system of the Ministry of Energy and Mineral Resources (ESDM)—together with integrated cross-sectoral modeling would close the gap. *Co-led by PLN, Statistics Indonesia (BPS), and the National Development Planning Agency (BAPPENAS), with ESDM, the Ministry of Industry (MOI), and the Ministry of Investment (BKPM).*
- **Establish a single inter-ministerial coordinating mechanism and write industrial energy demand into national power plans.** A single mechanism with a clearly defined coordinator and interoperable data systems should replace parallel processes, incorporate the mining and processing sector's energy demand into the RUKN and RUPTL, and extend planning to other critical minerals. *Led by the Coordinating Ministry for Economic Affairs, with ESDM, MOI, PLN, BAPPENAS, and others involved.*
- **Unlock the shared use of power infrastructure.** A power-wheeling framework with regulated open-access tariffs, captively generated renewable power brought under ESDM oversight, transmission and distribution frameworks for geographically constrained hydro and geothermal, and standardized offtake, cost-sharing, and interconnection contract templates (developed with the companion financing paper) would open up the shared use of power infrastructure. *Led by ESDM, with PLN, independent power producers (IPPs), and industrial park operators.*

- **Tie approvals and incentives to renewable capacity, and streamline permitting.** Aligning approvals with the transition need not add delay if new conditions are paired with faster processing. Certification of planned or available renewable capacity should become a precondition for PSN, KEK, and smelter approvals and for RKAB approvals and fiscal incentives, with siting favored near renewable resources and the AMDAL process streamlined so that compliant projects benefit from faster approvals. *Co-led by MOI and ESDM.*
- **Align environmental and social standards with international benchmarks and extend traceability to energy and carbon.** Responsible mining performance matters in its own right and safeguards access to export markets that increasingly price embedded carbon. Domestic and regional standards should be aligned with international standards and carbon intensity benchmarks, and the SIMBARA traceability platform expanded to capture energy source, tailings management, and carbon intensity data. *Co-led by the Ministry of Environment and the Ministry of Finance.*
- **Build regional frameworks that dock into ASEAN's minerals and power systems.** No single ASEAN economy holds all the inputs, processing capacity, and end-market demand the loop requires, and the least-cost renewable path runs through regional interconnection. National frameworks should connect to ASEAN cooperation on critical minerals, to power-system integration through the ASEAN Power Grid and ARIES, and to low-carbon regional shipping. *Led by the Ministry of Foreign Affairs, with PLN, ESDM, MOI, BAPPENAS, and the ASEAN Secretariat.*

2. Close technology transfer and research and development (R&D) gaps

- **Anchor technology transfer in a domestic innovation ecosystem.** To ensure that transferred technology is locally absorbed, adapted, and reinvested, Indonesia should link BRIN, the mining-industry holding company MIND ID, universities, and industry into a functioning ecosystem oriented toward mineral and energy priorities. *Led by BRIN, with the Ministry of Education, Culture, Research and Technology, ESDM, MOI, and MIND ID.*
- **Condition technology transfer partnerships on domestic capacity building.** Investment and technology transfer arrangements with Indonesia's principal investor countries—China, Japan, and South Korea—should be structured to build domestic capability and guarantee genuine knowledge sharing. *Led by the Ministry of Investment, with the Indonesia Investment Authority (INA), MOI, ESDM, and the Ministry of Finance.*
- **Prioritize grid and battery research suited to Indonesia's conditions.** An archipelagic grid, continuous smelting loads, and shifting battery chemistries each demand targeted research. Priorities include deep-marine and multi-terminal HVDC transmission, grid-enhancing technologies and demand response, a two-track battery strategy pairing chemistry-agnostic capabilities with next-generation nickel chemistries, and grid-technology manufacturing as an enabling sector. *Led by PLN and ESDM.*

3. Strengthen economic and financial feasibility

- **Diversify beyond nickel, where the business case justifies it, and pace capacity to demand.** Indonesia should expand into copper, bauxite, tin, and high-quality nickel-bearing steel alloys, where a business case supports it, and use the economies of scope and scale of shared-use infrastructure to lower risks and costs across mineral and industrial sectors. At the same time, based on the nickel experience, rapid expansion that outran demand produced structural oversupply and a price collapse that eroded producer margins and state revenues; the same must be avoided as other minerals scale. *Coordinated by the Coordinating Ministry for Economic Affairs, with BAPPENAS and MOI.*

- **Cultivate upstream, downstream, and spatial linkages, extending shared use beyond power.** To connect the loop to the wider economy, industrial policy should support domestic suppliers (upstream), incentivize domestic manufacture (downstream), and co-locate industry while opening the shared use of rail, port, water, and information and communications technology (ICT) infrastructure (spatial). *Led by the Coordinating Ministry for Economic Affairs, with BAPPENAS and MOI.*
- **Lower the project-preparation barrier to renewable adoption.** Costly, technically demanding feasibility studies push operators toward the familiar option of captive coal. Standardized, replicable feasibility studies and shared technical assistance would lower this barrier and accelerate adoption. *Co-led by ESDM and BRIN, with MIND ID and state-owned operators, PT SMI on project preparation, and the Ministry of Finance.*
- **Develop a workforce and skills strategy.** Whether Indonesia captures the loop's value depends on domestic skills, which also underpin a just transition. The strategy should tie company training commitments and government incentives to Technical and Vocational Education and Training (TVET) and university programs. *Led by the Ministry of Education, Culture, Research and Technology, with the Ministry of Manpower, ESDM, and BAPPENAS.*

Financing mechanisms that cut across these measures—anchoring revenue to production, instruments for risk transfer, and treating shared infrastructure as a financeable asset class—are addressed in the companion paper, *Financing Indonesia's Green Industrialization*.

These three sets of enabling conditions are complementary and mutually reinforcing: integrated planning determines where renewable capacity is built and which value-chain stages Indonesia anchors domestically; technology transfer and research determine whether Indonesia can operate and improve those systems; and the economic and financial conditions determine whether the loop pays for itself.

Next Steps for Implementation

The most immediate priorities are removing the regulatory confinement of captive power and the barriers to shared use, standing up the coordinating mechanism and the shared data foundation it needs, and pacing new capacity to demand.

Near-term regulatory and institutional steps are achievable within the current policy cycle. Moving from diagnosis to implementation will require sustained, coordinated effort across government, industry, and finance. The payoff for Indonesia will be the conversion of a coal-anchored nickel economy into a renewables-anchored industrial loop, with economic, environmental, and social benefits that reach well beyond nickel.



List of Acronyms and Abbreviations

ADB	Asian Development Bank
AMDAL	Environmental Impact Analysis (<i>Analisis Mengenai Dampak Lingkungan Hidup</i>)
AMI	Advanced Metering Infrastructure
AMIS	ASEAN Minerals Information System
ASEAN	Association of Southeast Asian Nations
BAPPENAS	Ministry of National Development Planning (<i>Badan Perencanaan Pembangunan Nasional</i>)
BESS	Battery Energy Storage System
BIM	Mineral Industry Agency (<i>Badan Industri Mineral</i>)
BKPM	Investment Coordinating Board (<i>Badan Koordinasi Penanaman Modal</i>)
BPS	Statistics Indonesia (<i>Badan Pusat Statistik</i>)
BRIN	National Research and Innovation Agency (<i>Badan Riset dan Inovasi Nasional</i>)
CBAM	Carbon Border Adjustment Mechanism
CCSI	Columbia Center on Sustainable Investment
DERMS	Distributed Energy Resource Management System
DMO	Domestic Market Obligation
ESDM	Ministry of Energy and Mineral Resources (<i>Kementerian Energi dan Sumber Daya Mineral</i>)
EV	electric vehicle
HPAL	High-Pressure Acid Leaching
HVDC	High Voltage Direct Current
ICT	information and communications technology
IMIP	Indonesia Morowali Industrial Park
IPP	independent power producer
IRMA	Initiative for Responsible Mining Assurance
IUPTLS	Business License for the Provision of Electricity for Own Use (<i>Izin Usaha Penyediaan Tenaga Listrik Untuk Kepentingan Sendiri</i>)
IWIP	Indonesia Weda Bay Industrial Park
JETP	Just Energy Transition Partnership
KEK	Special Economic Zone (<i>Kawasan Ekonomi Khusus</i>)
LFP	Lithium Iron Phosphate
LPDP	Indonesia Endowment Fund for Education (<i>Lembaga Pengelola Dana Pendidikan</i>)
LTMS-PIP	Lao PDR–Thailand–Malaysia–Singapore Power Integration Project
MHP	mixed hydroxide precipitate
MOI	Ministry of Industry
MOU	memorandum of understanding

NMC	Nickel Manganese Cobalt
NPI	nickel pig iron
pCAM	precursor cathode active material
PLN	State Electricity Company (<i>Perusahaan Listrik Negara</i>)
PSN	National Strategic Project (<i>Proyek Strategis Nasional</i>)
R&D	research and development
RKAB	Work Plan and Budget (<i>Rencana Kerja dan Anggaran Biaya</i>)
RKEF	Rotary Kiln Electric Furnace
RMAP	Responsible Minerals Assurance Process
RUKN	National Electricity Plan (<i>Rencana Umum Ketenagalistrikan</i>)
RUPTL	Electricity Supply Business Plan (<i>Rencana Usaha Penyediaan Tenaga Listrik</i>)
SOE	state-owned enterprise
UHV	ultra-high voltage



Introduction

Mining, energy, and industrial development each carry significant potential to advance sustainable development in resource-rich developing economies, and Indonesia is a case in point. Mining produces critical materials and value inputs that support private and public revenue generation, job creation, technological capacity, and industrial expansion; it can also serve as anchor demand for improved, renewable energy systems. Energy is a fundamental input for mining, industry, and other economic sectors, powering development in all realms. Green industrialization can allow mineral and renewable energy resources to yield mid- and downstream value addition and economic diversification—including in sectors relevant to the production, export, and domestic deployment of clean energy technologies.

Alone, each component can offer critical inputs for sustainable development; synergized, their interdependence creates a **mining–energy–industry feedback loop** that can be conducive to sustainable development and the achievement of climate goals, provided that the appropriate enabling conditions are met to support and align their respective benefits. The Columbia Center on Sustainable Investment (CCSI) has first explored the feedback loop in the African continent.¹

As part of the *Indonesia's Green Industrialization* project, developed by CCSI with support from Yayasan Visi Indonesia Raya Emisi Nol Bersih (ViriyaENB), this policy concept note outlines the structure of a mining–energy–industry feedback loop in Indonesia, with a focus on the nickel sector ([Section 1](#)), its potential benefits ([Section 2](#)), and its necessary enabling conditions, including policy recommendations to achieve them ([Section 3](#)).²

In recognition of the importance of circular economy and sustainable finance, alongside the mining–energy–industry feedback loop, in fostering Indonesia's sustainable development in mineral–industrial value chains, this policy concept note has two companion pieces: a policy report titled *Integrating Circular Economy Principles and Practices in Indonesia's Nickel Sector: Overview, Benefits, and Enabling Conditions*,³ and an applied research paper titled *Financing Indonesia's Green Industrialization: System Pathways, Structural Diagnosis, and Tailored Solutions*.⁴ Contextual information on Indonesia's current mineral and energy landscape is compiled in the project appendix: *Indonesia's Green Industrialization: Landscape and Trends in the Energy Sector and Critical Minerals Value Chains, with a Focus on Nickel*.

The Synergistic Nature of Three Sectors

Energy serves as a fundamental input for nearly every stage of development. Industrial development of any kind relies on significant volumes of inexpensive, reliable power.⁵ Meanwhile, large-scale energy development can benefit from large power purchasers serving as anchor demand that reduces off-taker risk and supports bankability. Mining operations can serve as these anchor demand customers, creating opportunities to develop renewable energy systems at scale. These energy developments can power industry for downstream production.

Mining-related products are essential inputs for the production of many clean energy technologies.⁶ By developing domestic capacity for the manufacturing of clean energy technologies that strategically use mining products, industrial players can become key customers for mining operations. As this domestic capacity grows, the cost of new energy technologies falls, creating system-wide efficiencies that benefit both mines and industrial users.

Each of the three sectors thereby fulfills needs and creates efficiencies that accelerate the subsequent development of the others. Mining improves the bankability of the development

of renewable energy systems by serving as anchor demand while enabling energy access for industrial development. Strategic industrial development for clean energy technologies can serve as demand for downstream mining production while also improving the capabilities and costs of clean energy technologies. And as energy technologies and capabilities improve, mining and industrial partners reap the benefits of more efficient, cost-effective production (Figure 1).

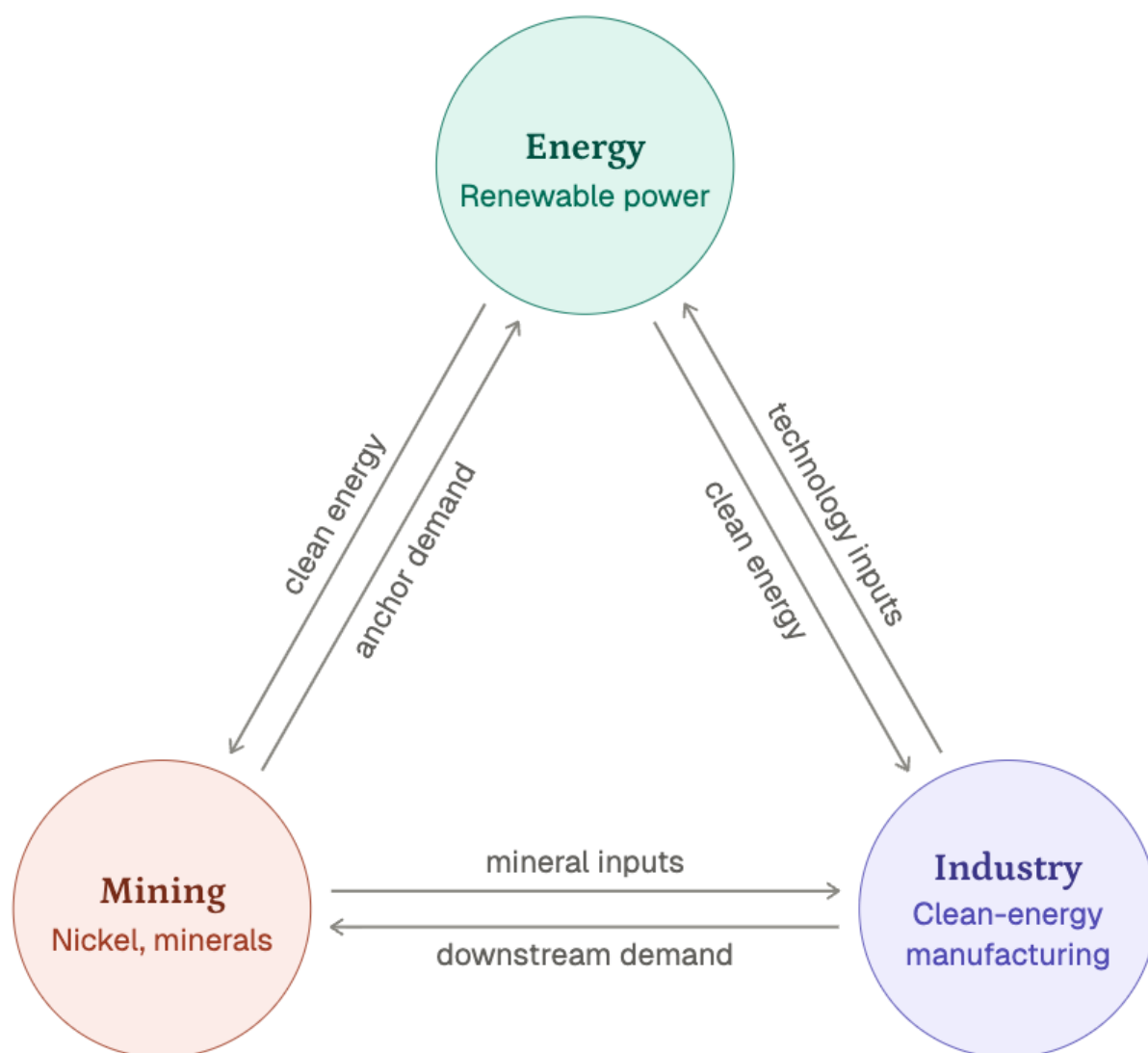


Figure 1. Mining–energy–industry feedback loop

Source: Prepared by the authors.

Indonesia’s mineral wealth, particularly in nickel, provides the primary input for establishing a mining–energy–industry feedback loop. The country’s significant strides in shoring nickel processing within its borders have contributed to its rise to the world’s largest producer of raw nickel ores and intermediaries.⁷ However, the rapid development of Indonesia’s nickel mining and processing industry has largely taken place with captive coal-fired power plants as the primary energy source.⁸ Building the mining–energy–industry feedback loop based on Indonesia’s abundant renewable energy resources would support national, regional, and global sustainable development and climate action goals. This policy concept note suggests a path to support the progressive displacement of coal-fired power by scaling up the deployment of renewable energy resources and industrial capacity in Indonesia and the broader Southeast Asian region to establish such a system.

