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An Analysis of Five Years of Electric Vehicle Regulation, Investment, and Industry Development in Indonesia

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List of Abbreviations

BEV	Battery Electric Vehicle
CO_2	carbon dioxide
EV	Electric Vehicle (includes battery electric vehicles, plug-in hybrid vehicles, hybrid vehicles)
GJ/t	Gigajoules per ton
GOI	Government of Indonesia
GWh	Gigawatt hours
HPAL	High-pressure Acid Leaching
ICEV	Internal Combustion Engine Vehicle
MEMR	Ministry of Energy and Mineral Resources
MOT	Ministry of Transportation
$MtCO_2e$	mega tons carbon dioxide equivalent
PHEV	Plug-in Hybrid Electric Vehicle
PLN	*Perusahaan Listrik Negara* (Indonesia's state-owned electricity company)
PR55/2019	Presidential Regulation 55/2019
2WEV	Two-wheeled Electric Vehicle

Introduction

On the occasion of Indonesia's transition from President Joko Widodo to new President Prabowo Subianto, this report reviews and assesses one of the previous president's major legacy initiatives, which the new president has vowed to continue: development and establishment of a full electric vehicle (EV) supply chain, "downstreaming" from critical minerals sourcing to battery manufacturing to vehicle production. The EV market is booming globally, thus raising demand for electric batteries and the mineral resources needed in their construction. Indonesia wishes to situate itself at the center of the transition from internal combustion to electric vehicles both globally and domestically, given its abundant resources, economic growth aspirations, and international emissions reductions commitments. The country's EV story thus far is one of mixed success and uncertainty, however, raising pressing questions for the new president's EV development and emissions reduction strategies and the country's economic, social, environmental, and climate priorities.

Indonesia is one of the top ten largest producers of CO_2 emissions in the world, with land use change and energy being the primary emissions sources. The country's transportation sector is nonetheless responsible for 25% of total national CO_2 emissions, with transportation emissions forecast to increase by 53% from 2015 levels by 2030.[1,2] The Government of Indonesia (GOI) has targeted EV development as an avenue for both investment and decarbonization, potentially reducing reliance on fossil fuels while establishing a leading position in an industry poised for substantial growth into the foreseeable future. Indonesia holds 22% of global reserves of nickel, a critical mineral used in the manufacture of steel and EV batteries, and accounts for 51% of global nickel production making Indonesia the largest producer of the mineral in the world (and is also the second-largest producer of cobalt, another critical mineral in EV battery production). These nickel reserves are primarily located in Sulawesi and the Maluku islands (particularly Halmahera and Obi islands), at the heart of Wallacea, which are home to unique terrestrial and marine biodiversity and dozens of different indigenous groups. For more than a decade, the country has envisioned leveraging its abundant nickel reserves into a full, value-added supply chain for domestic EV production.[3]

To capitalize upon these vast nickel reserves, the administration of President Joko Widodo (known familiarly as Jokowi) sought to "downstream" nickel into a domestic battery industry to supply growing battery electric vehicle (BEV) demand. The GOI aims to produce 140 GWh worth of EV batteries domestically by 2030, representing approximately 5% of the forecasted global battery demand in 2030.[4] Indonesia would thereby establish itself as one of the top three global producers of EV batteries by 2027, according to public statements made by Jokowi's Coordinating Minister for Maritime Affairs and Investment (newly appointed by Prabowo to lead the National Economic Council), Luhut Binsar Pandjaitan.[5] For his part, then-candidate Prabowo earlier this year announced that he would boost Indonesia's annual GDP from 5% to 8% within a couple of years, with the nickel industry being a major part of that growth.[6] Additionally, the GOI aims to have two million electric cars and 13 million electric motorcycles on the road by 2030, of which 600,000 would be manufactured domestically.[7] While emissions reduction is the expressed motivation for domestic EV development, the GOI hopes to use EVs to bolster its economy and attain developed nation status by 2045 (a plan referred to by the GOI as "Golden Indonesia 2045").[8] To that end, the GOI has implemented regulations and policies ostensibly to foster a climate conducive to foreign investment and the creation of an EV industry while encouraging the widespread domestic adoption of EVs. This regulatory push began on August 8, 2019 with the introduction of Presidential Regulation Number 55 of 2019 concerning the Electric Vehicle (PR55/2019). This regulation outlines the roadmap for the GOI to establish the country as an EV hub. It mandates that the Indonesian government enact legislation to:

1. Encourage and enable domestic manufacturing of EVs and EV batteries
2. Create incentives to encourage domestic adoption of EVs
3. Facilitate the buildup of infrastructure to support widespread EV adoption
4. Create technical standards for the testing and manufacture of EVs
5. Ensure the protection of the environment throughout the process

Since 2019, the GOI has indeed enacted numerous pieces of legislation and issued multiple regulations geared toward securing foreign investment in EV manufacturing and creating a domestic EV market. The following sections of this report assess the goals outlined in PR55/2019 and their respective successes and failures. The report identifies steps to facilitate further transportation sector electrification, overall emissions reductions, and the creation of a domestic BEV manufacturing sector within Indonesia.

Goal 1: To Encourage and Enable the Domestic Manufacturing of EV Batteries and BEV

Although the impetus to expand domestic battery manufacturing began with PR55/2019, the underlying drivers emerged much earlier under the previous administration of President Susilo Bambang Yudhoyono. Since at least 2009, the GOI has sought to leverage its vast mineral resources to foster domestic industrial growth and a shift from providing raw materials for overseas processing towards domestic processing and usage. The Yudhoyono administration began on January 11th, 2014 to enforce an unrefined nickel export ban first introduced in 2009 as part of Law No. 4/2009 on Coal and Mining, which required companies to process metal ore and minerals domestically before exporting. This export ban was enacted with the intent to boost domestic refining and smelting capacity and reduce Indonesia's exposure to volatile commodity prices by producing higher-value nickel instead of exclusively exporting the raw mined product. As expected, Indonesian unrefined nickel exports immediately plummeted in the wake of the ban. However, overall nickel production and mine output also fell immediately following the ban (Figure 1a), generating industry dissatisfaction and a budget deficit that prompted the GOI to relax the export restriction in 2017.[4] This allowed companies to export unprocessed nickel ore provided that they committed to building local smelters and refineries, with a full ban on unrefined nickel slated to go into effect again in January 2022. This change was enacted to give the companies additional time to build up domestic refineries and smelting capacity prior to the reinstatement of a full ban.[9]

PR55/2019 redefined the focus of the central government's nickel policy. Following the announcement of the nation's EV and domestic battery industry goals, the trade policy for nickel once again shifted. Regulation Number 11/2019 from the Ministry of Energy and Mineral Resources (MEMR) prevented the export of unrefined nickel ore, effective January 1, 2020. While this ban furthered the goal of promoting domestic mineral processing and a value-added approach to exploiting the nation's vast resources, the intent was also to encourage foreign EV battery manufacturers to invest in Indonesia and begin to build up production capacity locally rather than overseas.

