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Carbon Accounting as a Strategic Signal: Evaluating Emission Disclosure and Economic Resilience in Indonesia's Nickel Downstream Industry

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Abstract. Industrialization and downstream processing (particularly nickel processing) for economic transformation provide an important direction for developing global economic resilience; yet this is costly as smelting operations carry a high carbon burden. This study examines the carbon accounting system and the quality of emission disclosures in Indonesian integrated nickel processing industries. Drawing on legitimacy and stakeholder theories, the study assesses how firms perceive, estimate, and disclose their carbon footprint to demonstrate environmental responsibility and market adaptability. The method focuses on qualitative research, using content analysis of sustainability reports from listed nickel companies over 2022–2024. We find that although technical problems continue to arise when applying carbon accounting to the operational information of smelters, proactive emissions disclosure is a strategic "green signal" that adds corporate value and opens up access to global EV supply chains. This investigation offers policy implications for developers focusing on carbon reporting to reduce 'dirty' nickel perceptions. From a theoretical standpoint, the research strengthens the case for sustainability accounting in the context of a transparent and competitive industrial structure of the low-carbon global market.

Keywords: Carbon Accounting, Emission Disclosure, Nickel Downstreaming, Sustainability Accounting, EV Supply Chain

I. Introduction

Today, the global climate crisis has transformed the paradigm of businesses, and environmental sustainability has become a primary indicator of corporate performance (Borghei, 2021). Pressure from global investors and international regulations, such as the Carbon Border Adjustment Mechanism (CBAM), requires complete transparency of a company's carbon footprint (Li et al., 2024). In such a context, accounting is no longer simply a mechanism for recording financial transactions — it has become a strategic tool with carbon accounting as a tool; an accounting strategy (He et al., 2022). Carbon accounting is central to ensuring the systematic measurement, reporting, and evaluation of greenhouse gas emissions across companies, which affects the decision-making processes of individual stakeholders in a green economy (Luo & Tang, 2021). Moreover, it is fundamental for measuring, reporting, and managing greenhouse gas (GHG) emissions across industries, including nickel production and EV supply chains. This can also help to locate carbon-intensive areas and facilitate interventions against the carbon footprint and to implement solutions by organizations (Brohé, 2017; Csutora & Harangozo, 2017; Patro et al., 2025). Nevertheless, emissions disclosure is subject to significant effects of company governance, market value, and legal frameworks. For instance, firms with stronger environmental scores or sustainability profiles are more likely to report emissions (Córdova Román et al., 2021; Dharma et al., 2024).

In this regard, Indonesia, with the world's biggest nickel reserves, is currently in a structural change of its economy due to a large nickel downstream processing policy. To increase the resilience of the country's economy, this policy targets the production of nickel ore into premium products such as ferronickel, mixed hydroxide precipitate (MHP), and electric vehicle battery components. But its making process is energy- and emissions-intensive, especially during extraction and refining (Bartzas et al., 2021; Battaia et al., 2024; Mistry et al., 2016). Moreover, the growth of nickel smelters inherently drives up the energy demand, especially as coal-fired power plants produce high carbon emissions. He et al. (2022) emphasize that integrated manufacturing activities are often associated with the most significant emissions in the global supply chain. Thus, the progress of nickel downstreaming in Indonesia is analyzed not only through the growth of economic output but also judged in the industry's productivity versus Net Zero Emission targets.

Despite the established demand for sustainability, the practice of carbon accounting in Indonesia's downstream industry poses complex real-world issues. One of its biggest barriers is the uncertainty of the domestic regulatory environment, where the carbon tax has been delayed repeatedly from its original

schedule. It causes a speculative environment and no motivation for companies to incorporate emission information into formal accounting information systems. Córdova Román et al. (2021); Miah et al.(2021) have shown that many emerging market companies are limited in carbon disclosure, considering the absence of binding reporting standards and the high price of emission monitoring technology. In the absence of a transparent carbon accounting mechanism amidst regulatory uncertainty, the Indonesian nickel industry will be at risk of losing competitiveness in international markets and facing difficulties in accessing green financing.