Many of Indonesia's captive coal-fired power plants used in nickel production or processing are in the infancy of their lifespan; under current policy conditions, retirement of these energy resources may be uneconomical and unlikely in the foreseeable future.⁹ For Indonesia, early retirement of coal-fired power plants by 15 years would result in losses equivalent to 1.1% of GDP in 2020.¹⁰ A substantial literature examines coal retirement in general and in Indonesia in particular;¹¹ at the same time, the Indonesian government consistently frames coal as a domestic energy security resource and treats energy diversity as a source of competitive advantage.¹² Our approach takes this reality as its starting point. Rather than focusing on *coal phaseout* through early retirement, decommissioning, and replacement of a young captive coal fleet, our proposed approach to decarbonizing Indonesia's mineral, energy, and industrial system relies on a *renewables phase-in*: ensuring that new mineral and industrial development is anchored on newly built renewable energy systems, so that renewables progressively displace coal at the margin of new capacity. Acknowledging that coal will remain part of Indonesia's energy mix in the short to medium term, the objective is to steer *new* investment toward renewables, allowing the coal share to decline as overall demand grows and the existing fleet ages.

With a focus on zero-carbon mining, production and deployment of clean energy technologies, and downstream green industrial development, Indonesia can create a pathway for decarbonizing its future energy matrix and future industries. This paves the way for the eventual displacement of fossil energy both within mineral industries and more broadly across Indonesia's national energy system as well as Southeast Asia's regional energy system.



1. Structure of a Mining–Energy–Industry Feedback Loop in Indonesia

This section explores the three components of the mining–energy–industry feedback loop. [Section 1.1](#) zeroes in on **nickel mining and processing**, notably within industrial parks, and examines mining–energy interdependencies and the potential for shared-use arrangements for mining-related power infrastructure in the Indonesian context. [Section 1.2](#) focuses on the production of **renewable energy** technologies and the deployment of renewable energy systems, building on Indonesia’s nickel value chain and regional trade, integration, and energy interconnection. Closing the loop, [Section 1.3](#) offers an exploratory overview of the **industrial** and other economic sectors—within and beyond nickel value chains—that Indonesia can leverage to diversify its green industrialization strategy, hedging against over-reliance on nickel and preparing for a post-nickel economy.

1.1 Mining–Energy Interdependencies and Shared-Use Arrangements

Mining and mineral processing operations demand significant amounts of power, making power sourcing one of the most significant financial arrangements in the process of securing the viability of mineral operations. Mining power sourcing arrangements can take a number of different forms depending on the nature of the mining operations, local geography, and available energy resources. The typology of these arrangements can be organized along a continuum ranging from self-supplied power to full sourcing from the grid (Table 1).

Table 1. Spectrum of power sourcing arrangements

Option		Description	Main generation drivers
Self-supply		Mine produces its own power for its own needs.	Diesel, HFO
Intermediate options	Self-supply + CSR	Mine provides power to community through mini-grids or off-grid solutions.	Diesel, HFO
	Self-supply + sell to the grid	Mine produces its own power and sells excess power to the grid.	Coal, Gas, Hydro
	Grid supply + self-supply backup	The mine is first connected to the grid and is moving into own-generation when more economical.	Diesel, HFO
	Mines sell collectively to the grid	Coordinated investment by a group of mines, producers, and users in one large power plant off-site connected to the grid.	Diesel, HFO, Solar
	Mines invest in the grid	Mine invests with government in new, or in the upgrading of, power assets under different arrangements.	Hydro, Gas
	Mines serve as anchor demand for IPP	Mine buys power from an IPP and serves as an anchor customer.	Any
Grid supply		Mine does not produce any power, but buys 100% from the grid.	Any

Source: Taş et al. (2025).¹³

Three primary drivers influence a mine's power sourcing typology. The first is the **available primary energy mix**, as the relative sources of clean and affordable energy determine the required infrastructure. The second is **grid stability**, which impacts firms' vulnerability to power disruptions and implicates their management practices. As the third driver, **cost differentials between grid and self-supply tariffs** for electricity also have an outsize impact on firms' decision to interconnect or remain captive.¹⁴

Self-supply, with the mine producing its own power for its needs, largely occurs because a country's grid capacity is too low or nascent. At the other extreme of the spectrum, the choice to source power from the grid typically results from high availability and reliability of renewables (for example, hydropower), minimal power outages, and low electricity prices; the energy utility needs to provide reliable, affordable electricity and become a viable and creditworthy partner for energy development.¹⁵ In the event that utilities struggle to find the off-taker stability required for power development bankability, mining companies can help develop the power sector by filling this gap.¹⁶

Indonesia's nickel sector, particularly in the main nickel industrial parks, largely self-supplies power. The geographic remoteness of most nickel mining and processing operations and limited grid capacity make direct interconnection for power at many of Indonesia's mine sites uneconomical or technically unviable. Mining operations have supported local development of roads and basic infrastructure to house and sustain workers in industrial parks.¹⁷ Yet these system-level investments have historically not extended to interconnection and broader energy system investments across the islands, evident in the industry's outsize reliance on captive coal.

Geological and policy factors contribute to the abundance of coal as a primary energy source for Indonesian nickel mining and industrial operations. Coal is the most readily available fungible energy source in Indonesia, obtained from Sumatra and Kalimantan and distributed throughout the islands. Industrial offtakers benefit from domestic downstreaming obligations that ensure sufficient coal supply for industrial use, but do not benefit from the coal price caps available to Perusahaan Listrik Negara (PLN),¹⁸ the state utility company. Rather, for procurement in captive systems, coal prices are negotiated through individual contracts, often with a mix of fixed, negotiated, and index-linked pricing.¹⁹ Yet even these market-oriented prices experience policy support. Through a 2025 regulation, Indonesia removed the price floor for industrial coal purchasing contracts, leading to the potential for even lower prices for input fuel.²⁰ Whether grid-connected or captive, coal sees a supportive policy environment across Indonesia.

The fuel price distortion is not confined to coal. Even operators that have largely avoided captive coal can be steered toward it by the pricing of alternative fuels. For example, certain operations powered primarily by hydropower still use marine fuel oil (MFO) for parts of their processing; with MFO supply concentrated under the state-owned energy company Pertamina, prices have risen and leave little room to negotiate, creating a perverse incentive to substitute back toward coal.²¹ Fuel price signals thus continue to favor carbon-intensive options, even for firms actively seeking to decarbonize.

Grid maturity in regions of nickel production (Sulawesi and Maluku) remains limited. Much of Sulawesi's grid, for example, relies on hydropower. Yet with El Niño spells and climate change, hydropower dams suffer from increasing insecurity.²² On the matter of interconnection, the grid in Sulawesi remains divided into northern and southern sections. While extensive renewable energy generation potential exists in the south, northern regions of Sulawesi do not have access without interconnection to join the two grids.²³ The Sulawesi Backbone, critical grid infrastructure to interconnect the northern and southern regions, is included in Indonesia's Electricity Supply Business Plan (RUPTL), and the project is expected to commence in 2026.²⁴ These factors, while

solvable, complicate sourcing of power directly from the grid for mine use. However, given that large-scale infrastructure corridors are planned, mines have clear avenues to support grid infrastructure in nickel producing and processing regions.

Finally, and most significantly, the cost differential between coal and renewable energy remains high in Indonesia's nickel producing regions. As of 2023, supercritical coal remains the lowest-cost form of generation in Indonesia today, largely due to the subsidy from the price cap imposed through Domestic Market Obligations (DMOs).²⁵ Total system cost for non-interconnected renewable systems such as solar-plus-battery-storage remains as high as USD 0.16 per kWh, putting captive coal costs below competitive pricing from standalone renewable sources (Figure 2).²⁶

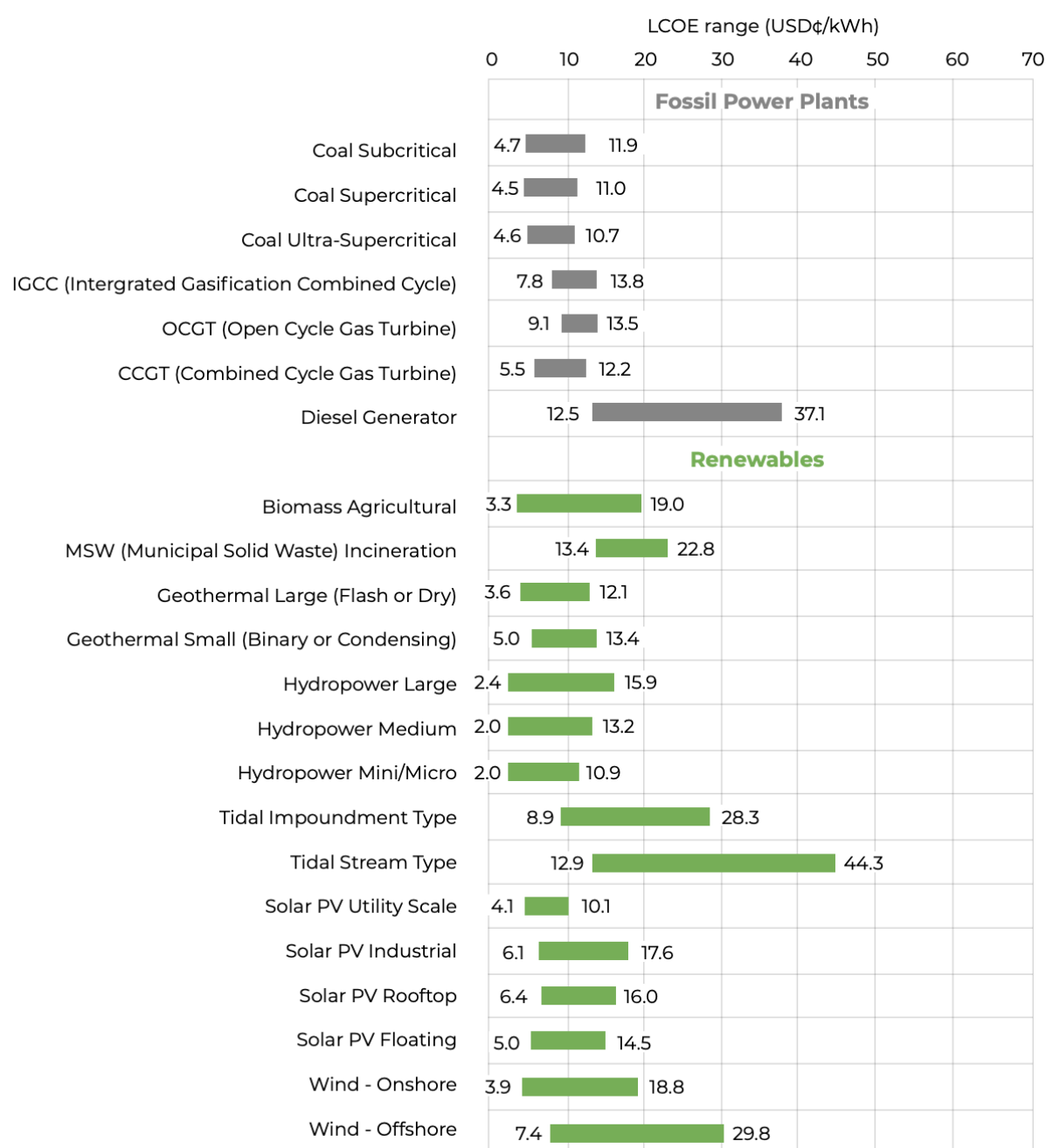


Figure 2. Levelized cost of electricity (LCOE) from various generation technologies, Indonesia, USD cents/kWh

Source: IESR (2023).²⁷

However, with additional development, cost-effective renewables generation does not seem distant. While not every project exhibits best-in-class unit economics, large geothermal projects in Indonesia have reached a levelized cost of electricity (LCOE) as low as USD 0.036 per kWh; some utility-scale solar projects reached an LCOE of USD 0.041 per kWh.²⁸ These emergent technologies could compete effectively with coal, if the necessary enabling conditions are ensured.

In between the extremes of self-supply and grid sourcing, the power demand from the mining industry can support the national power system in various ways through **shared-use arrangements of mining-related power infrastructure** (Table 1 above). According to CCSI's Framework to Approach Shared Use of Mining-Related Infrastructure (the Framework), the following steps can assess the potential of shared-use mining-related power infrastructure:²⁹

- *Step 1: Assessing the Current Situation* – The current arrangement should be thoroughly analyzed beforehand, especially the main reasons why the industry is set up as such.
- *Step 2: Identifying Operational Synergies* – The government can focus on one or more goals that shared-use energy infrastructure can help achieve: rural electrification, excess power generation for a sell-back arrangement, anchoring Independent Power Producers (IPPs), or overall power generation and transmission infrastructure development.
- *Step 3: Verifying the Necessary Preconditions* – Each of the potential arrangements has necessary preconditions, mainly the regulations in place and the dynamic between the players, including the government, financing bodies, mining companies, and civil society organizations (CSOs).
- *Step 4: Negotiation Points* – To support these preconditions, there are negotiating points that policy makers can refer to and strategize before enacting any interventions.

The remainder of this section follows these steps to apply the Framework to Indonesia's case and provide recommendations.

Step 1. Assessing the Current Situation

With PLN's monopoly, industry players in Indonesia receive a lower fixed price of electricity than their average cost of generation.³⁰ The abundant domestic production and obligation of coal also contributes to relatively inexpensive fuel sources. Therefore, the high cost of grid power is not an inhibition for industry players in Indonesia to connect to the grid. However, with an installed capacity of 46.8 GW, PLN cannot cater to the over 200,000 GWh industrial demand (203,000 GWh in 2023).³¹ Furthermore, Indonesia lacks transmission infrastructure (Figure 3) for several areas of mining concessions and nickel smelters, notably in Sulawesi and Kalimantan (Figures 4 and 5). Because of these conditions, industry players have resorted to self-generation.



Figure 3. Power grid system, Indonesia

Source: Hazarabedian, O'Neill, and Witto (2023).³²

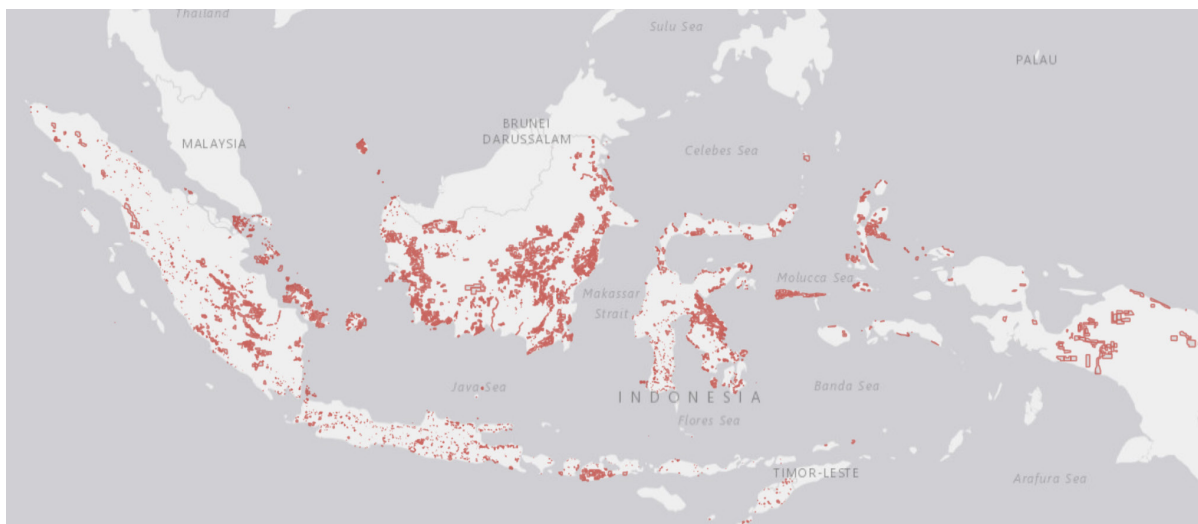


Figure 4. National mining concessions, Indonesia

Source: Nusantara Atlas (2025).³³

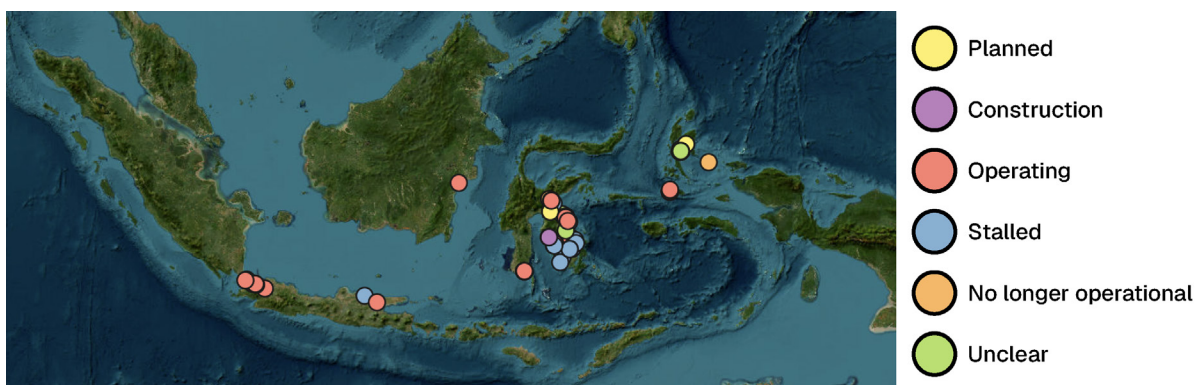


Figure 5. Nickel smelters, Indonesia

Source: Center for Global Sustainability (2025).³⁴

While mines in Indonesia are located in remote areas, the smelters and refineries are often located in broader industrial complexes (Figure 6). There are over 100 operating complexes in Indonesia, and more than 20 under construction or planned.³⁵ There are no set regulations regarding the vicinity of these industrial areas to residential and commercial spaces, but older ones were developed in urban areas or have now been reached by urban sprawl; in one case, a tenant broke the regulation and built its facility as close as 2 kilometers away from the nearest residential area.³⁶ Nearly 80% of the parks are in Java and Sumatra, the two most populous islands, with nearly 12 GW of electricity capacity.³⁷