This suite of export bans has produced varying outcomes for the BEV and nickel industries. First, since the initial ban in 2014, raw nickel mining output in

Indonesia has grown by 800% (Figure 1a). Second, since the implementation of the export bans, processed Indonesian nickel exports have increased significantly, reflecting the launch of domestic refining of nickel ore (Figure 1c). Nickel exports can be divided into three main categories based on the value of and the level of refinement from the original ore: nickel ore (unprocessed nickel), nickel pig iron and ferronickel (lower-grade intermediates utilized in stainless steel production), and nickel matte (higher-grade intermediate suitable for manufacturing pure nickel) [10]. Before the bans, Indonesia primarily exported unprocessed nickel, with total exports valued at $2 billion (Figure 1c). Since the 2020 ban, however, Indonesia has begun to export primarily ferronickel and small quantities of nickel matte. While overall exports have fallen significantly (Figure 1b), the overall value of Indonesian nickel exports has increased dramatically compared to pre-2014 levels due to the higher value of processed nickel (Figure 1c).

FIGURE 1a

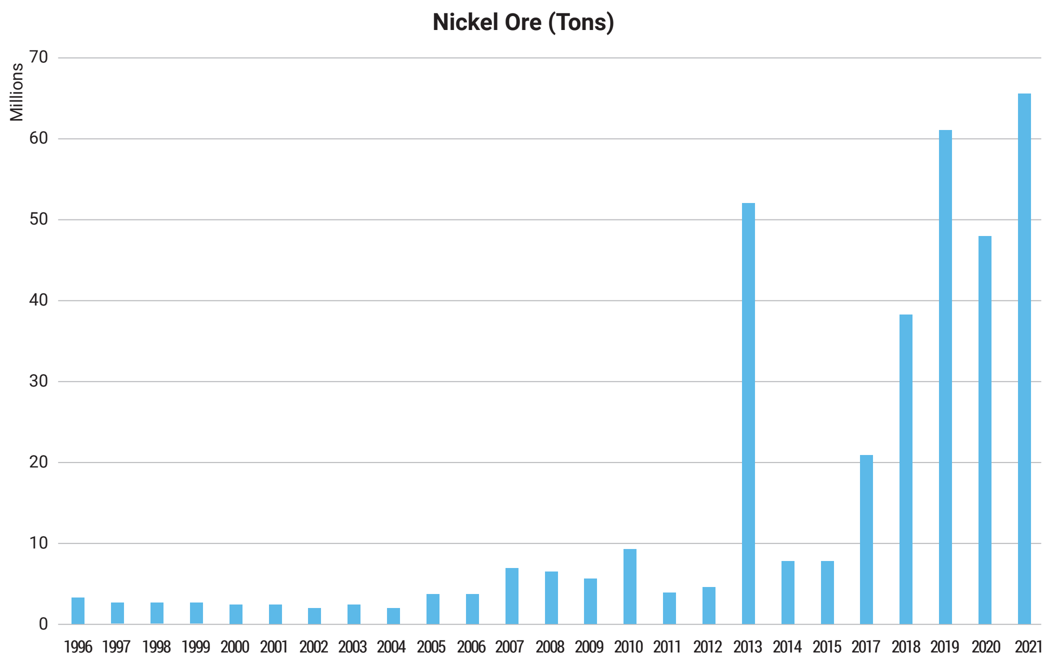


FIGURE 1b

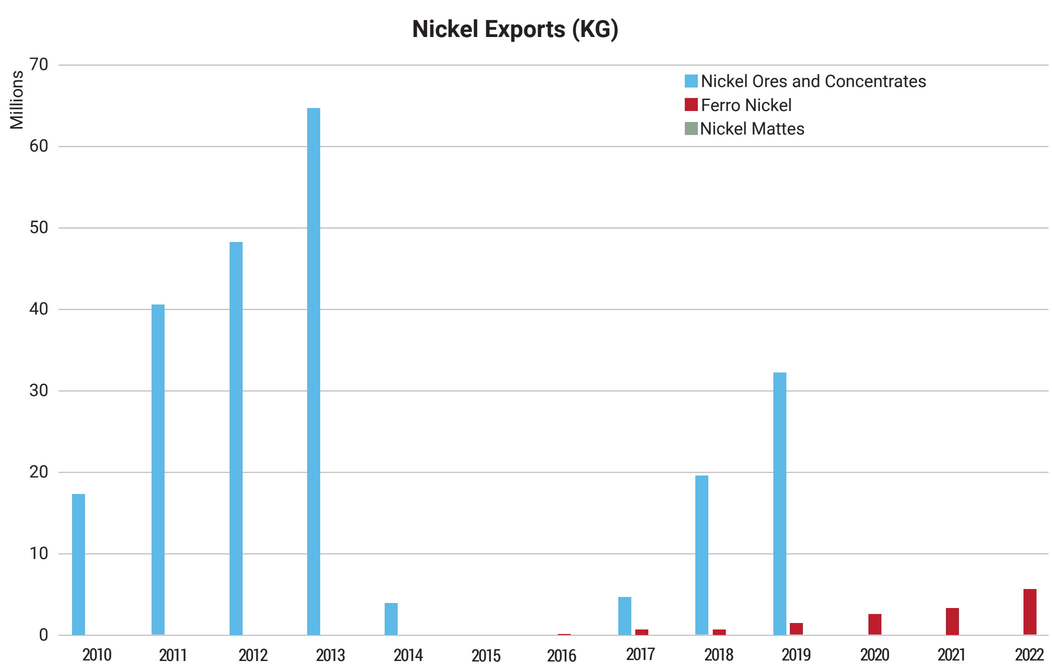


FIGURE 1c

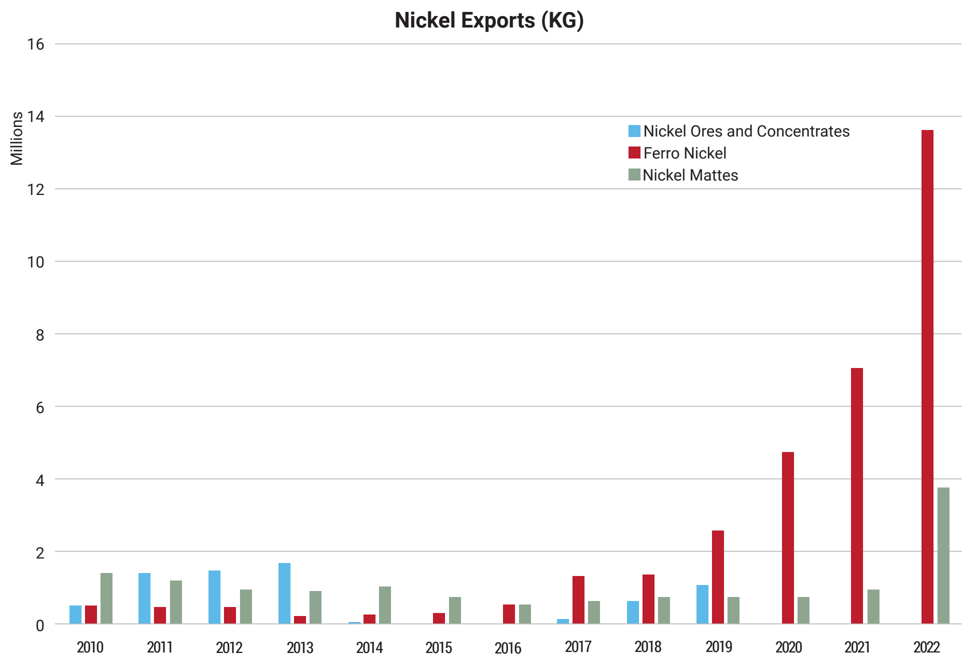


Figure 1: a. Nickel production by Indonesian mines since 1996 (note: 2016 omitted from Government data). Since the beginning of the push for local smelters and refineries in the mid-2010s, nickel mine production has grown by 800%.[11] **b**. Annual nickel exports (kg); **c**. Annual nickel exports (USD).[11]