This study addresses this gap and contributes to the literature by examining the adoption of carbon accounting and the transparency of emission disclosure in the integrated nickel processing industry in Indonesia. This paper uses legitimacy theory and stakeholder theory to assess the degree to which existing carbon accounting practices meet the demands of environmental accountability that emerge in complex and fast-moving regulatory environments. This research is intended to provide recommendations for policymakers and corporate leaders to develop a competitive and sustainable carbon reporting framework for downstream industry integration in the global market.

II. Literature Review

Legitimacy theory is still a central lens that has been utilized by carbon accounting researchers to reveal that firms disclose environmental data to align with societal expectations. Nowadays, legitimacy is not just a social compact but a "license to operate" in the global market; for the Indonesian nickel industry, one that was subjected to heavy scrutiny due to the smelter's high-carbon intensity. Borghei (2021) suggests that carbon disclosure serves as a defensive mechanism to bridge the legitimacy gap created by industrial expansion. Furthermore, Berradia (2026) suggests that, in emerging markets, companies adopt sustainability reporting to deal with the perceived bad image of heavy industrial activities, implying that carbon accounting is a tool for social survival.

Stakeholder theory explains that firms need to meet the needs of powerful actors, such as international electric vehicle manufacturers and green creditors. Luo & Tang (2021) observed that high-quality carbon accounting is strongly influenced by the "power" of creditors and international customers, who call for standardized emission data. For example, stakeholders in the nickel field, e.g., the European Union (via CBAM), are forcing Indonesian firms to implement transparent measurement systems. Sari et al. (2025) demonstrate that in the Indonesian manufacturing context, stakeholder engagement through transparent ESG reporting correlates directly with long-term resilience in firms and increased access to sustainable financing.

A blending of these theories leads to carbon accounting as an enabling mechanism for value addition. Recent empirical data, Liu & Yaacob (2025) suggest that high-quality carbon accounting reduces "information asymmetry," which should improve corporate governance. Even in countries where carbon taxes lag — like Indonesia— proactive disclosure indicates future preparedness as a "signal". Berradia (2026) provided evidence that firms that have robust carbon accounting frameworks achieve stronger market valuations because, during the global transition to a low-carbon economy, firms are viewed as lower-risk investments.