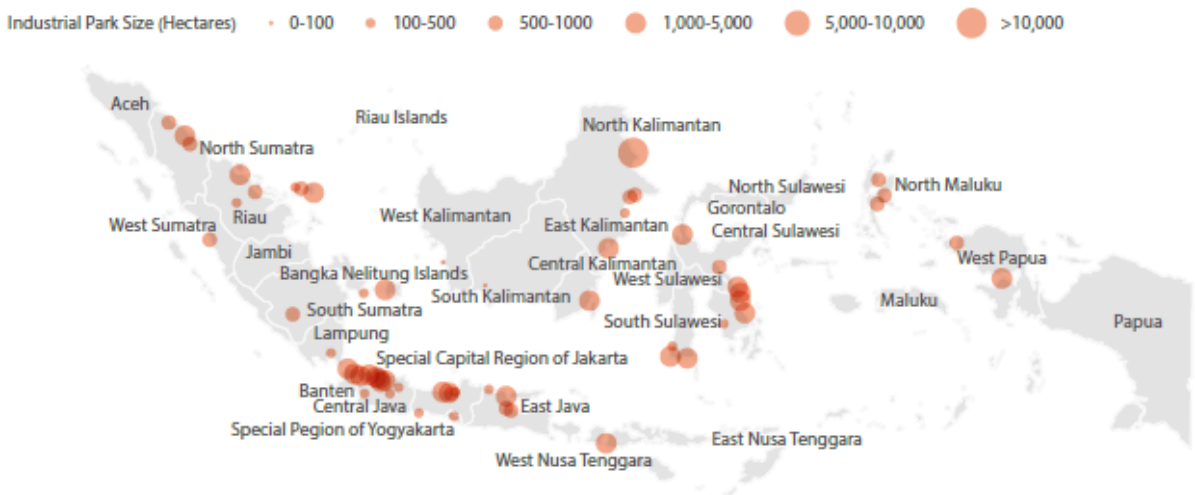


Figure 6. Industrial parks by size, Indonesia

Source: Zhu et al. (2023).³⁸

The high energy requirements of mining and mineral processing industries in Indonesia are currently fulfilled mostly by captive coal power generation, reaching 11.2 GW in 2023 with a projected additional 20 GW by 2032 (Figure 7).³⁹ This major expansion occurs in North Maluku and Sulawesi, driven by mineral smelting industries that need stable power for energy-intensive metallurgical processes (Figure 8).⁴⁰ For nickel, 37 MWh of electricity is used per metric ton produced via the pyrometallurgical Rotary-Kiln Electric Furnace (RKEF) process for ferro-nickel or nickel pig iron (NPI).⁴¹ RKEF is the most common method used in Indonesia to manufacture stainless steel and non-ferrous alloys.⁴²

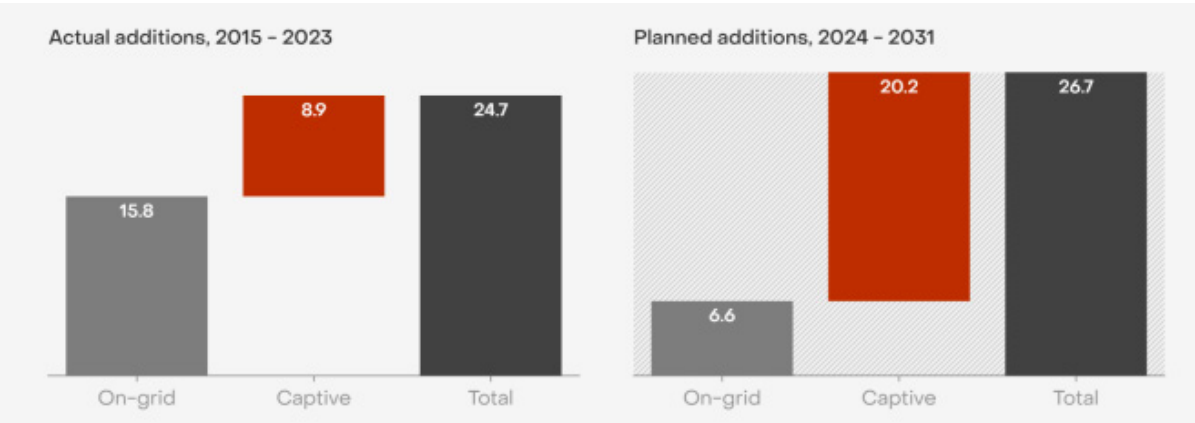


Figure 7. Coal-fired power plant capacity additions, Indonesia, GW

Source: Setiawan (2025).⁴³

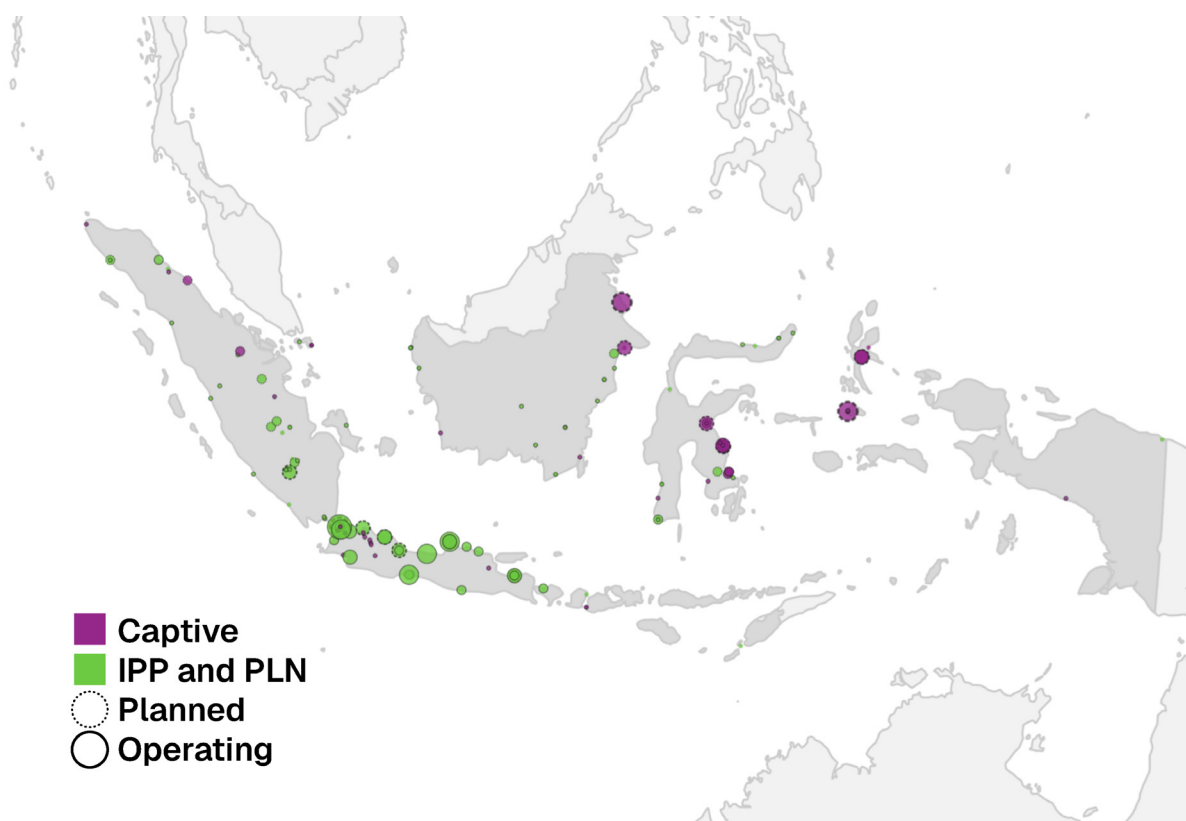


Figure 8. Current and future coal-fired power plants, Indonesia

Note: The size of the circles represents generation capacity.

Source: Parapat and Hasan (2023).⁴⁴

Therefore, in its present iteration, Indonesia powers its mining and processing through captive generation due to the insufficient capacity of grid and power systems in regions surrounding mines and industrial parks. Shared-use mining power infrastructure will still need to overcome the level of demand and energy intensity of the nickel industry and any resulting downstream sectors.

Step 2. Identifying Operational Synergies

As noted above, shared-use energy infrastructure can help achieve various governmental objectives, such as rural electrification, excess power generation for sale, anchoring IPPs, or overall power generation and transmission infrastructure development. The following sections analyze the potential for pursuing such objectives in Indonesia.

Supply to Communities: Leveraging Mines and Smelters for Rural Electrification

Areas that are too remote to reach the national grid often justify self-generation - this often applies in the case of communities surrounding nickel sites. Frequently, the surrounding communities also suffer from unreliable electricity as a result of their remoteness and inability to connect to the national grid or larger energy system. The development of captive power generation can then be utilized to power those areas as well, acting as mini-grids, should nearby communities be able to connect.

Isolated instances of this model already exist. In South Sulawesi, PT Vale channels 10.7 MW of the electricity from its 365 MW Larona–Balambano–Karebbe hydropower complex to PLN, contributing to supply for communities in East Luwu.⁴⁵ This example shows that mine-anchored renewable generation can serve surrounding populations where the infrastructure and commercial arrangements allow.

Currently, in Sulawesi, less than 5% of the total amount of electricity generated from the captive plants is used by residential units around the mines or smelters.⁴⁶ It is also a common practice for locals to steal electricity by pulling illegal lines from cables in less crowded areas.⁴⁷ If shared use is planned for when the infrastructure is being developed, there are more opportunities for governmental support and fiscal schemes that can be beneficial not only to mineral and industrial stakeholders, but also to other potential residential and commercial customers, particularly in remote rural areas in the vicinity of the mines or smelters.

Mini-grids have been abundantly considered for Indonesia, mostly being community-based and powered by renewable energy.⁴⁸ However, minigrids face issues with operation and maintenance as their revenues cannot support continuing costs. There have been government-led programs that finance the installations with international support, such as from the Millennium Challenge Corporation,⁴⁹ but low consumption levels and high costs hinder continued use.⁵⁰

Many cases in other countries show that power tariff subsidies have limited effect on power expansion, as they largely benefit those already connected to the existing infrastructure; it is instead recommended to direct subsidies toward renewable mini-grid operations, which would expand the capacity of mini-grids as off-grid infrastructure that serves broader communities.⁵¹ These lessons may also be relevant in Indonesia, where current financing schemes create a coal lock-in situation.⁵² Indonesia's current tariff regime involves a price cap on the cost of electricity, accompanied by a price cap on coal used for domestic consumption.⁵³ In focusing on electricity prices alone without considering the needs and capacity of anchor demand from mining and industrial actors, Indonesia bears the risk of locking out renewable energy generation from its broader infrastructure development.⁵⁴

Excess Supply: Leveraging Mines and Smelters for Increased Power Generation

Mining companies and smelters that have developed their own power generation could find themselves in an advantageous position to sell their electricity to the primary supplier, PLN in Indonesia's case. Provided that the companies are progressively integrated to the grid, they could generate additional revenues that could help cover the high upfront capital costs of investment in renewable power infrastructure. Joint investments or partnerships via industrial park complexes could also be considered, and the reduced risk could attract more investors.

Anchor for IPPs: Leveraging Mines and Smelters for Increased Generation

The power demand from mines and smelters can be used to stimulate investment for IPPs. These companies can either be the offtaker and direct customer of IPPs, or become direct investors and create IPPs through joint ventures (Figure 9). PLN can also purchase any excess generation for other residential or commercial customers.

Similar to the excess supply synergy discussed above, the involvement of various stakeholders can increase reliability and risk mitigation for the investment. It also reduces the capital requirement significantly compared to self-generation, while purchasing power from the grid can be more expensive. However, this scheme poses the highest level of risk of operational disruption for mining companies if energy supply is compromised.

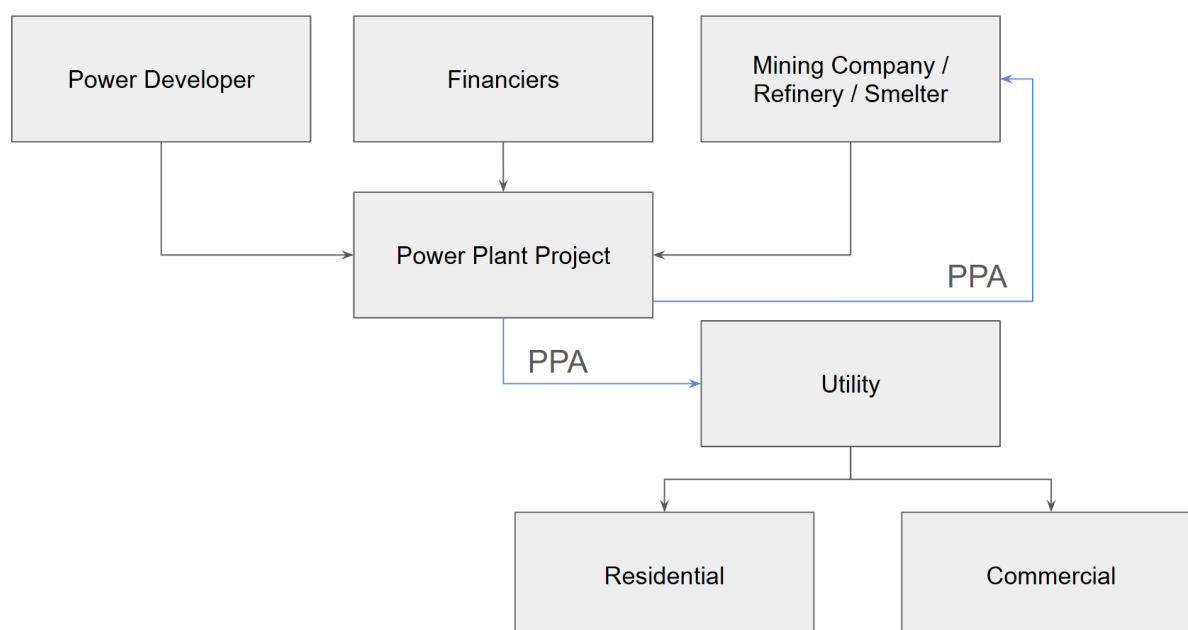


Figure 9. Example of a public–private partnership (PPP) for shared-use energy Infrastructure

Source: Adapted from CCSI (2014).⁵⁵

Sourcing from the Grid: Leveraging Mines and Smelters for Increased Generation and Transmission Infrastructure

In the case of sufficient and affordable power supply through the grid for mines or smelters, it is important to ensure that they do not overburden the grid, which prioritizes residential demand. There are possible commercial frameworks that help both the mining industry and subsequent development of power infrastructure for the country, including the following:

- *Mines and smelters extend transmission infrastructure* – The mines and smelters could invest in transmission lines, substations, and distribution within a loan scheme towards the utility company. The payment can either be through interest-based loans or be applied through offsets in invoices for power purchases.
- *Mines and smelters pay more for priority access* – Priority from the utility sector will be adjusted, but it comes with a price from the mines and smelters via investing in extra emergency power infrastructure or generators for communities, or paying premium access rates for the electricity.
- *Mines and smelters accept to pay higher tariffs if investment is by the utility* – This scheme refers to adjusting the price control from the utility to enable it to invest in both generation and transmission infrastructure. Tariff agreements should have sufficient flexibility to adjust for inflation and other potential factors.

Indonesia holds numerous pathways to integrate shared-use into its mining power infrastructure across the various dimensions of CCSI's *Framework*, should they be pursued.

Step 3. Verifying the Necessary Preconditions

To assess the preferred synergy for a country, some necessary preconditions should be attained (Table 2). Below, we examine these preconditions in Indonesia's case for three aspects: legal, regulatory, and institutional framework; capabilities and responsibilities of the utility; and the planning framework for power generation.