As Indonesia has developed its refining capacity and generated a larger domestic supply of high-grade nickel from its nickel reserves, the central government has continued to search for ways to court foreign investment to harness its nickel reserves for EV battery production. Under PR55/2019, companies can only import BEV components provided existing plants do not manufacture an equivalent component. PR55/2019 further encourages domestic manufacturing by outlining strict local content requirements for all BEVs sold in Indonesia, as outlined in Table 1 for two-wheel and four-wheel vehicles.

TABLE 1: Local manufacturing content requirements outlined in Presidential Regulation 55/2019.

Year	2W EVs	4W EVs
2019	40%	35%
2020	40%	35%
2021	40%	35%
2022	40%	40%
2023	40%	40%
2024	60%	60%
2025	60%	60%
2026	80%	60%
2027	80%	60%
2028	80%	60%
2029	80%	60%
2030	80%	80%

The GOI has attempted to further encourage domestic use of its processed nickel resources by reducing tax incentives that had been previously provided for lower-quality nickel production, including nickel pig iron and second-class nickel ore processing products. Additionally, the GOI designated several nickel-rich regions as National Strategic Projects. Under this designation, industries operating within these regions have access to benefits outlined in Presidential Regulation No. 3/2016 as amended by Presidential Regulation No. 109/2020, and Government Regulation No. 142/2015 as amended by Minister of Industry Regulation No. 40/2016. Regional governments also have the authority to offer investment incentives and facilitation through local taxes and levies under Government Regulation No. 24 of 2019 (PP 24/2019). Currently, there is a notable absence of regional regulations specifically governing investment incentives and facilitation, including those aimed at nickel processing and refining. To address this regulatory gap, regional governments could establish comprehensive frameworks for granting incentives, including potential reductions or exemptions on local taxes and levies for the mining and mineral processing sectors. Several regions have taken proactive steps in this direction, establishing general regulations on regional investment incentives and facilitation, including through Jambi Province Provincial Regulation No. 3/2022 and Klaten Regency Regulation No. 2/2022.

These changes combined with the export restrictions have resulted in substantial growth in domestic refinement capacity, with Indonesia constructing 60 new nickel smelteries since 2016.[4] The nickel export bans and local content production requirements have brought billions of dollars in investments to the archipelago, as many automotive manufacturers have begun building up production capacity in Indonesia (Table 2). In 2022, Chinese companies including Ningbo Brunp Contemporary, Zhejiang Huayou Cobalt, Sunwoda Electronic, and Zhejiang Weiming invested in nickel smelting and mining projects (Table 2). Other companies, including Britishvolt and Porsche, also secured footholds in the growing Indonesian nickel industry (Table 2).

To take advantage of the increased domestic nickel production, the GOI has been courting investment from global EV and EV battery manufacturers in the hope of securing Indonesia's vast nickel reserves at the center of the developing battery industry. Since beginning the electrification push with PR55/2019, the GOI has seen tremendous success at attracting foreign investment, securing production commitments and breaking ground on several EV and EV battery plants in conjunction with some of the largest global automotive manufacturers, including Hyundai and Toyota (Table 2). Indonesia has secured over $30 billion in foreign investment and commitments since 2019 and continues to negotiate with large EV manufacturers such as Tesla to continue to expand its domestic EV manufacturing capacity, with the goal of producing 600,000 EVs by 2030.[4]

The investment landscape remains fluid, however, as global critical mineral supply options change. For instance, despite BASF's initial plan for a $2.6 billion investment (listed in Table 2) in a refining project for battery grade nickel in resource-rich Weda Bay, North Maluku, the company backed out of the deal in June 2024, citing "near-term oversupply in the nickel market."[16]

Despite the unrefined nickel export restrictions, local content requirements, and the success in securing foreign investment, the GOI has not seen the desired growth rate in local EV manufacturing necessary to meet that goal of 600,000 units by 2030. As a result, the GOI has continued to move the goalposts, delaying full implementation of local content requirements and allowing for EVs to be imported into the country. At the end of 2023, the GOI announced that it would remove import duties and luxury goods taxes on imported EV vehicles while also granting tax incentives until 2025 on imports of completely built-up EVs to automakers providing that they commit to building EV plants.[17] The newly relaxed regulations also extended the deadline from 2023 to 2026 for attaining the required 40% minimum domestic content and delayed the 60% local content threshold increase from 2024 to 2027.[18] These policy changes were implemented to attract further foreign EV manufacturing investment and encourage automotive manufacturers to use Indonesia as a base from which to expand their EV production. When discussing these new EV policy changes at a webinar on Indonesia's economic prospects, Rachmat Kaimuddin, the Deputy Coordinating Minister of Maritime Affairs and Investment for Infrastructure and Transport Coordination and Chief of Indonesia's National Energy Taskforce, said the new decree would help automakers build their market in the country through EV imports. "We try to be progressive, because once we have created an EV industry in Indonesia, the battery [industry] will also come, and we already have the [raw] material and can create the supply chain".[17] While production has lagged behind the original goals, EV production has indeed expanded, with Indonesia producing 25,000 EVs in the past two years. Additionally, with multiple production facilities in the works and scheduled to start production in the coming years (Table 2), the GOI may be making steady progress, albeit slowly, toward increasing its production goals and becoming an EV manufacturing hub in Southeast Asia.

Since the initial nickel export restrictions in 2014, Indonesia has seen growth in both nickel production and the value of its nickel exports, which has been further bolstered by its attempts to develop a domestic EV manufacturing sector. The nickel bans encouraged foreign investment in the buildup of local refineries to allow Indonesia ostensibly to enjoy the benefits of the value added to their nickel resources. The GOI has been successful at courting investment from large battery manufacturing and EV manufacturing corporations since beginning their EV push five years ago, securing upwards of $30 billion in investments and commitments to aid in the establishment of Indonesia as a future EV manufacturing hub. However, the growth in EV production in recent years, and the pace of expansion raises doubts as to whether or not the GOI will meet the desired 2030 production targets.

It is important to note that much also depends on trends in global investment and trade in nickel, electric batteries, and EVs, as well as investor strategies. According to the Energy Shift Institute (ESI), despite Indonesia's boom in nickel production, it still only accounts for 0.4% of global battery manufacturing capacity, and global overcapacity may signal difficulty for Indonesia

TABLE 2: Foreign investment in Indonesian EV and battery manufacturing.[4,12–15]

Company	Nationality	Investment	Purpose	Year
CATL	China	$6 billion	To develop a battery project including battery recycling and critical mineral mining alongside Aneka Tambang (Indonesia) and Indonesian Battery	2022
Foxconn	Taiwan	$1.7 billion	To manufacture EVs and EV batteries, expand regional business activities, and strengthen supply chain linkage ****Delayed**	2022
Gem	China	$500 million	To invest in a nickel project to provide access to critical minerals	2022
Hyundai	South Korea	$1.5 billion	To expand a BEV and EV manufacturing plant and launch an EV charging network	2022
Hyundai Mobis	South Korea	$60 million	To manufacture battery systems for flagship EV models	2022
Mitsubishi	Japan	$667 million	To produce EVs and batteries	2022
Toyota	Japan	$1.8 billion	EV production	2022
BASF	Germany	$2.6 billion	To develop a battery plant in North Maluku ****Canceled**	2023
Eramet and BASF	France and Germany	$2.6 billion	To develop an HPAL complex to manufacture EV batteries and EVs ****Canceled**	2023
Glencore, Envision, and Umicore	Britain, Switzerland, and Belgium	$9 billion	To invest in mining and EV battery production	2023
LG Energy	South Korea	$3.5 billion	To create a smelting facility to produce nickel sulfate	2023
LG Energy Solutions	South Korea	$1.1 billion $3.5 billion $2.4 billion	Alongside Hyundai Motor, to develop integrated EV battery facilities through a $9.8 billion deal To construct a smelter to produce nickel sulfate To build a factory for production of battery precursors and cathodes	2023
Mitsubishi Motors	Japan	$375 million	To expand EV production	2023
Posco	South Korea	$400 million	To build a nickel smelting plant and increase capacity for intermediate materials for EV batteries. Plant expected in 2025.	2023
Vale, Zhejiang Huayou Cobalt, Ford Motor	Brazil, China, USA	$4.5 billion	Sign agreement to build a hydroxide precipitate plant in Southeast Sulawesi; production capacity to produce 120,000 tons of hydroxide precipitate.	2023
VinFast	Vietnam	$1.2 billion	To build an EV manufacturing facility	2023
BTR New Material Group and Stellar Investment	China and Singapore	$478 million $299 million	To build a plant to produce anode materials for EV batteries Phase two expansion to double capacity	2024
BYD	China	$1.5 billion	Plan to build a production facility in 2024 with a production capacity of 150,000 units per year ****Note that BYD's models do not use nickel-based batteries**	2024
Gotion and REPT Battero Energy Co LTD	Singapore	$1 billion	To invest in the battery sector and solar panel supply chain and produce LFP and Nickel/Manganese/Cobalt batteries	2024
Hyundai and LG	South Korea	$1.1 billion	A joint lithium battery plant is expected to begin production in 2024 with a production capacity of 10 GWh of batteries	2024

in achieving the added value to nickel production that the GOI has sought. Furthermore, "nearly all" recent investment plans by foreign investors in Indonesia "stopped short of building battery manufacturing capacity, opting to make intermediate nickel products instead that would supply their EV manufacturing" [19]. As ESI notes, around three quarters of intermediate nickel exports are destined for the stainless steel production, primarily in China. Nickel production and processing capacity growth has not translated into a boom in battery production in Indonesia, thus far truncating the nickel-to-batteries-to-EVs value-added supply chain the country has aspired to develop.

Goal 2: Create incentives to encourage domestic adoption of electric vehicles

Alongside efforts to expand manufacturing investment, the GOI has also prioritized the promotion of widespread domestic adoption of EVs. Shortly after PR55/2019, the GOI announced its goal of having two million electric cars and 13 million electric motorcycles on the road by 2030, of which 600,000 would be manufactured in-country.[7] This goal was and still is seen as highly ambitious, as at the time of PR55/2019's introduction, Indonesia had only sold 21 PHEVs and no BEVs and to date has produced 25,000 BEVs, all in the last two years.[20]

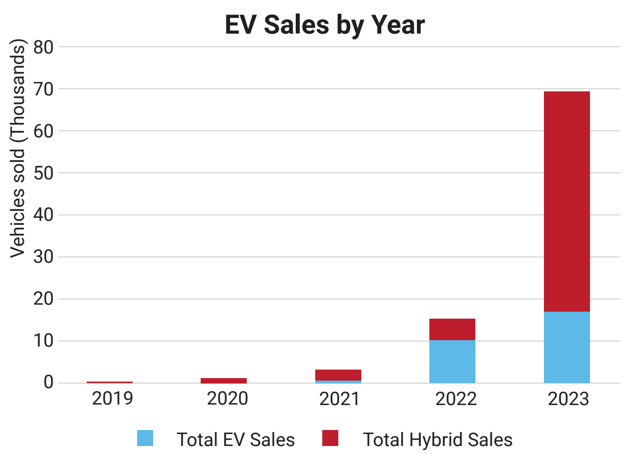
To meet the goals outlined in PR55/2019, several government agencies have introduced initiatives over the past five years to encourage domestic adoption of EVs and address the underlying barriers to adoption in Indonesia, among which is the prohibitive cost of purchasing a BEV. For context, as of 2020, the cheapest electric vehicle available in Indonesia cost USD 30,700, while the country's per capita income was USD 3,670 for the same year.[21] A new gas-powered Honda Brio, by comparison, costs roughly USD 9,900, or about three times less than a BEV.[22] This substantial discrepancy renders BEVs unaffordable for the majority of low-income and middle-class households without government subsidies or other interventions to make BEVs more cost-competitive.

To address these cost barriers and lower the prices of EVs for consumers, the GOI has adopted two strategies: reducing the tax placed on EV purchases and lowering the cost of EVs through government-issued subsidies. The first such program was introduced in October 2021 through Government Regulation No. 74/2021. This regulation exempted certain BEVs from the sales tax levied on luxury goods. It also aims to incentivize local manufacturing by linking the exemption to the level of local content in the BEV. In April 2023, taxes placed on BEVs were further reduced when the Ministry of Finance introduced Regulation No. 38/2023, followed in May by Permendagri No. 6 of 2023, which eliminated all vehicle taxes (Pajak Kendaraan Bermotor) for BEVs. This regulation enabled a value-added tax (VAT) reduction on BEVs until the end of 2023. Similar to the previous tax cut, this regulation also tied tax benefits to the local content of the eligible vehicles. The reduction provides a 10% VAT reduction for cars and buses with a minimum of 40% local content and a 5% VAT reduction for those with at least 20% local content but less than 40%. This has had the effect of nearly removing the VAT from certain EV purchases and has been linked to an immediate jump in sales of EVs meeting the local content requirements immediately following the regulation. The Hyundai IONIQ 5 vehicle saw its sales jump threefold to 600 units in April 2023 following the tax reduction and the Wuling Air EV, also eligible, saw a monthly sales increase of 80% immediately following the tax cut.[23] Additionally, to expand EV adoption beyond private consumers, Presidential Instruction 7/2022 directed agencies, ministries, and local governments to transition to EV use for their operations, mandating fleet growth.