Table 2. Preconditions of mining–energy synergy solutions

Solution	Necessary Preconditions
Mines and Smelters + Rural Electrification	• Contractual requirement for mines and smelters to participate in rural electrification initiatives • Coordination between mining and smelting companies and donor/ government/NGOs • Clear framework articulating responsibilities of each party • Capacity of each party to carry out their role • Presence of local government/utility in rural areas • Effective demand/willingness to pay for power in communities
Mines and Smelters + Excess Supply	• Liberalized power market with clear legislative and regulatory framework for private sector auto producers of power • Excess capacity built in at design phase of power plant project • Commercially viable offtake agreement between company and utility • Credible state-owned utility, if acting as offtaker • Adequate transmission infrastructure to offtake and distribute power • Demand for excess power (national or as part of regional power pool)
Mines and Smelters as an anchor for IPPs	• Liberalized power market with clear legislative and regulatory framework for IPPs • Sufficient IPP power supply to meet mining demand as well as excess supply for national grid • Sufficiently low-cost and reliable power supply anticipated (vis-à-vis current self-supply arrangement) to incentivize mining company to act as offtaker • Power plant to be available to fit with mine's planned timetable. Other mine logistics (rail, port) not likely to delay mining project and thus mining power demand • Investment in transmission infrastructure to supply power to mine site • Utility to act as a credible partial offtaker of power from IPP
Mines and Smelters source from grid	• Sufficient and reliable national power supply to meet demand • Cost of power sufficiently low to dis-incentivize mining company from self-supply, but sufficiently high to enable utility to achieve cost recovery (covering capital and operating costs) • Transmission infrastructure in place to supply mine or smelter or extension as a manageable investment • Management of the mine's or smelter's power demand so as not to saturate the national grid • Commercial frameworks in place to incentivize mines to participate in or fund upgrade of transmission infrastructure and development of national power generation capacity

Source: CCSI (2014).⁵⁶

Policy, Legal, Regulatory, and Institutional Framework

Legal frameworks should provide a conducive environment to attract investment. This includes creating room for flexibility within PLN's vertical integration so mining and smelter investments can supplement PLN or encourage IPPs. This is especially true if the utility has limited financial power to build generation off its balance sheet. More broadly, a stable long-term regulatory and business environment is important in reducing the perceived risk of investment in renewables, which carry large upfront capital and long-term recovery periods.⁵⁷

In Indonesia, the power arrangement is vertically integrated via PLN, but private investments have supported national electricity supply via governmental regulation No. 30 of 2009, Indonesia's Law on Electricity. Moving forward, Indonesia will rely heavily on IPPs, especially for adding renewable generation to the energy mix.⁵⁸ Though PLN still has the utmost control for electricity generation and distribution, captive power (whether from fossil or renewable sources) is outside their authority and instead is coordinated by ministries. Licensing for captive power (IUPTLS) is submitted in one centralized portal for all licenses under a website of the ministry of investment and downstreaming,⁵⁹ with approval being managed by the Ministry of Energy and Mineral Resources (*Kementerian Energi dan Sumber Daya Mineral*, ESDM). This is mandatory for generators above 500 kW within one installation system—smaller generators only require a report.⁶⁰ The Ministry of Industry (MOI) also has authority for special request cases if it is under a certain generation limit.⁶¹

The Indonesian government and PLN are responsible for managing the risks and contractual obligations and controlling tariffs for market viability. Regulations seek to avoid discriminatory tariff values that create competition between the IPPs themselves or against the state utility. The Indonesian government has tariff regulation in place where the values set for non-subsidized customers are reviewed every three months.⁶² This value is set by the ESDM based on the U.S. dollar, Indonesian crude price, coal prices, and inflation.⁶³

Subsequently, strong regulatory oversight is crucial to ensure long-term investment is protected, especially towards IPPs either serving the mines and smelters or general excess supply purchases by the state utility company for residential and commercial usage. Regulators must pay special attention when setting rates and tariffs, such that the correct incentives align to protect reliability and price stability, depending on the shared-use configuration at play.

Capabilities and Responsibilities of the Utility

The state utility has an essential role in the feedback loop arrangement as the main partner for the mining companies/smelters and IPPs. The success will heavily depend on the state utility's financial health and creditworthiness, in addition to its ability to supply electricity.

PLN has claimed a national electrification ratio of 98.45%,⁶⁴ but is increasingly criticized for its monopoly position, incapability to power areas of the country, and financial constraints, especially during the pandemic and subsequent economic recessions.⁶⁵ Proposing a shared-use scheme under these circumstances may raise concerns among mines and smelters and other industrial users regarding the reliability of the energy supply distribution. In the worst-case scenario, low supply can force PLN to prioritize power supply to certain residential or industrial customers, creating a “us versus them” mentality.

Planning Framework for Power Generation

Establishing shared-use power infrastructure requires extensive coordination between the government, mines and smelters, investors, and community stakeholders. The local government needs to have a solid presence, especially in the rural areas, to assess the energy needs thoroughly and uphold clear legislation and regulatory frameworks for the private sector to follow. A team or specialized body can be created to craft the agreements between the parties while ensuring productivity that follows the timeline set by the companies. They should also oversee transmission, not only to satisfy the demand but to manage saturation of the national grid.⁶⁶

Goals of the Indonesian government are clear with net-zero commitments, coal phaseout plans, and nickel industrialization, followed by ESDM's national electricity plan (RUKN) and PLN's power deployment plan (RUPTL). However, the division of generation development between PLN and the ministries has left gaps in the data on available and planned energy supply and demand. As a result, when mineral

processing permits are issued without reference to up-to-date data held elsewhere in government, capacity approvals can outrun both feedstock and power availability. ESDM has begun to address this by developing a public geospatial platform intended to consolidate reserves, resources, land-use overlaps, existing permits, and proximity to transmission, so that investors and planners can price risk against a common information base.⁶⁷ Alignment within and across ministries around shared data is crucial, as the intricacies of industrialization activities span many functions under different departments.

The existence of a coordinating ministry is essential; however, the government was reshuffled in late 2024, including the dissolution of the one that housed all these ministries. Now, they are placed under the Coordinating Ministry for Economic Affairs, which has stated the need to synergize and implement changes step by step.⁶⁸ Another issue faced is the lack of influence and involvement from local governments towards infrastructure planning, which restricts their ability to monitor on-location daily activities.⁶⁹

Conclusions from the Application of CCSI's Framework to Indonesia's Case and Negotiating Points for Implementation

The fragmented condition of Indonesia's electricity development makes it difficult to adopt one single solution for the entire country. Even the major islands and their corresponding grids face varying degrees of remoteness or stability in different areas. In places where mines and smelters are or can be connected to the grid and the electricity price is cheap, mines and smelters should consider investing in increasing renewables-based power generation and building or improving transmission infrastructure.

Based on the potential synergies discussed above, there are several possible actions for the power sector from the nickel mines and smelters in Sulawesi and Maluku:

- 1. Mines and smelters supply power to surrounding communities** – This synergy should be the primary goal, especially for remote places in the smaller islands.
- 2. Mines and smelters collectively build power plants with larger capacity** – Industrial parks already serve as an umbrella regulator and organizer for several companies, which eases coordination.
- 3. Mines and smelters serve as anchors for IPPs** – This option can be explored simultaneously with the two options above.
- 4. Mines and smelters sell excess power to the grid** – This option would be possible for facilities that are on the Sulawesi main island, most likely in the southern area near PLN's South-Central Sulawesi grid.

In the region, mines and smelters are economic anchors and have more leverage, while local governments have less power. Infrastructure development plans by the central government can create social tension between citizens as they depend highly on the location of these mines and smelters.⁷⁰

Furthermore, the Indonesian government has an interest in prioritizing domestic industrialization. Sites in South Sulawesi are more often owned by Chinese companies compared to Halmahera sites managed by Indonesian companies and state-owned enterprises (SOEs). Foreign owners, who can have their own interests, can add political complications to development plans as well. Nonetheless, this external influence can also keep planning and activities accountable to an international standard.

Implementing shared use would have to be done according to plans and in a timeline set out in the appropriate policy and legal instruments.⁷¹ The plan can dive deeper into the different industrial complexes and set priorities depending on active players in the area, the density of communities affected, the financial capabilities of the stakeholders, and the geographic advantages for the energy sources.

1.2 *Production of Renewable Energy Technologies and National and Regional Deployment of Renewable Energy Systems*

As nickel mining and processing activities anchor demand for renewable electricity (Section 1.1 above), they also produce invaluable inputs for producing nickel-based batteries and other technologies that support the deployment of renewable energy systems and green industrial development in Indonesia and in Southeast Asia more broadly.

This section discusses the current state and immediate plans for renewable energy systems deployment in Indonesia, examining whether and to what extent it (a) responds to the energy demand from mining, mineral processing, and industrial activities, and (b) fulfills the opportunities arising from a potential feedback loop. The importance of energy interconnection within Indonesia and throughout the Southeast Asian region is also highlighted (Section 1.2.1). The section then turns to the industry pillar of the feedback loop, exploring the production of renewable energy technologies in Indonesia, with a focus on nickel-based batteries (Section 1.2.1).

1.2.1 *Deployment of Renewable Energy Systems in Indonesia*

As part of the Indonesian government's plans for net-zero by 2060, 42.6 GW of renewable energy capacity is to be added by 2034.⁷² In addition to funding from the central government and ministries, the sovereign wealth fund Danantara Indonesia, established in 2025, is expected to enable investment in the strategic renewable energy sector, supported by agreements with PLN.⁷³ Another essential body for renewable energy development is the Just Energy Transition Partnership (JETP), which aims to invest USD 20 billion in the sector.⁷⁴ This section provides an overview of renewable energy system deployment and its relevance to the proposed mining–energy–industry feedback loop.

Energy Generation

Hydropower. Indonesia's hilly landscape with high rainfall and humidity makes hydropower the current highest source of renewable energy, with locations mostly in Java and Sumatra.⁷⁵ The government plans to add nearly 1 GW of hydropower capacity per year between 2026 and 2030, and in 2031 a major increase of 3.6 GW is projected.⁷⁶

Various projects are already in progress to fulfill this objective, with many under partnerships with foreign entities.⁷⁷ Japanese utility Electric Power Development Co. (J-Power) is involved in the construction of five river-based plants in North Sumatra totaling a capacity of 55.6 MW, mostly starting operations in 2027.⁷⁸ With South Korea's KOMIPO, the Siborpa plant will have a capacity of 114 MW.⁷⁹ Previously, the partnership has constructed the Wampu and Tanggamus plants, which began operations in 2016 and 2018, respectively.⁸⁰ PLN (sole taker) did not indicate specific usage for these plants, but the power will most likely be redirected towards residential use or towards the nearest industrial areas that process palm oil.⁸¹

As part of a JETP program, the European Union has funded feasibility studies for large-scale pumped-storage hydropower, one in North Sumatra for 500 MW capacity and one in East Java for 1,000 MW.⁸² Both will be implemented through PT SMI, a state-owned enterprise (SOE) that also serves as the Country Platform Manager for Indonesia's Energy Transition Mechanism (ETM).⁸³ The facilities are hoped to stabilize each of the island's main grids, Sumatra and Java-Madura-Bali,⁸⁴ but are not expected to power industrial areas specifically due to the far distance to the nearest parks.

Currently for nickel, Vale Indonesia is the leading company in using this source for their processing operations. Starting from 1979, they depend on their Laronia plant for their site in Sorowako, South Sulawesi.⁸⁵ They have added two plants since, the Balambano and Karebbe, totaling a capacity of 365 MW.⁸⁶ New company Neo Energy aims to follow, with their HPAL smelter to be powered entirely by renewable energy, mostly from hydropower, with a mix of solar.⁸⁷ They began construction in 2024 with a target to start by the third quartile of 2026.⁸⁸

The largest hydropower project in Indonesia, Kayan Cascade, will have five dams and a total capacity of 9,000 MW.⁸⁹ It is set to power the Kalimantan Industrial Park Indonesia (KIPI) estate and their planned downstream industrialization, which includes a product lineup of EV batteries, solar panels, semiconductors, petrochemicals, and aluminum.⁹⁰ Collaborating with Japan's Sumitomo and China's Shanghai Electric Power,⁹¹ the Indonesian counterpart and owner of the project is Kayan Hydro Energy, who is also constructing the 1,375 MW Mentarang Induk hydropower plant.⁹² Targeted to be operational in 2030, it is set as a national strategic project to also support KIPI's power requirements, supplemented by 255 km of 400 kV transmission line system.⁹³

Hydropower development often poses environmental and social risks that require careful identification, mitigation, and management. For example, China's SDIC Power Holdings Co. began construction of the Batang Toru dam in 2015 and has since received extreme negative response from local communities.⁹⁴ The 510 MW capacity project was previously delayed due to the COVID-19 pandemic, but the government later revoked its permit due to environmental breaches leading to the flood disaster in Sumatra in late 2025.⁹⁵

Solar. Solar generation in Indonesia is consistent due to the country's equatorial position,⁹⁶ making it the main target for increasing renewables in the energy mix.⁹⁷ There are several small-scale projects around the country under 10 MW,⁹⁸ with the current largest farm being the Cirata floating solar power plant, a joint venture between Indonesia Power and Masdar of the United Arab Emirates (UAE). It is located in the Cirata reservoir, West Java, and has a capacity of 192 MW over 200 hectares to power 50,000 residential units from 2023.⁹⁹

For a ground-mounted plant, PT Aruna and PLN (through subsidiaries) have developed 100 MW of capacity using 170,000 modules.¹⁰⁰ Located in Kota Bukit Indah Industrial Estate, West Java, it will fulfill the area's energy demand with an expected annual generation of 150 GWh.¹⁰¹ It was inaugurated at the beginning of 2024, ahead of schedule by seven months.¹⁰² Most of the tenants in this complex are manufacturers in the automotive, chemical, and food sectors.¹⁰³

So far, JETP has a materialized project in the form of solar panel deployment last year by mobilizing USD 60 million for the floating solar farm of Saguling reservoir near Bandung, West Java.¹⁰⁴ Worth USD 1.2 billion in total, the farm has an installed capacity of 92 MW and is a partnership between PLN and ACWA power of Saudi Arabia.¹⁰⁵

Another floating solar project is the Tembesi site in Batam, near Singapore.¹⁰⁶ It is hoped to replace the current gas-fired plants the area depends on. Nearby, Singapore's Sunseap group has signed an MOU with BP Batam worth USD 2 billion for a 2.2 GW floating facility.¹⁰⁷ It will have an energy storage capacity of 4,000 MWh and provide for both Singapore and Indonesia.¹⁰⁸ The group has also partnered with the government of Riau Islands for the feasibility of two other farms over 3,000 hectares combined in Combol and Citlim islands.¹⁰⁹ Though the study had started in 2022, there are no recent developments on these facilities.

Specific for the new capital, PLN has partnered with Singapore SOE, Sembcorp, to install a 50 MW solar plant with 14.2 MWh of battery energy storage system (BESS).¹¹⁰ It requires an area of 87 hectares for an estimated production rate of 92.8 GWh.¹¹¹ PLN will be the sole offtaker through a 25-year PPA.¹¹²

As solar becomes a crucial segment for the renewable energy targets of the country, there are still some considerations. First, other than the cheap availability of coal, solar has a large demand of area, needing 1.3-1.7 ha/MW, compared to 0.3 ha/MW for coal-fired power plants.¹¹³ This requires extensive financing initiatives for an appropriate investment rationale. Furthermore, as it is heavily reliant on the availability of sunlight, it cannot be used as the baseload supply since transmission to the existing grids is designed from large, controllable generators.¹¹⁴ Curtailment is necessary in peak times of solar irradiance as there are concerns of electricity oversupply, transmission constraints, load balancing issues, and local grid outages.¹¹⁵ These challenges make this option unviable for mining and smelting that require constant firm power.

Nonetheless, BESS might be able to help manage this, though there are high costs for both construction and O&M, with an estimated LCOE of USDc 16.04 / kWh, in comparison to the current PPA for the Cirata floating solar power plant at USDc 5.81 / kWh.¹¹⁶ However, the costs of these energy systems are projected to be nominally constant over the next 25–30 years, providing economical protection from fuel price volatility and supply disruptions.¹¹⁷

Geothermal. JETP's portfolio includes a plan for a 170 MW geothermal power plant in Muara Laboh, West Sumatra.¹¹⁸ There are already 46 geothermal power plant (GPP) units spread across 17 geothermal working areas, mostly across Java due to the energy potential (Figure 10).¹¹⁹ PLN is the sole off-taker of the total installed 2.64 GW capacity, adding to the grid of Java-Madura-Bali for general use, including connected industrial facilities.¹²⁰ Danantara has also facilitated a cooperation between Pertamina and PLN through their affiliates PT Pertamina Geothermal Energy Tbk (PGE) and PT PLN Indonesia Power (PLN IP).¹²¹ The developments are considering various sites in Southwest Sumatra and North Sulawesi, with one in West Java, aligned with the energy potential. There are 19 projects planned totaling a combined capacity of 530 MW and are expected for general grid connection, not specific for industrial use.¹²²

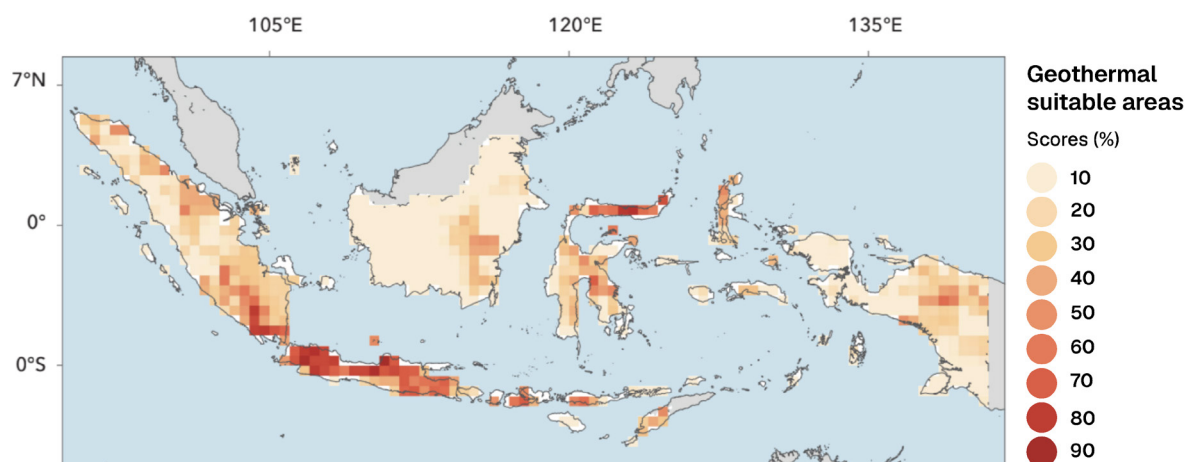


Figure 10. Geothermal energy potential, Indonesia

Source: Hazarabedian, O'Neill, and Witto (2023).¹²³

Wind. ESDM has conducted a feasibility study for investment in the technology implementation for wind power.¹²⁴ Currently, there are two active on-shore wind farms powering the regional Southern Sulawesi (*Sulawesi Bagian Selatan*, SulBagSel) electricity grid and local households: Tolo in Jeneponto regency (72 MW) and Sidrap in Sidenreng Rappang regency (75 MW), both in South Sulawesi.¹²⁵ The former is being expanded, with Singapore-based Vena Energy as the main facilitator.¹²⁶ Previously, the first phase was financed by the Asian Development Bank (ADB),¹²⁷ and now PLN is offering a tender for the planned development as the offtaker.