The most substantial incentives to generate demand for two-wheeled electric vehicles (2WEVs) emerged in 2023 with the introduction of two government programs designed to encourage consumers to choose a 2WEV over a motorcycle or scooter: the Ministry of Industry (MOI)'s Regulation No. 6/2023 and its expansion under MOI Regulation No. 21/2023. These two regulations outline government assistance for the purchase of 2WEVs, offering a subsidy of USD 440 for the purchase of 200,000 2WEVs for fiscal year 2023 and 600,000 units for fiscal year 2024. These discounts are available to any Indonesian citizen over 17 years of age possessing an electronic identification card and applies the subsidy to the purchase of any 2WEV with a local manufacturing content of 40% or more. The government is also working to make its existing motorcycles more environmentally friendly through a motorcycle conversion program. MEMR Regulation No. 3/2023 outlines a government assistance program to provide for the conversion of gas-powered internal combustion motorbikes into battery-powered electric motorbikes. This program provides discounts and subsidies for the purchase of the components required for electric conversion and provides a USD 440 discount to motorbike shops offering the conversion service to support their purchase of parts. The budget for this program provides for the conversion of 50,000 units in 2023 and a maximum of 150,000 units in 2024.

While the GOI has enacted several policies in line with Goal 2 over the past five years, these policies have achieved mixed success. BEV and overall EV sales have increased significantly following the EV push, with 17,000 EVs and 52,000 hybrids sold in 2023 (Figure 3). However, these figures fall short of the ambitious target of 2.2 million EVs on the road by 2030 set by the GOI in 2021. In order to meet this goal, EV sales would have to increase 31-fold over the next six years. If this goal is to be accomplished, the GOI must continue to incentivize the purchase of EVs to make them cost-competitive with ICEVs.

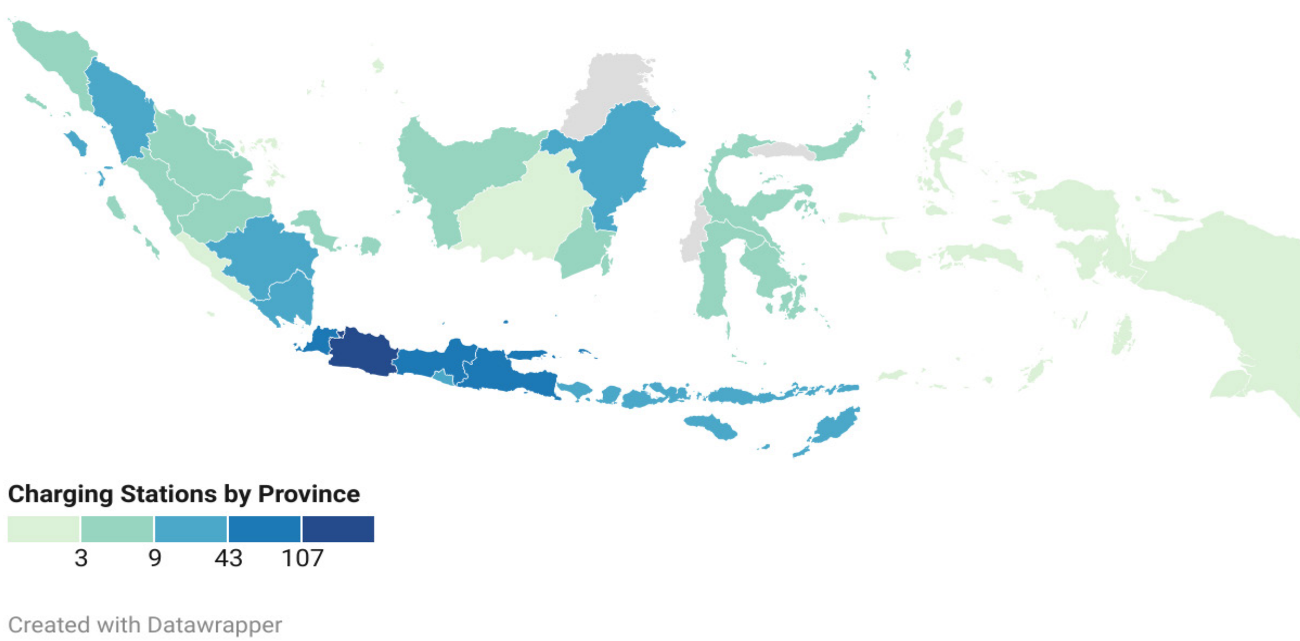
FIGURE 3: Annual EV sales[20]



Goals 3/4: Facilitate the buildup of infrastructure to support widespread EV adoption/Create technical standards for the testing and manufacture of EVs

The third goal outlined in PR55/2019 mandates that Perusahaan Listrik Negara (PLN), the state electricity company, build out national EV charging infrastructure, tasking the Ministry of Energy and Mineral Resources (MEMR) with outlining the technical requirements for this infrastructure. According to MEMR roadmaps, Indonesia will need approximately 32,000 EV charging stations (what Indonesia terms Sistem Pengisian Kendaraan Listrik Umum, or SPKLU) to support the two million EVs projected to be on the road by 2030. As of the end of 2023, however, only 440 charging stations across 328 locations and 960 battery swap stations exist nationwide, the majority of which are concentrated in Bali, West Java, and Jakarta, areas with the highest population density (Figure 4). To support the nationwide adoption of EVs and overcome public perception barriers such as range anxiety, the GOI must continue to support the buildup of EV charging stations to make this infrastructure accessible to the public at large. The GOI has not yet earmarked funds to enable large-scale EV infrastructure buildout. Even then, with public charging more expensive than home charging, charging costs at EV stations may be prohibitive for many consumers.[24] It is likely that Indonesia will need to get creative in overcoming these barriers in the country given the particular characteristics of the Indonesian market and the country's demographics. For example, one proposal suggests that lower infrastructure investment costs and potentially lower charging costs could be achieved by mobile charging stations accessible on-demand via an app.[25] PLN itself is mounting small charging stations (referred to as PLN EYE) on electricity poles to avoid the cost of full charging stations while increasing consumer access.[26] Limited infrastructure in general in more remote areas of the country suggests that nation-wide charging availability outside of urban areas is unlikely in the immediate future.

FIGURE 4: Distribution of EV charging stations[27–29]



The fourth goal of PR55 charged government ministries with creating the regulatory framework necessary for standardizing the technical specifications of EVs used in Indonesia. This provides a standard definition for what constitutes an EV, BEV, or 2WEV, as well as outlining the technical requirements for EV manufacture and charging. Ministry of Industry Regulation No. 27/2020 on Specification, Roadmap for Development, and Calculation of Local Content for BEV outlines specifications for electric motor usage and charging for BEVs. This regulation also outlines the methods used for determining local manufacturing content for BEVs, a crucial step for determining EV eligibility for the subsidies and tax relief programs later established.

Despite needing a projected 32,000 charging stations to support the targeted number of EVs on the road by 2030, Indonesia only had 624 operational charging stations by the end of 2023.[30] To meet the required infrastructure to support its EV goal, the GOI would need to construct 70 times more than the current number of charging stations. While the initial charging station rollout lags behind the infrastructure required for EV adoption, PLN appears to be taking steps to remedy this situation, with the goal of having 6,318 EV charging stations by 2025.[31] This level of infrastructure development requires the GOI to take significant steps to invest in and accelerate charging infrastructure construction to support the widespread adoption of EVs nationwide and/or create a better environment for the private sector to generate innovative approaches grounded in the realities of the Indonesian context. Further infrastructure construction could potentially incentivize further consumer adoption of EVs by alleviating range anxiety and charging cost concerns, and facilitating the continued shift from ICEVs to EVs in Indonesia, though returns from such initiatives may diminish after a certain level of investment.

Goal 5: To ensure the protection of the environment throughout

The global scramble by governments and investors for critical mineral resources and a market share of the EV supply chain suggests real economic promise for the industry in general. Nonetheless, the transition to electric vehicles is foremost a means for cutting global transportation emissions, meeting national emissions reductions commitments, and developing "green" economies. The EV transition does not come without environmental and social costs, however, and significant questions remain as to whether "downstreaming" broad EV supply chain development is indeed an emissions reducing and sustainable "green" solution for the Indonesian transportation sector.[32]

This section discusses whether Indonesia's pursuit of a robust EV industry will help or hinder its emissions reduction and sustainability goals by examining the environmental consequences of EV manufacturing in Indonesia. While this report primarily focuses on the national emissions ramifications of an EV industry in Indonesia, this is by no means the only point of concern when it comes to the sustainability of EV manufacturing in the country, which can ultimately belie the ostensible benefits of emissions reductions. The growth of mining and manufacturing involves inherent environmental and social challenges. These include marine and terrestrial pollution through byproduct disposal, deforestation and land use change for mining and factory buildup, biodiversity loss, and serious social inequities such as land grabbing, violent conflict, local livelihood losses, lack of transparency in mining data and policy decisions, and lack of consultation and prior informed consent with local and indigenous communities. These problems are all present in Indonesia [33]. Furthermore, smaller illegal mines often exist alongside larger legal mines, as seen in satellite imagery of areas such as Sulawesi or Maluku, often with no publicly available information about either of them.[34] To fully understand the impacts of the EV industry in Indonesia, these factors necessitate further transparency and further studies that fully consider local social and environmental impacts. Additionally, the numbers used for emissions estimates in the subsequent sections are rough estimates and exclude emissions from many key elements of the supply chain, such as the transport of raw materials and transportation emissions inherent to international trade and shipping. Increasing land use change emissions from the mining sector (discussed in this report, although such emissions are not quantified here) further complicates Indonesia's ability to achieve its emissions reduction targets. And, of course, refining and manufacturing require large amounts of energy and, thus far, that energy is provided by coal plants, often captive plants constructed for that specific purpose. Any emissions estimates excluding land use change and transportation emissions should be treated as underestimates, with more research needed to understand the full emissions and sustainability implications of an Indonesia-based EV manufacturing industry.

Challenges in Nickel Mining Emissions Quantification

Indonesia's nickel reserves are primarily lateritic (high in iron oxide), which is best used to produce class II nickel products. These are of a lower purity grade and are used in stainless steel products.[35] While oxidic ore deposits are generally less energy-intensive to extract compared with sulfidic ores, the refining and processing of these ores into usable forms of nickel requires a significant amount of energy and therefore generates higher downstream emissions.[36] Fluctuations in the energy input requirements for extracting nickel ores result in difficulty estimating the carbon footprint of a given electric vehicle as the emissions involved in extraction can vary greatly.

The primary extraction method for lateritic nickel, and therefore the primary mining technique employed in Indonesia, is open-pit mining whereby minerals are extracted from the earth through a large open-air pit, in contrast to underground nickel mining.[37] Nickel laterite ore deposits, in contrast to sulfidic nickel, are found near the land surface with open-pit mining typically requiring large-scale excavations of the earth. As such, mining tends to expand horizontally with surface defacement spreading as mineral extraction deepens.[38, 39] Nickel mining therefore results in significant land conversion in Indonesia and is expected to increase. Between 1990 and 2010, the area of land-use change associated with nickel mining increased by a factor of 2.3, following rising demand for laterite ores.[40] Given the lower density of nickel in these ores, however, the quantity of extracted nickel increased only by a factor of 1.8, suggesting that the area of land use change per ton of nickel produced will steadily grow as the market turns increasingly towards laterite ores for its nickel supply.[37] One projection sees the direct land conversion footprint of nickel doubling between 2020 and 2026 to more than 800 km^2, especially given limited efforts at land remediation (less than 1% of direct land use change).[41] Indeed, after several years of declining deforestation rates in Indonesia, deforestation spiked dramatically last year, due in part to rapidly expanding mining operations.[42]

While the emissions focus tends to center on energy use, land use change from expanding nickel mining is increasing CO_2 emissions (while destroying natural ecosystems, generating pollution, and causing erosion and coastal sedimentation). Given rapid surface mining expansion in Indonesia, any accurate and comprehensive quantification of nickel industry emissions must measure and incorporate land use change emissions.

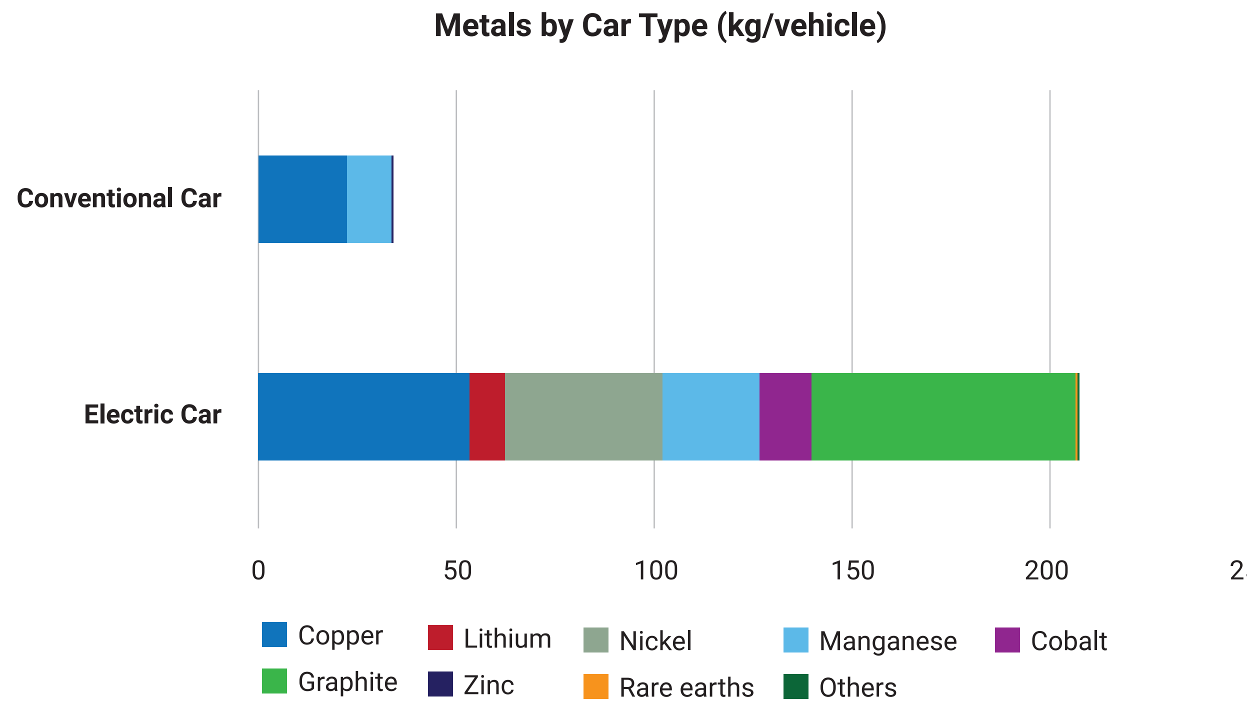
Emissions Consequences of Nickel Refinement in Indonesia