Other possible additions of wind energy are located in East Lombok, Sukabumi, Banten, and South Kalimantan, with a total of 500 MWs of added capacity to be expected.¹²⁸ Furthermore, the Indonesian Ministry of Marine Affairs and Fisheries is working with Denmark to assess off-shore wind potential.¹²⁹ There is no information or plan yet regarding possible locations, but current industrial parks, especially for nickel production, do not have the geographic conditions for strong wind.¹³⁰ Unfortunately, this limits the possibility of captive wind power for industrialization without extensive transmission.

Bioenergy. Danantara's 2025 year-end letter has firmly established their focus on waste-to-energy (WtE) projects, though the motivation stems from Indonesia's production of 35 million tons of waste per year over an underdeveloped disposal system that makes processing ineffective, instead of the energy needs of industry.¹³¹ Therefore, the planned plants for this technology are located near populous cities, not industrial parks.¹³²

Nonetheless, WtE's steady feed and continuous combustion acts well as a baseload electricity supply that is needed by industrial operations. The thermal conversion process utilized by the system can also be used as cogeneration for processes such as drying, refining, or chemical processing, reducing overall energy demand.¹³³ If the government manages to implement these projects successfully, locations near industrial parks should be heavily considered, especially the ones in Java, closer to urban settlements.

Overall assessment. Few of the current and planned renewable energy deployments in Indonesia are specifically developed for nickel mining, processing, and industrial parks at large. This shows a disconnect from mining and industry development with their large energy needs, an apparent missed opportunity from a feedback loop perspective.

Specific to nickel mining and smelting, anchoring renewable energy development, while possible, should be mindful of market and technological trends that lead to oversupply and inability to further implement the loop of renewable energy infrastructure strictly for the industry due to geographical positioning of the reserves.¹³⁴

Domestic and Regional Interconnection

Transmission is also an issue Indonesia constantly strives to improve. Most recently, the World Bank announced the Indonesia Electricity Network Transformation (I-ENET) program, mobilizing USD 500 million for the Java, Madura, and Bali region.¹³⁵ PLN is the borrower and implementing agency, and justified these regions for the commercial and industrial demand, also the readiness to increase EV usage with additional chargers.¹³⁶ While for Eastern Indonesia, the ADB has started a result-based loan (RBL) program for the distribution network worth USD 600 million.¹³⁷

As a region, Southeast Asia's electricity demand is rapidly growing, expected to double between 2023 and 2050.¹³⁸ Unfortunately, the transmission lines planned across the countries independently still have not reached targets set by the IEA through their annual pledged scenarios (APS).¹³⁹ As a mix of both public and private interest, financial constraints and misplaced burden of responsibility often occur after electricity infrastructure is developed, due to unclear cost separation, payment security guarantees, or currency risk.¹⁴⁰ Also, energy systems of the countries are mostly set up with a single-buyer system by a state-owned utility, limiting purchase options.

The Association of Southeast Asian Nations (ASEAN) has aspirations to strengthen the power transmission landscape by integrating electricity networks of the country members.¹⁴¹ The main challenge lies in the technical mismatch between countries' systems that will need extra costs for infrastructure and engineering.¹⁴² The digital infrastructure to support these systems is also lacking.¹⁴³

In response, the World Bank and the ADB are showing support for the ASEAN Power Grid (APG) initiative.¹⁴⁴ As the first program, Singapore's Energy Market Authority's (EMA) plan to import renewable energy commenced the Lao PDR– Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP) sale of hydropower.¹⁴⁵ Launched in 2022, the project is expanding the capacity to 200 MW from the previous Malaysia direct supply stream of 100 MW.¹⁴⁶

In addition, Laos has also initiated the Monsoon wind project with Asian Infrastructure Investment Bank (AIIB) funding worth USD 150 million.¹⁴⁷ The 600 MW wind generation facility will sell the electricity to Vietnam through a 500 kV substation and transmission line.¹⁴⁸ Located in Southern Laos over 250 hectares of land, it is the largest windfarm in Southeast Asia.¹⁴⁹

Indonesia has had plans to export solar energy to Singapore from Batam via an undersea cable. MOUs were signed in 2023, aiming for a 2028 commercial operation start date, but construction has not made significant progress due to a lack of clear funding.¹⁵⁰ This lack of appetite from investors stems from the government's requirement of permits for RE exporters that need to be renewed every five years,¹⁵¹ creating long-term uncertainty. The government also has total control of the supply, including revocation and temporary bans if local conditions are not favorable, even though the island of Batam has frequent electricity oversupply.¹⁵²

With various transmission development plans laid out, Indonesia stands to be part of a regional powerhouse via multilateral partnerships and laying strong foundations for growth in the energy infrastructure sector.

1.2.2 Battery Technology Production

The full EV battery production cycle from ore to final product consists of **mining, processing, refining, precursor manufacturing, cathode or anode manufacturing, and cell manufacturing and packaging**. Indonesia has successfully established global capacity and dominance in the mining and processing stages, but remains at nascent stages for refining, precursor and cathode manufacturing. Currently, the Indonesia Morowali Industrial Park (IMIP) leads in established capacity for full downstream battery cell manufacturing capabilities. Other parks such as South Kalimantan follow, with precursor cathode active material (pCAM) manufacturing facilities coming online in 2026.¹⁵³

IMIP is one of Indonesia's first sites for further nickel downstreaming to battery-grade nickel components. Through joint ventures with QMB New Materials, Huayue Nickel Cobalt, and GEM manufacturing from China, and with Excelsior Nickel Cobalt from Australia, IMIP exhibits significant

vertical integration of the nickel battery value chain in Indonesia.¹⁵⁴ Additional investments in nickel battery value chains have arisen, with joint ventures in West Java and Central Java, and planned battery industry development at the Kalimantan Industrial Park Indonesia (KIPI) in North Kalimantan, spanning non-nickel segments of battery manufacturing.¹⁵⁵

Nickel-based batteries require a number of material inputs for advanced battery cell production, particularly for the precursor manufacturing stage. pCAM manufacturing marks the stage that forms the chemical structure of a battery cathode prior to charging with lithium ions.¹⁵⁶ Following the battery cell packaging stage, this pCAM manufacturing step represents the largest stage of value addition in the lithium-ion battery manufacturing process. The additional complexity and breadth of inputs required for pCAM manufacturing explain the increased value addition; in addition to high-purity Class I nickel, pCAM manufacturing requires battery-grade cobalt and manganese.¹⁵⁷ While Indonesia's nickel deposits maintain co-deposits of cobalt,¹⁵⁸ further technological and workforce capacity needs remain to establish the supply of additional inputs at scale.¹⁵⁹

Indonesia's pCAM production capacity is nascent as of 2025, but this capacity is expected to increase in the coming years. In 2024, GEM maintained 30,000 metric tons of pCAM manufacturing capacity in IMIP, with projections to increase to 50,000 metric tons per year in 2026.¹⁶⁰ CNGR Advanced Material Co., Ltd., a leading precursor manufacturer, has just commenced operations on its precursor facility in Kalimantan, ramping up to a capacity of 20,000 metric tons per year.¹⁶¹ GEM also announced a joint venture with South Korea's EcoPro to include precursor and CAM manufacturing capacity of up to 200,000 metric tons per year.¹⁶² Investment in these stages of value addition looks to continue, with demonstrated interest from various regional players (Table 3).

Table 3. Emerging precursor cathode active material (pCAM), Indonesia

Company	Local Entity	Location	pCAM Capacity	Operational Status	Key Partners
GEM Co. (China)	Qingmeibang New Energy	IMIP, Morowali, Central Sulawesi	30,000 → 50,000 t/yr	Operational since Sept 2024; expansion ongoing ¹⁶³	SK On, EcoPro BM
Huayou Cobalt (China)	Huanneng New Materials (Indonesia)	Weda Bay Industrial Park, North Maluku	50,000 t/yr (Phase 1)	Operational since Oct 2024 ¹⁶⁴	PT Weda Bay Nickel
CNGR Advanced Material (China)	Zhongtsing New Energy	South Kalimantan	20,000 t/yr	Operational since Jan 13, 2026 ¹⁶⁵	—
CNGR Advanced Material (China)	—	North Morowali, Central Sulawesi	20,000 t/yr	Under construction; expected end-2026 ¹⁶⁶	—
CBL/Brunp (CATL subsidiary)	Indonesia Battery Integration Project	Karawang, West Java	30,000 t/yr CAM	Under construction; groundbreaking June 2025 ¹⁶⁷	PT ANTAM, Indonesia Battery Corp (IBC)

Source: Prepared by the authors.

Parallel Paths to Nickel in the Battery Manufacturing Ecosystem

Shifting battery chemistries challenge Indonesia's heavy reliance on nickel as its primary export. In a volatile energy transition, not all minerals remain "goldmines," and over-investing in primary extraction risks creating economically stranded assets.¹⁶⁸ Lithium Iron Phosphate (LFP) batteries, once secondary, now rival Nickel Manganese Cobalt (NMC) chemistries because they are cheaper and offer higher thermal stability, leading to broad market proliferation in EVs and grid storage.¹⁶⁹ Separate from lithium and nickel chemistries, merging sodium-ion and fluoride-ion technologies threaten to disrupt the market by offering lower-cost, abundant, and safer battery technologies than traditional lithium-ion models.

In this context, despite its dominance in nickel production, Indonesia seeks to hedge against the shift away from nickel-based batteries by establishing domestic LFP manufacturing capacity. Indonesia has entered joint ventures for LFP and anode manufacturing, with Lopal Tech's first LFP cathode facility reaching trial production in 2024 and mass production in early 2025, and its second phase expected online by the end of 2025.¹⁷⁰

China currently dominates the LFP value chain, but Indonesia is positioning itself as a future global player. While manufacturing capacity of LFP and graphite anode products in early 2026 stands at roughly 110,000 metric tons (based on Phase 1 completions), announced and in-construction projects will boost production to 280,000 metric tons annually.¹⁷¹

Indonesia has also begun onshore production of anodes, another critical component for battery cell manufacturing. In a partnership with China's BTR, Indonesia established its first domestic graphite anode manufacturing facility in IMIP with a manufacturing capacity of 80,000 metric tons of anode material.¹⁷² As of 2024, the BTR facility was the largest anode manufacturing site outside of China.¹⁷³ Additionally, Indonesia's National Research and Innovation Agency (BRIN) has conducted recent pilots to convert coal into graphite anode manufacturing materials, indicating further development for domestic capacity.¹⁷⁴

Energy Requirements for Battery Cell Manufacturing

Battery cell manufacturing requirements are generally measured in terms of energy inputs per unit of energy capacity. Inputs vary depending on the type of battery chemistry due to manufacturing differences in creating cathode and anode material, but NMC cathode manufacturing energy inputs amount to approximately 40 kWh/metric ton of material.¹⁷⁵ Additionally, energy inputs vary significantly for industrialized versus laboratory-based battery cell manufacturing processes. Laboratory studies indicate that energy inputs for battery cell manufacturing can be as high as 1,469 kWh per kWh of cell capacity.¹⁷⁶ Industrialized energy inputs are significantly lower, at roughly 93 kWh per kWh of cell capacity.¹⁷⁷ While industrial values are relevant for large-scale manufacturing, lab-based figures can be indicative of energy requirements for research-based applications for future battery development capabilities.

Impacts of Regionalization on Indonesian Nickel and Battery Manufacturing Value Chains

Domestic interest in nickel downstreaming is high, but international partners make up a significant percentage of owners of nickel mining and processing facilities. The metal industry at large is made up mostly of foreign investors, with more than half being Chinese (including Hong Kong) (Figure 11). Relatedly, more than 70% of existing and planned captive coal ownership involves Chinese investors,¹⁷⁸ as Indonesia's domestic strengthening policies coincide with China's Belt and Road initiative; China's stainless steel production demand is the main customer of the intermediate nickel products manufactured in Indonesia.¹⁷⁹

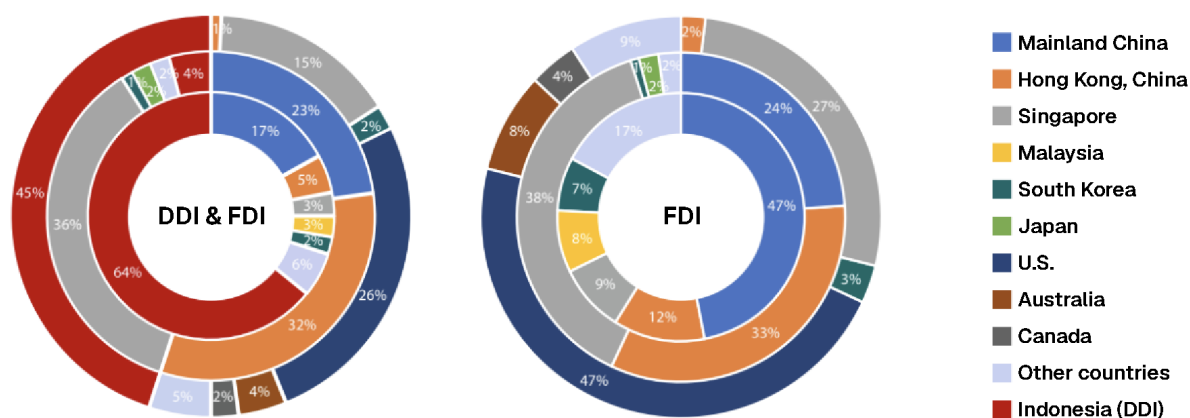


Figure 11. Domestic direct investment (DDI) and foreign direct investment (FDI), nonmetallic mineral industry (inner ring), metal industry (middle ring), and mining industry (outer ring), Indonesia, 2022

Source: Zhu et al. (2023).¹⁸⁰

Moving down the value chain to the battery downstreaming ecosystem, the government has initiated the Indonesia Battery Corporation (IBC) with Pertamina, PLN, and the mining industry holding company (MIND ID) (through subsidiaries ANTAM and Inalum) as shareholders.¹⁸¹ The aim is to establish control in the industry with a strong state-owned presence.¹⁸²

Working with international partners, they have a joint venture with China's CATL for a full battery value chain manufacturing plant worth nearly USD 6 billion, dubbed the Indonesia Battery Integration Project.¹⁸³ The plant will be in Karawang, West Java, with a capacity of 15 GWh and expected to begin operations in 2028. For power, it will depend mostly on steam power with a capacity of 2 x 150 MW and 80 MW of gas, but will also be supported with a 30 MW waste heat recovery system and 172 MWp of solar power.¹⁸⁴ Previously, CATL partnered with IMIP, along with other entities—stainless-steel maker Tsingshan Holding, battery firm GEM, and Japanese trading firm Henwa—to make battery-grade nickel chemicals.¹⁸⁵ Most recently, their subsidiary has also signed an MOU with IBC for exploration of local EV development.¹⁸⁶

The government also has an initiative with a consortium of South Korea, a deal called the Indonesia Grand Package from 2020, referring to investments across the EV battery supply chain worth USD 8.45 billion.¹⁸⁷ The development will center on the joint venture HLI Green Power, operator of the country's first EV battery manufacturing plant.¹⁸⁸ With a 10 GWh annual capacity, the mass production will supply Hyundai's EV models.¹⁸⁹ However, the leader of the consortium, LG Energy Solution, withdrew from the project last year, attributing it to market conditions.¹⁹⁰ The plant is not affected, and China's Zhejiang Huayou Cobalt will take over responsibilities of ongoing sub-projects, including planned five JVs to produce 30 GWh of EV batteries annually.¹⁹¹

Furthermore, Huayou Cobalt has established HYD Investment Limited as its subsidiary with EVE Energy and Indonesian mining services firm PT Daaz Bara Lestari. This entity has signed an agreement with IBC and ANTAM to coordinate investments across the full battery value chain, from upstream resource development located in East Halmahera, North Maluku, to manufacturing and recycling in West Java.¹⁹² These battery cells will not only be for EV production, but also BESS for the planned solar power development.¹⁹³

While Indonesia is seeking to onshore much of the downstream capacity for EVs, regionalization plays a key role in opening up markets for Indonesia's downstream products and critical inputs. Both NMC and LFP battery chemistries require lithium either as the cathode component or as the electron source for the battery. Indonesia has recently discovered a domestic lithium reserve, but these sources remain far from development.¹⁹⁴ While battery manufacturing capacity continues to

grow, Indonesia has no domestic lithium production capacity and imports from China and Australia.¹⁹⁵ Processing facilities and anode plants have been constructed since 2022 for further processing and use in EV batteries.¹⁹⁶ Working with CATL, the government will begin operations of a lithium-ion battery plant later this year.¹⁹⁷ With an initial production capacity of 6.9 GWh, the plant is designed to expand until an eventual 15 GWh, for both domestic use and export.¹⁹⁸

State-owned geothermal developer Geo Dipa Energi is also working with the U.S Trade and Development Agency through Californian company Lilac Solutions to draw lithium from geothermal brine.¹⁹⁹ These outlooks will strengthen domestic power on yet another critical mineral, reducing reliance on trade with other countries. The United States at large has a new trade pact for Indonesia's critical minerals and development of an export corridor for American energy products.²⁰⁰ Similarly, Japan and Indonesia have signed a cooperation pact for critical minerals and their use for energy security.²⁰¹ Phosphate also remains a critical input for LFP manufacturing, of which Indonesia has little domestic capacity. Continued production of LFP cathodes and battery cell components will depend on robust cooperations and trade ties beyond Indonesia's borders.

Additionally, shipping and logistics needs drastically change depending on the stage of downstream production. While cathodes, anodes, and cell inputs remain safe and economical to transport in bulk quantities, manufactured battery cells carry significantly higher transport safety and infrastructure costs. Charged battery cells store substantial energy in a flammable electrolyte and can enter thermal runaway if damaged, demanding high safety standards for shipping and transit; they are classified as Class 9 "dangerous goods" under UN regulations,²⁰² requiring specialized certifications, temperature-controlled reefer containers, and equipment for transit.²⁰³ These logistical constraints push final product development to a much more diversified and regional footprint for downstream manufacturing. Indonesia can safely manufacture battery cell inputs for batteries and EVs produced and consumed domestically. However, in order to avoid the uneconomical costs of shipping heavy batteries, which can represent 30–40% of a vehicle's value,²⁰⁴ larger-scale battery cell and EV manufacturing for consumption abroad will likely lean towards regionalized production.

1.3 Other Industrial and Economic Sectors

The government's focus on downstreaming stimulated the massive growth of basic metal manufacturing for the country's GDP, particularly nickel processing for stainless steel and battery materials.²⁰⁵ However, as the issue of oversupply looms, economic diversification acts as a hedge to avoid long-term overreliance on nickel. Other minerals and industries can also be focused on for this reason, with some examples provided in this section, including how their outlook can contribute to the feedback loop and green industry development.

Minerals and Raw Materials

Copper. Copper is a sought component of EV battery manufacturing, and its global market is forecasted to grow due to trends for grids, other energy technologies, and construction, but Indonesia's share is relatively small even though there are operational domestic reserves.²⁰⁶ Current downstreaming interests are starting to include copper with prohibition of raw export—only refined products (minimum as cathodes) are allowed.²⁰⁷ The industry aims to expand for refinement and is considering trading partners outside of China to avoid lock-in like with nickel, most prominently with the U.S. due to Freeport's long-standing presence in the industry.²⁰⁸

The smelting facilities require extensive power, and the infrastructure gap is the main concern for investors, aside from regulations.²⁰⁹ The key refining location is located in East Java, creating a higher possibility of main grid connection for shared infrastructure.²¹⁰ This can stimulate development of power sources which, in line with the government's interest, can center in renewable energy. More importantly, with the mineral itself being essential for transmission and distribution, and renewable

energy technologies,²¹¹ having a domestic supply can expedite implementation and lower costs for these developments.

Tin. Indonesia is the second largest producer of tin and has the highest estimated reserve in the world.²¹² The demand for the mineral is rising, especially for energy technologies, as it is a crucial component for semi-conductors²¹³ and its use in solar panels, specifically in the photovoltaic ribbon between cells.²¹⁴ Domestically, tin mining and smelting are centered in the Bangka Belitung islands, next to Sumatra.²¹⁵ This area still depends on fossil fuel, and there are grave concerns regarding access to energy due to low generation capacity.²¹⁶ Moreover, unlike the other metal processing facilities in the country, tin smelters are connected to PLN's grid for electricity since SOE PT Timah controls the majority of production.²¹⁷

There is already an initiative of undersea transmission to the main island of Sumatra, which began in 2022 with a capacity of 150 kV.²¹⁸ As explained in the previous sections, there are many developments for renewable energy currently in progress in the island, particularly hydroelectric power.

The domestic industry is currently in a reform period after years of corruption and poor regulation.²¹⁹ The government is poised to establish a minimum reference price with an export ban likely to be enacted as well.²²⁰ By stabilizing the domestic conditions and establishing a proper manufacturing process, there would be a rise in confidence for investors, as the industry grows in sectors including electronics, AI, and EV.

Bauxite, alumina, and aluminum. Bauxite is another critical mineral widely available in the country, with the government closely controlling it. Like nickel, an export ban for the raw ore has been enacted since 2023.²²¹ The ore's primary product, alumina, is used to make aluminum metal, essential for a variety of manufacturing processes. The outlook for the metal is positive, with an estimated 40% increase by 2030 due to transportation, construction, and electronics development.²²² The demand for low-carbon aluminum, labeled 'green aluminum', is growing, and is achieved by better refining processes powered by renewable energy. This is an appropriate example that embodies the mining-energy feedback loop for RE development, and the country has high interest and capabilities for this development.²²³ Inalum, an SOE for aluminum monopoly, has smelters that are powered by a dedicated hydropower plant from three dams, with a total capacity of 603 MW.²²⁴ Furthermore, an alumina refinery and aluminum smelter are part of Danantara's first phase of downstream projects, where they will use USD 7 billion to process natural resources within six projects.²²⁵

As bauxite and aluminum scale, however, the nickel experience offers a cautionary precedent. Rapid capacity expansion outpacing demand produced structural oversupply and a sharp price decline, eroding company margins and state revenues, while the high energy intensity of processing led to overreliance on captive coal. Extending the feedback loop to bauxite, alumina, and aluminum therefore depends on coordinated, data-backed permitting that paces capacity to demand, as well as on integrated planning across mining, renewable energy, and industry (Sections 3.1.1 and 3.1.2), so the sector does not replicate nickel's trajectory of oversupply and captive coal dependence.²²⁶

REE. The newly established Mineral Industry Agency (*Badan Industri Mineral*, BIM) also has a focus on accelerating research and development (R&D) of rare earth elements (REEs) and their role in expanding the downstream industry.²²⁷ Though REEs are available in Indonesia, the country currently has no significant share in either supply or demand.²²⁸ Initial research has shown that mining blocks for these resources have been identified in various islands all over the country,²²⁹ providing opportunities for electricity powered by RE.

Bioethanol. The other projects announced by Danantara include bioethanol production from sugarcane to reduce fuel imports and doubling the capacity of a bio-refinery that processes

3,000 barrels of used cooking oil daily for sustainable aviation fuel (SAF).²³⁰ The latter is high in the government's interest due to the need for air travel between the country's islands and the utilization of biofuel to increase RE part in the energy mix. The demand for the product is also increasing globally, with many airlines and airports now establishing requirements for SAF usage.²³¹

The high thermal energy need of distillation can be cogenerated if facilities are located with established infrastructure such as smelters or power plants. The waste of the process can also be used for co-firing in existing CFPPs. Nonetheless, practitioners are faced with the logistical issue of transporting stocks, which can be mitigated by strategic collection locations or dedicated barges/cargos via trains.

Business Sectors

Food and beverage. The country's main GDP contributor sector is expected to steadily grow through the decade.²³² The government always has targets for national food security and reducing import reliance, pushing development of domestic processing capabilities for the F&B industry. Large-scale players are mostly located in industrial estates, notably in West (Cikarang, Karawang, MM2100 Industrial Town) and East Java (JIIPE).²³³ These parks can trigger implementation of the feedback loop by increasing dependency on renewable generation and shared use arrangements with communities surrounding them.

Warehousing and shipping. E-commerce usage has increased significantly since the pandemic, and this includes delivery of daily life products that need refrigeration.²³⁴ These products need to be stored in cold storage (refrigerated warehouses), which will have significant power usage.²³⁵ EVs for delivery are also sought after as the government is stimulating nickel downstreaming via this sector with tax and regulations exemptions.²³⁶ Furthermore, cold storage vehicles will need batteries and other materials that are nickel-based for the cooling technology.²³⁷

Data centers. On the other hand, the global trend of AI usage and data centers is also being considered in Indonesia. Tax incentives are being offered for investments in the sector.²³⁸ Kabil Industrial Park in Batam will be housing three data centers jointly owned by Indonesia's Telkomsel and Singapore's Singtel through their subsidiaries.²³⁹ The project reportedly cost USD 600 million and will have a combined capacity of 56 MW. A Special Economic Zone (SEZ) of the island, Nongsa Digital Park, is also becoming a data center hub for global tech players.²⁴⁰

To cater to the high and continuous energy needs for the servers and cooling of these facilities, captive plants or behind-the-meter solutions are likely to be used.²⁴¹ Renewable energy is a viable source, such as in Malaysia, where TotalEnergies has created a 21-year PPA with Google to power their data center operations by a solar farm that will only begin construction in 2026.²⁴²

Green Industrial Parks. There have been several projects geared towards more environmentally-friendly industrial parks, starting with the government partnership with United Nations Industrial Development Organization (UNIDO) as part of their Global Eco-Industrial Parks Programme (GEIPP) in 2020. In the first phase from November 2022, MM2100 Industrial Town, Batamindo Industrial Park, and Karawang International City acted as pilot projects to implement energy-saving measures, reduce resource consumption and greenhouse gas emissions, and adopt solar PV systems.²⁴³ Deemed successful, the project continues to the second phase from 2024 until 2028, adding Greenland International Industrial Center and Kawasan Industri Medan as participating parks.

Existing parks, such as Weda Bay Industrial Park (IWIP) in North Maluku, are adding renewable energy sources to power their processing zones using solar and wind.²⁴⁴ Nonetheless, the pinnacle of the government's green industrial park strategy is KIPI, previously mentioned to rely entirely on hydropower. The facilities and products of the complex are also designed for green energy transition, such as solar panel manufacturing and fully integrated EV battery factories.²⁴⁵

2. Overview of Potential Benefits of a Mining–Energy–Industry Feedback Loop in Indonesia’s Nickel Sector

Establishing a mining–energy–industry feedback loop in Indonesia based on the country’s nickel mining and smelting sector, combined with the increased production and deployment of renewable energy technologies and with green industrial development within and beyond nickel value chains, can yield economic, environmental, and social co-benefits, contributing to Indonesia’s long-term sustainable development and its achievement of national and global climate change goals.

While a detailed assessment and quantification of these potential benefits lies outside the scope of this policy concept note and merits further study, this section presents an overview of potential or expected benefits, supported by available literature on Indonesia and lessons learned from other studies, including on experiences of other countries and regions which may be applicable to Indonesia’s case. Our choice to categorize benefits as economic ([Section 2.1](#)), environmental ([Section 2.2](#)), or social ([Section 2.3](#)) is intended to systematize and simplify the narrative, not to ignore or minimize the inherent interdependence and synergy among them.

This overview, laying out a vision of the benefits of an established feedback loop, can help public and private stakeholders in developing the rationale and justification for taking the appropriate planning, coordination, policy, technical, and financial measures to realize the enabling conditions ([Section 3](#)) of the feedback loop, for the benefit of Indonesians.

2.1 *Economic Co-Benefits*

The most immediate potential benefit of a mining–energy–industry feedback loop is to maximize the economic spillovers of Indonesia’s natural resources, leveraging its nickel reserves for the **growth of domestic economic activity** based not only on its already strong upstream extractive and midstream smelting and refining sectors, but also increasingly in **downstream green industries**. The synergy between nickel extraction and processing and the renewable energy system would support the increased competitiveness of Indonesia’s economy for investment in **higher value-added segments** of nickel and renewable energy value chains, such as domestically produced batteries and electric vehicles (EVs).²⁴⁶ At the same time, an increasingly robust renewables-based energy system in Indonesia would progressively support greater **economic diversification beyond nickel value chains**—in industrial sectors such as those discussed in [Section 1.3](#) above—building economic resilience in Indonesia to avoid the risk of over-reliance on nickel resources and the risks associated with commodity price fluctuations.²⁴⁷ The feedback loop could also be conducive to a knowledge economy in Indonesia, with the creation or strengthening of public and private research centers and universities, with **increased R&D and innovation** both within and beyond nickel value chains.

By anchoring demand for renewable power and fostering cooperation among energy customers through shared-use of mining- and smelting-related power infrastructure, the feedback loop would help spread the **high upfront capital costs** of deploying renewable energy generation and digitized transmission infrastructure²⁴⁸ across various economic actors—PLN, mines, smelters, industrial parks, and to a lesser extent other industrial and residential customers—none of whom would likely be able to cover these costs individually. The **economies of scale** unlocked by the coordination mechanisms implicit in the feedback loop and in shared use could enable and expedite the progressive decarbonization of Indonesia’s fossil-based energy matrix by phasing in renewable energy systems and phasing out coal-fired power plants.²⁴⁹

In addition to increased tax revenues from expanded economic activity spurred by the feedback loop, energy decarbonization would also ease the burden of **fossil fuel imports** (notably diesel for remote operations) and **subsidies** (including for coal production) on the government budget,²⁵⁰ improving Indonesia's trade balance and adding to the fiscal space for investment in infrastructure and public services.

The **modern energy services** resulting from the feedback loop would serve not only nickel, renewable energy, and industrial value chains, but also the broader Indonesian economy, by helping to create a resilient and reliable renewables-based energy system. A robust clean energy system could turn Indonesia into a **green or clean industrial hub**, increasing its attractiveness and competitiveness as a cluster of investment in low-carbon and sustainable industrial activity, and contributing to the Indonesian government's objective to strengthen domestic industrial capacity. A progressively decarbonized energy system could help Indonesian firms **access sustainable finance, mitigate the risk of stranded assets** associated with coal-fired power plants, and **comply with climate policy tools**, such as carbon pricing initiatives or standards of trading partners for the embedded emissions of industrial goods, such as the European Union (EU)'s Carbon Border Adjustment Mechanism (CBAM). Furthermore, through **coordination between Indonesia and neighboring countries** in Southeast Asia—for example, in the context of creating a regional integrated energy system for the Association of Southeast Asian Nations (ASEAN)—these potential benefits could be scaled regionally.²⁵¹

Finally, a potential indirect economic benefit of the feedback loop is that the coordination mechanisms created to realize it could facilitate additional opportunities for mutually beneficial **investment in other physical infrastructure projects** in Indonesia. For example, in addition to shared-use renewables-based power infrastructure, economic actors in mineral, renewable energy, and industrial value chains could coordinate investments in **shared-use railway, port, water, and information and communication technology (ICT) infrastructure**, in line with the priorities and infrastructure development plans of the Indonesian government. Coordinated investments in shared-use infrastructure projects offer opportunities for greater economic gains across the productive sectors directly involved and additional industrial beneficiaries that may develop as a result, along with their neighboring communities.²⁵²

2.2 Environmental Co-Benefits

Careful planning and implementation are crucial in addressing risks and negative impacts of mineral and industrial activity on the environment. Notable risks and impacts from Indonesia's nickel mining and processing are deforestation, biodiversity loss, and water and soil contamination (particularly as a result of acid and heavy metals present in tailings from HPAL nickel processing).²⁵³ With appropriate measures to mitigate risks and address impacts, a feedback loop based on environmentally responsible mineral extraction, renewable energy, and green industry could enhance aspects of environmental sustainability.²⁵⁴

For example, the transition away from coal mining and coal-fired power plants toward renewable energy systems would significantly reduce particulate matter pollutants and **improve air quality** across Indonesia, in producing regions and cities alike. Decarbonizing electricity generation in Indonesia would significantly **reduce the country's greenhouse gas emissions**, contributing to the achievement of its international commitments to climate change mitigation. An appropriately designed and implemented feedback loop could support **sustainable land-use practices** that encourage ecosystem conservation and restoration and the use of degraded areas for renewable energy deployment.²⁵⁵ Finally, a significant environmental co-benefit of the feedback loop pertains to the **opportunity to embed circular economy principles** into nickel value chains, analyzed in detail in a companion policy report within this project, titled *Integrating Circular Economy Principles and Practices in Indonesia's Nickel Sector: Overview, Benefits, and Enabling Conditions*.

2.3 Social Co-Benefits

While careful planning and implementation is also necessary to address the reported negative social impacts of nickel value chains in Indonesia,²⁵⁶ energy decarbonization and green industrialization as a result of the mining–energy–industry feedback loop can significantly improve the quality of life of Indonesian workers and communities.²⁵⁷

Decent job creation and **skills development** in green mineral–industrial sectors feature among the most important social co-benefits. Increasingly digitized nickel mining and processing operations, the production of renewable energy technologies and the deployment of renewable energy systems, and green industrial activities developed along and beyond nickel value chains will require a highly skilled workforce, providing opportunities for training, upskilling, and reskilling—supporting just transitions for workers in coal- and nickel-dependent regions who may otherwise face displacement.

Securing a stable power supply for mineral and industrial activities would benefit not only the large-scale demand anchors, but all customers, including neighboring families and small businesses. Indonesian communities that currently experience power shortages would have **improved access to modern and reliable clean energy services** for essential needs (such as lighting and refrigeration), helping alleviate energy poverty and improve living standards. Adopting rights-respecting practices and implementing appropriate community benefit-sharing arrangements in renewable energy siting and deployment are crucial measures in ensuring the realization of these social co-benefits.²⁵⁸

The progressive decarbonization of Indonesia's coal-based energy system would reduce the incidence of respiratory diseases affecting workers and communities surrounding coal mines and coal-fired power plants. In addition to improving public health and overall societal wellbeing, reduced air pollution would **ease the burden of healthcare costs on families and the public health system**, amplifying the benefits of the fiscal space created by economic growth.