Nickel laterite ore processing is accomplished through three main methods: high-pressure acid leaching (HPAL), ferronickel, and direct nickel process.[43] HPAL is the process of greatest environmental concern for EV battery manufacturing in Indonesia.[44] HPAL refinement is energy- and emissions-intensive relative to sulfidic nickel ore processing.[45] The energy requirements to produce one ton of nickel from laterite nickel ores can be quite intensive. Researchers found that the Sorowako mine in Indonesia required 454 gigajoules of energy to extract one ton of nickel product from the laterite ores passed through the process (GJ/t). By comparison, refining sulfide nickel ores requires fewer than 100 GJ/t using traditional smelting methods.[46] Increased energy requirements combined with the emissions produced through the HPAL process beget a large carbon footprint for the nickel used in battery manufacturing.[47] One analysis of the life cycle emissions of nickel produced using HPAL found that the equivalent of roughly 54 tons of CO_2 was emitted for every ton of nickel produced.[43] Nickel processing alone involves significant global warming consequences that should be considered when promoting the growth of the mining sector and battery manufacturing in Indonesia.

Emissions Consequences of Other EV Battery Minerals

When comparing the environmental impact of EVs and ICEVs, the most important raw materials to consider are the minerals used in EV battery technology. Steel, aluminum, and other materials used to construct the frame and interior of the vehicles are largely the same across vehicle types. In addition to nickel, the minerals used in EV batteries include copper, lithium, manganese, cobalt, and graphite.[36] Figure 5 shows a breakdown of the quantities of each mineral used per vehicle. The electric car examined for this study is based on a 75 kWh nickel manganese cobalt battery utilizing a 6:2:2 ratio of minerals for the cathode.[36] For the carbon calculation in this paper, the emissions produced by mining and refinement of the aforementioned minerals are as follows: 4.15 kg CO_2e/kg Cu,[48] 15 kg CO_2e/kg Li,[49] 54 kg CO_2e/kg Ni,[50] 6 kg CO_2e/kg Mn,[51] 17 kg CO_2e/kg graphite.[52] The supply of cobalt is largely derived from the processing of laterite nickel, so emissions occurring in cobalt production are captured in the estimate for nickel.[43] Using the estimates for the number of materials used in EVs found in Figure 5, the mining

FIGURE 5: The quantities of minerals used in the manufacturing of EVs vs. the manufacturing of ICEVs. Retrieved from (IEA, 2021).



and extraction of the minerals required to produce an EV result in roughly 3,800 $kgCO_2e$/unit.

Emissions Consequences of Battery Manufacturing

The emissions produced through the manufacturing of a battery vary widely depending on the manufacturing location and the energy makeup of the regional electric grid.[53] As such, a life cycle analysis of the carbon footprint underlying EVs based on emissions estimates from the United States or China, for example, is not comparable to the emissions produced from a battery manufactured in Indonesia.[53] While there is some variation among studies on the energy input required to manufacture a battery, the energy usage for a large-scale battery cell factory is generally estimated to be around 50-65 kWh to produce a single kWh of battery capacity.[54] For this study, we consider a BEV battery to have a capacity of between 60-100 kWh, meaning that producing a battery at a large-scale plant requires between 3,000-6,500 kWh of energy input. According to the Institute for Global Environmental Strategies (IGES), the Indonesian electrical grid has a grid emission factor of 0.813 $kgCO_2$/kWh.[55] Under the current Indonesian grid, an EV battery manufactured in Indonesia would result in between 2,439-5,284.5 $kgCO_2e$ (2.4-5.3 tCO_2e).[56] This brings the total emissions involved in producing an EV in Indonesia to roughly 6,300-9,100 $kgCO_2e$/unit. This range is consistent with research on EV manufacturing in China, which finds that CO_2 emissions from EV production range from 14.6-14.7 tCO_2/unit, around 60% higher than the level of emissions produced by the production of an ICEV, 9.2 tCO_2/unit.[56] While significant, as EV battery technology advances and more energy-efficient manufacturing processes are developed, this number is expected to decrease.[53] Additionally, as Indonesia switches from its predominantly fossil fuel and coal-based energy grid to renewable energy sources, overall energy consumption emissions should decrease.

Potential Emissions Reductions Through EV Adoption

In light of emissions generated from manufacturing, EV emissions during daily use will have to be significantly lower than those of ICEVs if EVs are to be the sustainable alternative. A typical electric vehicle with a battery capacity of around 60 kWh has a combined city/highway range of 354 kilometers on a full charge, a distance that can fluctuate depending on the kinds of driving activity.[57] If the full charge is used, a battery consumes 60 kWh of power to fully recharge, which, based on the current grid emission factor in Indonesia, results in 48.75 kg of CO_2 emissions, or about 137.7 grams of CO_2 per kilometer of travel.[55] This level of emissions during day-to-day travel is higher than other estimates for global EV usage due to the relatively low level of renewable energy powering the Indonesian grid. By comparison, the popular Honda Brio, the number-one-selling passenger car in Indonesia, delivers a combined mileage of 19.4 km/liter.[22] According to the U.S. Environmental Protection Agency, most internal combustion engines produce 2.3 kg of CO_2 per liter of gasoline consumed.[57] Based on these numbers, the Honda Brio produces roughly 118 grams of CO_2 per kilometer of travel. Given the current energy makeup of the Indonesian grid, with its heavy reliance on high-carbon energy sources such as coal, the emissions generated from battery charging exceed those generated by the day-to-day travel of an ICEV. As such, under the current power system in Indonesia, EVs emit more over their lifetime than a typical compact ICEV sold in Indonesia. For EVs to reduce their carbon footprint in Indonesia, the grid on which they are charged must have a higher proportion of clean energy sources. Additionally, the emissions estimates in this report are likely an underestimate, as the report omits the emissions contributions from the transportation of materials and finished products and the emissions resulting from land use change, further necessitating the need for Indonesia to aggressively pursue cleaner energy sources to realize the emissions reduction potential of EVs.

Takeaways Regarding Environmental Sustainability of EVs

Creating a minerals-to-batteries-to-vehicles industry holds both promise and peril for Indonesia as it looks to become a prominent actor in the global market while drawing down on carbon emissions. The country certainly holds vast quantities of the natural resources necessary for the manufacture of EVs and batteries, particularly nickel. The growth of the EV industry and market is a priority in Indonesia that will continue with the new president. Electrification of the transportation sector should, in principle, help decarbonize Indonesia in line with its Nationally Determined Contributions (NDCs) under the Paris Agreement. Although it might be tempting to generalize impact assessments across the industry, environmental outcomes of EV development can vary widely from country to country.[58] Life cycle analyses of the EV carbon footprint in other countries cannot be assumed to be analogous to the unique complexity of the Indonesian case. Under current conditions, the growth of nickel mining and battery manufacturing in Indonesia threatens to escalate its carbon emissions, creating a situation in which EVs manufactured and used in Indonesia emit more CO_2 over their lifetimes than traditional compact ICEVs. IEEFA estimates that four major Indonesian nickel mining companies (three of which are powered by coal and the fourth by hydropower), projected to double production over the next few years, could alone generate a further 39 mt of GHG emissions by 2028, which amounts to roughly 5% of Indonesia's total GHG emissions.[59]

Downstreaming the electric vehicle supply chain while lowering emissions requires that investments be made to decrease the high-emissions energy involved in refinement and manufacturing. Without an accelerated transition to clean, renewable energy sources in Indonesia, EVs will not be an effective means of emissions reduction. Indonesia's reclassification of captive coal plants in the country's green investment taxonomy as low-carbon transition technology in cases where these plants provide energy to the nickel smelting and refining industry undermines emission reduction efforts and has been met with significant criticism.[60, 61] Presidential Decree 112/2022 still allows for the construction of new captive coal-fired power plants servicing "national strategic" needs, including the nickel sector,[62] and the growth of captive coal plant capacity over the past decade has exceeded that of the rest of the world by a factor of five. Moreover, Global Energy Monitor estimates that, as of 2022, nearly 25% of electricity generated in Indonesia was from captive coal plants, 76% of captive coal capacity powered the metals industry, and nickel smelters constituted 67% of captive coal power.[63] IEEFA has estimated that captive coal could amount to 52% of total coal-fired energy capacity in 2023. Coal continues to power nickel smelting and refining capacity growth.

Additionally, without cleaner energy sources for battery recharging, EVs will be unable to offset the high emissions resulting from the extraction and refinement of the minerals used in battery manufacturing. Caution about carbon emissions must temper economic optimism when discussing the development and implementation of EVs in Indonesia as any widespread EV adoption must also be accompanied by significant investments in clean, renewable energy technologies, the decarbonization of Indonesia's electric grid, and more sustainable mining and manufacturing processes.

Conclusion

Although Indonesia is the largest economy in ASEAN, the share of GDP of the country's manufacturing sector (just under 19% for 2023) has historically been lower than that of the other major economies of Asia, including fellow ASEAN members Malaysia, Thailand, and Vietnam. Resource-rich Indonesia has long sought to build a more robust value-added manufacturing base for its economy in order to transcend its historical role as a raw commodities export nation, an aspiration currently embodied in "Golden Indonesia 2045" and in Prabowo's desire to attain 8% annual GDP growth.[64] President Jokowi had explicitly formulated the objectives actuating the nickel ore export ban in terms of this historical aspiration (along with expected concrete gains in state tax revenue and, in theory, expanding skilled job opportunities for Indonesians).[65] This is the context in which the ambitions of Indonesian mining-battery-EV downstreaming arise.

Over the past five years, propelled by PR55/2019, Indonesia has intensified its efforts to develop a domestic EV industry and position itself as a global leader in EV production. The EV downstreaming aspirations outlined in PR55/2019 and framed by a subsequent series of trade and investment regulations have been met by a mix of challenges, setbacks, and successes. Through the GOI's suite of nickel ore export bans requiring value-added domestic ore processing and local manufacturing content commitments, Indonesia has leveraged its large reserves of nickel to secure billions of dollars worth of investments in refining and manufacturing and the prospective foundations of an EV supply chain while also trying to ensure that value added to its nickel resources occurs in Indonesia instead of overseas. Indeed, while nickel exports plummeted in terms of total quantity since 2019, the value of Indonesia's nickel exports has boomed (from about $8 billion USD in 2021 to nearly $20 billion USD in 2022), confirming the country's goal of transitioning from nickel ore exports to value-added exports. However, about two thirds of these value-added nickel exports is lower-grade ferronickel, of which 90% was exported to China for its steel industry in 2022.[9] Much of the downstream investment in Indonesia is from foreign companies; however, as noted above, at least two — BASF and Eramet — have recently canceled a $2.6 billion USD investment agreement in the face of what is currently a global oversupply of nickel. Despite government pronouncements that Indonesia will become the largest EV battery manufacturer in the world within the next three years, battery production capacity in Indonesia this year comprises a mere 0.4% of global capacity.[19] Furthermore, EV battery manufacturing investments in Indonesia are not necessarily coupled with value-added Indonesian nickel. The Chinese conglomerate BYD, the largest BEV and PHEV manufacturer in the world,[66] this year announced a $1.6 billion investment in construction of an electric vehicle plant in West Java.[67] BYD's EV models, however, use lithium iron phosphate (LFP) batteries, not nickel, manganese, and cobalt (NMC) batteries. LFP batteries could surpass NMC batteries by 2028 in the global market. While investment may be viewed as generally robust, that in itself does not necessarily confirm Indonesia's nickel-battery-EV downstreaming narrative.

Indonesia's goal of capturing a significant part of the global market for nickel and EV batteries must also be placed in the context of global trade trends. The surge of growing demand and investment is from the European Union and the United States (both of which, incidentally, have challenged Indonesia's nickel export ban as a violation of WTO obligations).[9] Especially as the U.S. and Europe continue to tighten environmental and emissions standards for imports, that demand will come with sustainability requirements (sometimes known as ESG, or Environment, Social, and Governance, investment principles).[19] Given the environmental, social, labor practice, and governance shortcomings in Indonesia's mining and downstreaming efforts, there is a risk that Indonesia's anticipated role in the global EV supply chain market will not materialize without significant ESG improvements in mining, refining processes, and battery manufacturing. Although there are plans by Bappenas, the National Development Planning Agency, in partnership with the World Resources Institute, to launch a nickel decarbonization and ESG roadmap next year as part of Indonesia's 2025-2029 National Medium-Term Development Plan,[68] deferring action on robust ESG and emissions reduction targets into the indefinite future could simply come too late for both Indonesia's ambitions in the global market and its climate obligations.

Domestically, investment in Indonesian EV manufacturing has helped the nation to produce tens of thousands of BEVs in recent years, representing a significant change in manufacturing capability from just five years ago. EV sales have grown over that same time period, helping Indonesia to slowly electrify its transportation sector. However, these advances come with a major caveat as they still trail well behind Indonesia's original production targets. Indonesia currently lacks the necessary infrastructure to support the widespread adoption of EVs and must increase its charging station capacity in order to bolster domestic demand. Furthermore, the GOI must continue to incentivize the purchase of EVs to ensure that prices are competitive with cheaper, fuel-efficient ICEV alternatives already popular in Indonesia.

If Indonesia is to use the domestic adoption of EVs as a means of reducing its overall carbon emissions and meeting its commitments under the Paris Climate Accords, it must prioritize the phase-out of coal power plants and the transition to cleaner, renewable forms of energy while also investing in less energy-intensive means of metal refinement and battery manufacturing. Without these steps, Indonesia cannot take advantage of the emissions reduction potential of widespread EV adoption and could even see an increase in overall emissions while incurring deep social and environmental costs.

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