Finally, an indirect social co-benefit of the feedback loop is the **additional investment in public infrastructure to support sustainable development and other national priorities**—such as schools, hospitals, and transit systems—allowed by the fiscal space created by higher revenues and lower healthcare costs. Other indirect co-benefits are **potential social gains from extending the shared-use model beyond energy**, such as improved access to clean water, digital connectivity (ICT), and passenger and small-cargo logistics for Indonesian communities.



3. Enabling Conditions and Recommendations

To realize the vision of catalyzing growth and decarbonization of Indonesia's nickel and mining sectors (Section 1), attaining the co-benefits of a mining–energy–industry feedback loop (Section 2), this section concludes the analysis by outlining critical enabling conditions and strategic recommendations. It begins with the requirement of a strong policy, legal, regulatory, and institutional framework to align mining and industrial activities with domestic and regional energy planning that is steered towards renewable energy (Section 3.1). It then turns to the technology transfer and R&D gaps that must be closed (Section 3.2), and finally to economic and financial feasibility (Section 3.3).

3.1 *Policy, Legal, Regulatory, and Institutional Frameworks for Domestic and Regional System Planning*

Systemic planning—covering the mining extraction and processing sector, renewable energy systems, downstream industrial sectors, and shared-use infrastructure—should be brought to the core of relevant policy, legal, regulatory, and institutional frameworks. While each sector has developed and coexisted in silos, with various governance frameworks applying to specific sectors, the interconnected nature of mining, energy, and industry and the potential co-benefits of the feedback loop require integrated, systemic approaches. This integration operates at two scales: domestically, cutting across sectors and levels of government within Indonesia, and regionally, because mineral and renewable energy value chains do not stop at Indonesia's borders.

To create a cohesive strategy, robust information sharing should be conducted within and across the various government agencies. Starting by gathering georeferenced data on renewable energy potential, grids, and energy demand trends from mining, energy, and industrial activities, **Indonesia should institutionalize a shared, cross-ministerial data platform and conduct an integrated modeling for a stronger policy development plan.** This effort can build on practices already emerging within government: ESDM's electricity planning increasingly seeks to anticipate industrial energy demand over a multi-year horizon and to draw demand projections from industrial park operators as well as PLN.

While policies and regulations from the central government may be clear for nickel operators, coordination between local governments has been less successful. Conversations with government officials have surfaced the lack of local government capacity and intergovernmental coordination with the national government as key challenges in negotiating community benefits with private mining companies. **Coordination must occur within local governments, PLN, and institutions to include broader infrastructure in the development plans of private actors.** Intergovernmental coordination around local assets, needs, and planning must develop sufficiently to engage with mining and downstream companies.

The regional scale arises out of structural necessity, not mere diplomatic aspiration. Indonesia cannot source domestically all of the inputs its downstreaming ambitions require—lithium, phosphate, and manganese among them—nor can it economically site every stage of battery and EV production within its borders. At the same time, the least-cost path to the reliable renewable power its industry needs depends on regional interconnection through the APG. **Indonesia's national frameworks should therefore be built to dock into ASEAN's minerals, energy, and trade systems**—a thread carried through the recommendations that follow.

3.1.1 Integrating the Mining Sector into Energy Planning

Indonesia must consider the mining sector within the broader energy system's future plans. Thus far, Indonesia's long-term renewable energy plans have not explicitly incorporated mining in its system requirements. The exemption of mineral processing from the renewable energy mandates prevents energy system planners from reasonably accounting for future mining and processing energy demand. **Government energy planning must sufficiently account for the energy demand that the mining sector will generate.**

The need to consider mining in broader energy and industrial planning goes beyond nickel and spans other minerals. **Indonesia must expand its planning to encompass the value chains of other minerals, particularly those that are critical to further nickel downstreaming.** This serves dual purposes of bringing greater value addition across a wider array of commodities, as well as de-risking exposure to nickel as a singular commodity. A comprehensive critical mineral strategy requires greater planning and coordination across different sectors of supply and manufacturing demand, as each resource is different.

Integrating the mining sector into energy planning is relevant to Indonesia not only from a domestic point of view, but also regionally, considering Indonesia's position as a major player in mineral and renewable energy value chains in the ASEAN region. Since neither Indonesia alone nor any other single ASEAN economy holds the minerals, processing capacity, and end-product demand required to build batteries and other clean energy technologies, but together these economies can work complementarily in a way to enhance their global competitiveness, Indonesia should seek to cooperate regionally on mining and energy planning. ASEAN has begun to organize cooperation around critical minerals, including through the 2026–2030 ASEAN Minerals Cooperation Action Plan, which seeks to increase trade and investment attractiveness, reduce mining's environmental footprint, build human and institutional capacity, and develop the ASEAN Minerals Information System (AMIS) as a shared platform.²⁵⁹ Bilateral momentum also exists between the Indonesian and Philippine industries, which have created the IndoPhil nickel corridor.²⁶⁰ Notably, however, these agendas are silent on mining–power integration, with regional energy coordination advancing separately through the APG and the efforts to build the ASEAN Regional Integrated Energy System (ARIES) as a least-cost, renewables-based regional system.²⁶¹ Beyond the domestic mineral and energy planning frameworks, **Indonesia should foster regional alignment through planning frameworks that systemically consider regional cooperation on both critical mineral value chains and power system integration.**²⁶²

An important component of systematizing mining and energy planning consists of strengthening the environmental and social standards governing Indonesian mining. Aligning domestic and regional standards with international benchmarks—notably on carbon intensity, reinforcing the argument for a renewables-powered mining sector—can help improve mining's environmental and social performance as well as safeguard access to export markets where buyers and border measures increasingly price embedded carbon. Accordingly, **Indonesia should align domestic—and seek to align regional—environmental and social standards applicable to the mining sector with international benchmarks.**²⁶³

Indonesia's cross-ministerial SIMBARA traceability system, applicable to nickel since 2024, already tracks ore from mine to transporter to buyer in order to enforce royalty compliance and detect illegal flows,²⁶⁴ operating alongside the MinerbaOne licensing platform.²⁶⁵ **Indonesia could consider extending this system to record energy sources** alongside mineral flows, making it a practical tool for integrated mining and energy planning.

3.1.2 Integrating Industrial Policy into Energy Planning

Primary energy source is the most significant driver in industrial nickel emissions; this difference can be seen in the emissions footprint of smelters operating off of hydropower in Sorowako versus captive coal generation in other parts of Sulawesi. Some of these constraints are inherently geographic; thus far, nickel production has remained on the Sulawesi and Maluku islands given the location of reserves. While Sulawesi and Maluku Islands are characterized by limited primary renewable energy sources, other islands have greater renewables availability. Fortunately, as further downstreaming brings nickel intermediates to market, production can move toward Indonesian regions with the greatest potential for solar, wind, and hydro power development.

Kalimantan holds abundant hydropower potential, with large rivers and significant rainfall on the island. Abundant geothermal energy potential also exists in various other regions. Both hydropower and geothermal energy provide reliable sources of renewable electricity, reducing the intermittency challenges of solar and wind generation. Consequently, **strategic siting of new mineral processing facilities and industrial parks must consider the location of future renewable energy resources as a first-order consideration.**

Industrial parks and participating tenant companies have long held significant policy benefits through National Strategic Project (PSN), Special Economic Zone (KEKs), and other formal designations; fiscal incentives tied to annual Work Plan and Budget (RKAB) approvals are also available to mining and processing firms. These tools can be leveraged and designed to prioritize siting of industrial parks to be in close proximity to renewable energy sites, as their developments should be in tandem with each other, also by including the necessary infrastructure for transmission and distribution. **Indonesia should make certification of available or planned renewable power capacity a precondition for PSN, KEK, and industrial park or smelter approvals, and should tie RKAB approvals, concessions, and fiscal incentives to the same standard.**

In tandem with these renewable capacity preconditions, process simplification can also help expedite investment in renewable energy and low-carbon industry. Stakeholders identify permitting complexity—including the environmental impact assessment (*Analisis Mengenai Dampak Lingkungan Hidup*, AMDAL) process—as a source of delay and cost.²⁶⁶ **Indonesia may wish to consider opportunities for reforms to further streamline and clarify permitting, including the AMDAL process, so that projects meeting these preconditions benefit from faster approvals.**

Parallel to the development of future downstream production, and consistent with the renewables phase-in approach set out in this policy concept note, Indonesia should consider a long-term path for renewables to displace its captive coal-fired power plant fleet that currently powers the RKEF smelters in Sulawesi. Despite heavy attention on coal retirement from JETP and international organizations, the likelihood of near-term retirement of Indonesia's captive coal facilities remains slim for current RKEF production. However, opportunities may arise when considering a longer time horizon. While land use presently limits the capacity for utility-scale solar generation, questions arise regarding the land use implications of mine sites as they become depleted. Indonesia should consider renewable energy generation options as they explore remediation practices for retired reserves. Utility-scale solar currently stands as an option for future displacement of Indonesia's current captive RKEF CFPP fleet, but more opportunities and choices may become available in the coming decades.

To achieve successful mineral downstreaming for nickel alone, Indonesia requires development or procurement of a number of other input resources. As mentioned before, Indonesia has no developed domestic sources of lithium, despite a recent reserve discovery. Such limitations are true for phosphorus and manganese for the various battery chemistries involved in EV battery production. Nickel alone will not enable downstream manufacturing development; Indonesia must

build the requisite international trade partnerships to secure input supply for future downstreaming initiatives. Therefore, a singular focus on one type of production will produce limited returns for Indonesia's downstreaming efforts. **Strategic diversification of downstream production will be necessary for Indonesia not to suffer the negative macroeconomic consequences of market oversupply as the nickel market currently stands.**

Indonesia should hedge its battery manufacturing ambitions with high-quality steel alloy production as another path to high-quality manufacturing prowess. Battery manufacturing is only one production vertical where nickel plays an outsize role in value creation. High-quality steel alloys require higher levels of nickel content for production, and these higher-grade materials also fetch higher prices in global markets. While steel alloy value addition involves several stages of additional refining and manufacturing capacity, a cohesive vision and a robust policy and legal framework can go a long way to generate and align actors and regulations. Coupled with nickel supply control and technology transfer incentives, Indonesia can invite leading technology partners to advance domestic alloy production.

Indonesia's dependence on other inputs makes regional cooperation and integration as well as trade—within the region and more broadly—a necessity requiring planning. Because it may not be economical for Indonesia to onshore every stage of the battery and EV value chain, and because a strategy anchored on nickel batteries is risky in light of competing battery chemistries, Indonesia may want to concentrate domestic industrial policy efforts where it has advantages—upstream extraction, midstream processing, and cathode manufacturing—while leveraging regional partnerships and trade to secure the remaining inputs and downstream offtake. This industrial policy choice is also an energy planning decision because it determines which energy-intensive stages of the value chain will be located in Indonesia, and therefore how much renewable energy Indonesia must deliver. **Indonesia should treat regional cooperation, integration, and trade as an important component in industrial and energy system planning, prioritizing the stages of the value chain where Indonesia is most competitive and coordinating input supply and product offtake at the ASEAN level.**

Transport economics reinforces the argument for regionalization. While cathodes, anodes, and cell inputs can safely and economically be shipped in bulk, finished battery cells are classified as Class 9 dangerous goods that consequently are costly to ship (Section 1.2). As a result, final cell and EV assembly will tend to gravitate toward consumer markets, but Indonesia can anchor the manufacturing of inputs and cathodes and trade them regionally, ideally through additional investment in low-carbon shipping. Accordingly, as an integral part of its industrial and energy policy, **Indonesia should develop low-carbon regional shipping to support its mineral and battery value chains, in coordination with ASEAN's power system integration.**

3.1.3 Integrating Shared-Use Energy Infrastructure into Mineral and Industrial Planning

Thus far, shared use of energy infrastructure has largely been absent from the planning of nickel production and processing facilities and industrial parks in Indonesia. As shared in interviews with mining company representatives, local governments approach mining companies to negotiate shared power agreements with the significant amounts of captive coal generation in their vicinity, yet regulations require captive power production to remain limited to the company's mining concession. The principal barrier is regulatory: even where a mine or smelter has surplus power from its captive generation plant that could be used by a neighboring industry or community or the grid, the law does not allow the exchange. The same confinement applies to captive renewable power generation, hindering its shared use. Government oversight further complicates the issue: PLN does not collect data about captive plants, which fall under the MOI,²⁶⁷ and smaller installations below the licensing threshold escape ESDM oversight (Section 1.1). Therefore, a large portion of Indonesia's power generation is invisible to the government institutions responsible for energy planning.

Unlocking shared use requires opening access to the grid. Under PLN's monopoly over generation and distribution, a renewable IPP cannot directly sell to an industrial offtaker; any PPA must run through PLN, foreclosing independent renewable supply to mines and smelters.²⁶⁸ Introducing third-party access through a power wheeling framework—allowing IPPs to use PLN's network under regulated open-access tariffs²⁶⁹—would let renewable generators reach industrial offtakers directly, turning mining and industrial demand into anchor demand for additional renewable capacity. **Indonesia should adopt a power wheeling framework with regulated open-access tariffs that allows renewable IPPs to use PLN's grid to serve mining and industrial offtakers.**

Where renewable generation is developed captively, it should fall under ESDM oversight so energy planners can account for it in system-wide plans, and the conditioning of RKAB approvals and fiscal incentives on renewable capacity (Section 3.1.2) should extend to shared-use commitments. Existing systems can carry much of this load: the SIMBARA traceability platform (Section 3.1.1) could record the energy source alongside the mineral flows it already tracks. Intra-governmental coordination within and across energy, industry, mining, environmental, and planning authorities will require a single coordinating platform with a clearly defined coordinator, particularly because ministries operate separate information systems built to their own specifications that do not interoperate; even where the mandate to coordinate exists, the underlying data and platforms may not fit together.²⁷⁰ The Coordinating Ministry for Economic Affairs, mandated to coordinate, synchronize, and control policy across the relevant line ministries, is the natural anchor for this function. **Indonesia should bring captively generated renewable power under ESDM oversight and establish a single inter-ministerial coordinating mechanism—anchored in the Coordinating Ministry for Economic Affairs, with a clearly defined coordinator role and interoperable data systems—to integrate shared-use within broader mining–energy–industry planning.**

The nature of energy resources similarly affects the types of shared-use infrastructure that takes priority. Given the geographically determined nature of hydropower and geothermal energy, transmission then becomes a critical technology, operational, and financing objective for bringing future downstream operations online. Transmission and distribution also carry significant system benefits by making electricity accessible to other industrial as well as residential users. **Indonesia should establish policy, legal, regulatory, and institutional frameworks for deploying transmission and distribution, integrated with PLN, bringing geographically constrained hydro and geothermal power to demand centers.**

Shared use also has a regional dimension. As discussed in Section 1.2.1 and 3.1.1, ASEAN is advancing regional power-system integration, and Indonesia's domestic shared-use frameworks should be built to connect to it. Indonesia needs to follow through on its existing interconnection commitments and pursue similar initiatives, learning from established proof of concepts, to reduce domestic and regional reliance on fossil fuels while securing national supply. A regional integrated energy system would let domestic capacity be prioritized for industry while residential and commercial demand is met through interconnection—providing reliability, future-proofing the system against shifts in where new generation is added, and allowing low-carbon demand from neighboring countries to anchor domestic renewable development.

The challenge remains, where the country's archipelagic form requires costly infrastructure.²⁷¹ However, regional cooperation creates avenues to more funding sources, including multi-national public-private partnerships to further support funds such as JETP, which are also considering projects for transmission and distribution aside from generation.²⁷²

Table 4 summarizes the recommendations for a policy, legal, regulatory, and institutional framework to align mining and industrial activities with domestic and regional energy planning that is steered towards renewable energy.

Table 4. Summary of recommendations: policy, legal, regulatory, and institutional frameworks for domestic and regional system planning

Recommendation	Stakeholders	Priority Level
Build a shared, cross-ministerial data and modeling foundation: 1. Gather georeferenced data on current and forecasted renewable energy generation, grids, and energy demand from mining, energy, and industrial activities. 2. Institutionalize a shared, cross-ministerial data platform. 3. Conduct integrated cross-sectoral modeling to inform policy development.	Co-leads: PLN (on energy-related data), BPS (on statistical databases), BAPPENAS (on policy modeling and planning). Involved: ESDM, MOI, BKPM.	High
Strengthen intra-governmental coordination and policy, legal, regulatory, and institutional frameworks to integrate long-term mining, energy, and industrial planning, including shared-use energy infrastructure: 1. Establish a single inter-ministerial coordinating mechanism with a clearly defined coordinator role and interoperable data systems, replacing parallel ministry processes. 2. Explicitly incorporate the mining and mineral processing sector's energy demand into the National Electricity Plan (RUKN) and PLN's Electricity Supply Business Plan (RUPTL). 3. Encompass the value chains of other critical minerals beyond nickel, including not only those required for batteries but also high-quality nickel-bearing steel alloys.	Lead: Coordinating Ministry for Economic Affairs. Involved: ESDM, MOI, PLN, BAPPENAS, BKPM, Ministry of Trade, provincial and regency governments.	High
Strengthen local government capacity to engage in mining, energy, and industrial planning, including on shared-use infrastructure.	Lead: Ministry of Home Affairs. Involved: Provincial and regency governments.	Medium
Strengthen environmental and social standards and their traceability: 1. Align domestic environmental and social standards applicable to critical mineral value chains with international benchmarks to improve environmental performance as well as safeguard export market access and carbon competitiveness. 2. Expand the SIMBARA platform to capture energy source, tailings management, and relevant carbon intensity data across the mineral-industrial value chain.	Co-leads: Ministry of Environment, Ministry of Finance. Involved: ESDM, MOI, Ministry of Trade, industrial park operators, mining and processing companies.	Medium
Pursue regional cooperation through ASEAN on critical minerals strategy, integrated power systems, and clean shipping, building on existing initiatives.	Lead: Ministry of Foreign Affairs. Involved: PLN, ESDM, MOI, BAPPENAS, ASEAN Secretariat, ASEAN Member States.	High
continued...		

Recommendation	Stakeholders	Priority Level
Align siting and permitting requirements with the renewables phase-in: 1. Site new mineral processing facilities and industrial parks in proximity to renewable energy resources. 2. Mandate certification of planned or available renewable energy capacity as a precondition for certain approvals or fiscal advantages, such as: a. RKAB approvals, concessions, and fiscal incentives. b. ESDM sign-off for PSN, KEK, and industrial park or smelter approvals. 3. Streamline and clarify permitting, including the AMDAL process.	Co-leads: MOI, ESDM. Involved: Coordinating Ministry for Economic Affairs, PLN, BKPM, BAPPENAS, provincial and regency governments, industrial park operators, mining and processing companies.	High
Establish policy, legal, regulatory, and institutional frameworks to deploy transmission and distribution for renewable-powered downstream operations. • Adopt a power wheeling framework with regulated open-access tariffs to allow renewable IPPs to use PLN's grid.	Lead: ESDM. Involved: PLN, IPPs, industrial park operators, mining and processing companies, other industrial offtakers.	High

3.2 Technology Transfer and R&D

Closing the technology gap requires two complementary moves: importing and adapting mature technologies that do not need to be reinvented domestically and concentrating Indonesia's own R&D on challenges specific to its resources, geography, and industrial strength. This section covers the former as technology transfer (Section 3.2.1) and the latter as targeted R&D (Section 3.2.2), treating the domestic innovation ecosystem as the connective tissue that allows technologies to be successfully transferred and local R&D to mature.

3.2.1 Technology Transfer

The top three countries of origin for Indonesia's industrial park tenants (China, Japan, and South Korea) have each developed technologies that could strengthen the mining–energy–industry feedback loop, and their established presence in Indonesia makes them promising partners for technology transfer.²⁷³ Though EVs dominate the downstreaming efforts in Indonesia, the reality is that most nickel produced in Indonesia still goes to stainless steel production.²⁷⁴ Japanese and South Korean steelmakers have high ambitions to decarbonize this industry and are therefore likely partners in decarbonizing the energy used to process the nickel inputs. South Korea's major steelmaker, POSCO, is developing hydrogen reduction technology (HyREX), with a pilot plant operating since 2014.²⁷⁵ Japan's three largest steelmakers have been developing various technologies through the COURSE50 program, which involves hydrogen injection to blast furnaces and carbon capture.²⁷⁶

In grid infrastructure, China holds world-leading expertise in ultra-high voltage (UHV) and long-distance transmission,²⁷⁷ directly relevant to Indonesia's plans to link the Sumatran and Javanese grids by High Voltage Direct Current (HVDC) technology.²⁷⁸ The same competencies underpin the longer-term ambition of regional interconnection throughout ASEAN. Accordingly, transfers of transmission technology serve Indonesia's domestic as well as ASEAN's regional objectives at once. Indonesia is already a production ground for its main investor countries. **Indonesia should expand technology transfer partnerships with its principal investor countries while conditioning these arrangements on domestic capacity building**, importing knowledge as an input and exporting the resulting products through trade relationships.

Leveraging mineral wealth for economic growth and development based on mid- and downstream activities depends on “multi-level collaboration across training, research, and innovation.”²⁷⁹ An important component of a conducive environment for successful technology transfer is the existence of a domestic and regional innovation ecosystem, to improve technical aspects and develop human capital and institutions to adapt and improve transferred technologies. Indonesia can strengthen this base by expanding investment in national research bodies such as the National Research and Innovation Agency (*Badan Riset dan Inovasi Nasional*, BRIN) and by orienting university research centers toward mineral and energy priorities. The establishment of the new agency, BIM, signals this intent, but its long-term success requires sustained investment in young talent. Targeted scholarships, most notably the Indonesia Endowment Fund for Education (*Lembaga Pengelola Dana Pendidikan*, LPDP), are increasingly directed toward downstream-related fields; their value, however, depends on deliberate planning to absorb graduates into the industry through an expanded and well-defined job market. **Indonesia should anchor technology transfer in a domestic innovation ecosystem linking universities, industry, and government, so that transferred technology is locally absorbed, adapted, and reinvested.**

3.2.2 R&D for Specific Technologies

Grid

With Indonesia’s geographical conditions as an archipelagic country, working on technical capabilities for grid adjustments is a fundamental step. This includes technologies such as deep marine HVDC, multi-terminal HVDC to support various islands, and other research for infrastructure that can withstand frequently occurring natural disasters in various parts of the country, such as earthquakes and volcanic eruptions.

Domestic capability in R&D for an improved grid would be relevant within Indonesia and as part of Indonesia’s participation in ASEAN’s regional interconnection. An interconnected grid is among the most effective ways to manage renewable intermittency, since pooling geographically diverse solar, wind, hydro, and geothermal resources across borders smooths supply better than isolated national systems can. At present, however, regional interconnection is advancing mainly through bilaterally negotiated subsea cable projects, concentrating revenue and planning risk and falling short of genuine integration. Indonesia should treat regional grid development as an industrial and technological opportunity: domestic manufacturing capacity in transmission and HVDC equipment places the country along the road to the APG. **Indonesia should align its domestic grid R&D and transmission manufacturing capacity with regional interconnection planning within ASEAN, while diversifying beyond bilateral subsea-cable arrangements toward multilaterally planned interconnection.**

In response to the major energy need of industrial smelting loads and the intermittent nature of renewable energy generation, the country should focus on developing grid-enhancing technologies and demand response. The RUPTL already states plans for PLN’s Smart Grid strategy development, including Advanced Metering Infrastructure (AMI), Distributed Energy Resource Management Systems (DERMS), and automated restoration systems.²⁸⁰ The persisting challenge is to successfully implement and to improve the systems’ capabilities for the larger industrial scale. **Indonesia should prioritize the development and industrial-scale deployment of grid-enhancing technologies and demand response to integrate large, continuous smelting loads with variable renewable energy generation.**

Battery Chemistry

As battery technologies diversify, Indonesia should hedge against over-reliance on nickel-based chemistries. The growing market share and promise of LFP batteries²⁸¹ makes research beyond nickel-based chemistries necessary to reduce the risk of stranded investments and overcapacity in nickel-based battery production. While a certain amount of nickel-based battery production is likely to remain for weight-sensitive and high-performance applications, Indonesia should build capacity in the segments of battery production that are applicable regardless of cathode chemistry, such as anode manufacturing and domestic productization. At the same time, Indonesia should leverage its outsized position in nickel production to strengthen its comparative advantage in more advanced nickel-based battery chemistries. While nickel cathodes have evolved significantly (NMC111, NMC811, Nickel Cobalt Aluminum, etc.), improving energy density, stability, safety, and cost,²⁸² nickel-based batteries have yet to reach their full potential in safety and stability.²⁸³ Targeted R&D could help keep Indonesian nickel-based production resilient and differentiated in the face of globalized production. **Indonesia should pursue a two-track battery R&D strategy: building chemistry-agnostic and non-nickel capabilities to hedge demand risk, while strengthening next-generation nickel battery chemistry.**

Demand-Driven Product Design: Two- or Three-Wheelers and DERs

Indonesia's automotive manufacturing industry is well-developed, catering to the abundant domestic and regional markets, including Southeast Asia and the Middle East.²⁸⁴ While government incentives for EV development center on passenger cars,²⁸⁵ the government has introduced targets and incentives for electric motorcycles,²⁸⁶ and many private companies are independently trying to develop electric two/three wheelers.²⁸⁷ The government has supported these initiatives in the form of price subsidies for domestic customers, but the bottleneck still remains in general EV development, where the country's industry is still currently in the cathode or cell manufacturing stage and is still importing core battery components from China. On a systems level, these vehicles and their mobile battery storage units can provide utility value as distributed energy resources (DERs) to help regulate the grid's power distribution, strengthening the general EV ecosystem while also improving grid quality at large.²⁸⁸ **R&D for domestic manufacturing for two- or three-wheelers and battery management systems could strengthen the industrial pillar of Indonesia's feedback loop.**

Even as the electric mobility sector grows, Indonesia need not develop the entirety of the supply chain solely within its borders. Neighboring countries in Southeast Asia have mature vehicle manufacturing supply chains, all of which will need battery manufacturing integration. Developing a robust, mature, vertically integrated electric mobility sector will take time, while such ecosystems already exist in China, India, and Vietnam. China's largest electric 2-wheeler manufacturer, YADEA, is establishing its ASEAN hub in Thailand,²⁸⁹ and India leads in 3-wheeler manufacturing globally.²⁹⁰ Vietnam has vertically integrated much of its electric 2-wheeler manufacturing supply chain through strong state incentives, with its leading manufacturer reaching 60% localization in 2025 and targeting 80% by 2026.²⁹¹ Indonesia's EV mobility industry sits in a rapidly evolving competitive ecosystem. Through partnerships within the region, Indonesia can see growth in its electric mobility sector while maintaining its competitive edge in battery manufacturing without establishing the full EV manufacturing supply chain. Such investments can move towards establishing charging infrastructure, developing grid resilience for flexible load, and implementing demand response systems as discussed above.

Table 5 summarizes the recommendations for closing technology transfer and R&D gaps.

Table 5. Summary of recommendations: technology transfer and R&D

Recommendation	Stakeholders	Priority Level
Build out the domestic innovation ecosystem around BRIN, MIND ID, industry, and universities.	Lead: BRIN. Involved: Ministry of Education, Culture, Research and Technology; ESDM; MOI; MIND ID; Indonesian universities.	High
Structure technology-transfer conditions on existing investment relationships with China, Japan, and South Korea that ensure knowledge sharing.	Lead: Ministry of Investment. Involved: MOI, ESDM, MOF, Indonesia Investment Authority (INA), BAPPENAS, Coordinating Ministries, industrial park operators.	High
Prioritize grid technology manufacturing as a critical enabling sector	Lead: PLN, ESDM. Involved: MOF, Coordinating Ministry for Infrastructure and Regional Development, BAPPENAS, industrial park operators.	Medium

3.3 Economic and Financial Feasibility

Indonesia's position as the market leader in the nickel industry and the associated revenue inflows strengthen its ability to expedite industrial development within nickel value chains. Yet global nickel demand trends should be treated with caution in light of factors including shifting battery chemistries. As demand grows for other minerals found in Indonesia that are critical to the energy transition and the digital economy—copper for grid transmission, bauxite for aluminum, and tin as solder for electronics—selectively developing these value chains, where the business case supports it, can reduce overreliance on nickel and buffer the economy against shifts in technologies and product trends. The case for diversification and downstreaming must be tested against demand, comparative advantage, and energy requirements, among other factors. Aluminum smelting, for example, is very electricity-intensive and could deepen captive coal lock-in if not anchored to newly built renewable capacity.²⁹² Indonesia should therefore pursue diversification, where the business case supports it, and extend shared-use renewable power infrastructure across mineral and industrial sectors, increasing the economies of scope and scale that lower costs for individual companies and reinforcing the feedback loop.

The economic case for the feedback loop also rests on the breadth of economic linkages it can generate. As mining, processing, renewable energy deployment, and industrialization create sustained demand for domestic suppliers of equipment, reagents, components, and services, **upstream linkages** arise. As processed outputs such as nickel intermediates and cathode and cell inputs feed domestic manufacturing of batteries, EVs, and grid and solar equipment, **downstream linkages** arise. Beyond power, other types of infrastructure in Indonesia have been built solely to cater to the needs of mining and industrial activities. For example, port access is reserved for industrial activities, while smaller vessels have limited access to these key infrastructure facilities. Governments have even discovered undeclared airstrips reserved for mining activity.²⁹³ The same shared-use approach applied to power infrastructure in this analysis should also be considered for other infrastructure types—including rail, port, water, and information and communications technology (ICT).²⁹⁴ In turn, by co-locating mining, mineral processing, energy generation, and downstream industry to the extent possible, and fostering shared-use infrastructure, Indonesia could capture the benefits of **spatial linkages** as well. **Indonesia should design industrial policy to deliberately cultivate upstream linkages by supporting the development of domestic suppliers, downstream linkages by incentivizing domestic manufacture, and spatial linkages by co-locating industry and creating the policy, legal, regulatory, and institutional conditions to unlock the shared use of mineral-industrial infrastructure.**

Diversified green industrialization, low-carbon energy development, and related upstream, downstream, and spatial linkages cannot be realized without a skilled workforce. A high-technology grid, advanced metallurgical smelting, and battery-cell manufacturing, for example, demand skills that Indonesia's labor market would need to be able to supply at scale, without excessive reliance on foreign investment and labor that would risk letting much of the value and the learning escape the domestic economy. Building human capital is an economic precondition that determines whether Indonesia can capture the feedback loop's benefits. Investing in human capital also helps ensure a just transition through training, upskilling, and reskilling of workers in coal- and nickel-dependent regions (Section 2.3). **Indonesia should invest in workforce development by requiring commitments from mineral, industrial, and renewable energy companies to offer training and upskilling opportunities, providing government incentives for workforce development, and cooperating with universities and industry in training, research, and innovation programs.**

Costly and technically demanding feasibility studies are another practical barrier to evaluating and adopting renewable power at a mine or smelter site. State-owned and privately-owned enterprises alike may lack the in-house capacity to conduct them and therefore default to the more familiar option of captive coal. Publicly supported or standardized feasibility studies, shared technical assistance, and replicable assessment methodologies could help lower this barrier and accelerate adoption,²⁹⁵ particularly if paired with support for project preparation.²⁹⁶ **Indonesia should support standardized, replicable feasibility studies and shared technical assistance for renewable power adoption at mine and processing sites to reduce the project preparation burden on individual operators.**

Finally, finance is a critical enabler of the feedback loop. The companion applied research paper within this project, *Financing Indonesia's Green Industrialization: System Pathways, Structural Diagnosis, and Tailored Solutions*, discusses in depth relevant financial mechanisms, including anchoring revenue by aligning payment obligations with production, instruments, and parties for risk transfer, and setting shared infrastructure as financeable asset classes.²⁹⁷

Table 6 summarizes the recommendations on the economic and financial feasibility of the feedback loop.

Table 6. Summary of recommendations: economic and financial feasibility

Recommendation	Stakeholders	Priority Level
Create the policy, legal, regulatory, and institutional conditions for the shared use of renewable power infrastructure across mineral and industrial value chains Develop standardized contract templates for offtake, cost-sharing, and interconnection (see companion piece, <i>Financing Indonesia's Green Industrialization</i>)	Co-leads: ESDM, PLN. Involved: Coordinating Ministry for Economic Affairs, MOI, MOF, BAPPENAS, industrial park operators, mining and processing companies.	High
Design industrial policy that deliberately cultivates linkages: - Upstream: support the development of domestic suppliers - Downstream: incentivize domestic manufacture - Spatial: co-locate industry and create the policy, legal, regulatory, and institutional conditions to unlock the shared use of mineral-industrial infrastructure (beyond power)	Lead: Coordinating Ministry for Economic Affairs. Involved: BAPPENAS, MOI, industrial park operators, mining and processing companies.	High

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Recommendation	Stakeholders	Priority Level
Develop a workforce and skills strategy tied to Technical and Vocational Education and Training (TVET) and university programs and capacity	Lead: Ministry of Education, Culture, Research and Technology. Involved: Ministry of Manpower, ESDM, BAPPENAS.	Medium
Lower the project preparation burden for renewable adoption at mine and processing sites through standardized, replicable feasibility studies and shared technical assistance.	Co-leads: ESDM, BRIN. Involved: MIND ID and SOE operators, PT SMI (project preparation), MOF, industrial park operators, mining and processing companies.	Medium

The three sets of enabling conditions for the mining–energy–industry feedback loop in Indonesia are complementary and mutually reinforcing. Integrated planning across mining, energy, and industry ([Section 3.1](#)) determines where renewable capacity is built, which value-chain stages Indonesia anchors domestically, and how Indonesia leverages regional integration and trade. In turn, technology transfer and targeted R&D ([Section 3.2](#)) determine whether and how Indonesia’s innovation ecosystem develops capacity to operate and improve those systems. The economic and financial conditions examined here underpin the diversification, linkages, and human capital on which the feedback loop depends. Pursued in concert, the three reinforce one another, as the loop’s three sectors do: mineral and industrial demand anchors renewable energy development in a regionally interconnected system, renewable energy and industry add value to the mineral base, and the resulting growth and revenue fund further investment and economic development. With these enabling conditions in place, Indonesia’s nickel endowment can support a diversified, renewables-based industrial economy beyond the nickel cycle, along with its economic, environmental, and social co-benefits ([Section 2](#)).



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