Figure 1. Theoretical Framework

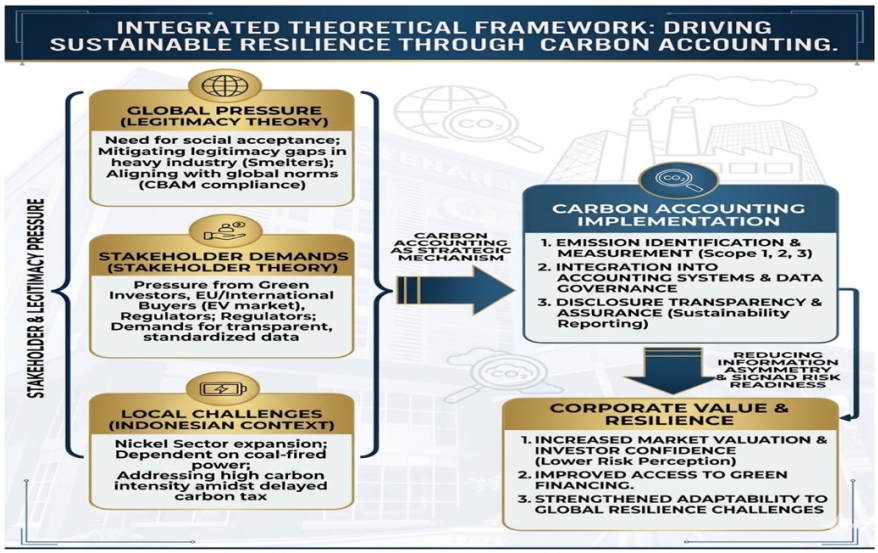

Figure 1 presents a conceptual framework depicting the strategic relationship between external pressures, internal accounting practices, and long-term corporate outcomes in the nickel downstream industry. First, Stakeholder & Legitimacy Pressure (Input): This represents the external drivers that compel a company to address its carbon footprint. They include pressures from green investors (e.g., sustainable funds), stringent international regulations such as the Carbon Border Adjustment Mechanism (CBAM), and societal demands for environmentally responsible nickel smelter operations. These pressures result in corporate management taking proactive measures with formal monitoring and recording systems.

Second, Carbon Accounting Implementation (Process/Core Variable): at a primary level, it is about measuring emissions—Scope 1, 2, and 3—then placing estimates on how much "carbon" they represent as costs, and then making this available transparently in Sustainability Reports. The establishment of carbon accounting is a strategic "positive signal" to world markets: the company takes steps to help mitigate its impact on the climate. Third, Corporate Value & Resilience (Output): This represents the outcome of the framework. Transparent disclosure helps ensure that there is no information asymmetry or perceived environmental risks, all of which boost investor confidence and increase the company's market value. Moreover, it makes facilitating green financing easier and ultimately enhances the company's long-term business resilience against global economic and environmental challenges.

III. Research Method

This study employs a qualitative descriptive method with a content analysis approach. This method is selected to systematically evaluate the quality and extent of carbon accounting disclosures within the sustainability reports of integrated nickel companies. According to Krippendorff (2019), content analysis allows researchers to make replicable and valid inferences from texts to the contexts of their use, making it ideal for examining environmental transparency.

The sources of data for this study are mainly secondary data, such as annual reports and sustainability reports of integrated nickel processing companies listed on the Indonesia Stock Exchange (IDX) or those undertaking major smelter projects. The sampling period covers 2022–2024 to capture the most recent reporting trends amidst global sustainability pressures. The period from 2022 to 2024 marks the first widespread adoption of standardized frameworks like the ISSB (International Sustainability Standards Board) and updated GRI standards, which were designed to improve data comparability (Cumbana & Ventura, 2025). Purposive sampling is adopted according to the following criteria:

1. The company is actively involved in downstream nickel processing (ferronickel, MHP, battery components, etc.).
2. The company has published a sustainability report or a dedicated ESG disclosure.
3. The company operates within Indonesian jurisdiction.

Table 1. Research Sample and Data Sources

No	Company Name	Stock Code	Main Business Activity (Downstream Focus)	Data Source
1	PT Vale Indonesia Tbk	INCO	Integrated Nickel Mining & Smelting (Matte Nickel)	Sustainability Report
2	PT Aneka Tambang Tbk	ANTM	Integrated Mining & Ferronickel Production	Sustainability Report
3	PT Trimegah Bangun Persada Tbk	NCKL	HPAL & RKEF Smelting (Nickel Sulfate for EV Batteries)	Sustainability Report
4	PT Merdeka Battery Materials Tbk	MBMA	Nickel Assets for Electric Vehicle Battery Supply Chain	Annual Report & Sustainability Report
5	PT Central Omega Resources Tbk	DKFT	Ferro-Nickel Smelting Operations	Annual Report & Sustainability Report
6	PT Merdeka Copper Gold Tbk	MDKA	Parent company of MBMA; manages major nickel assets and acid iron metal projects.	Sustainability Report
7	PT Harum Energy Tbk	HRUM	Aggressively diversifying into nickel mining and smelting (Inalum & Westrong projects).	Annual Report & Sustainability Report
8	PT United Tractors Tbk	UNTR	Diversified into nickel via acquisition of Nickel Industries Limited and smelter interests.	Sustainability Report & ESG Disclosure
9	PT Resource Alam Indonesia Tbk	KGGI	Diversified into nickel	Sustainability Report

Table 1 lists the chosen samples, which are the crux of the Indonesian nickel downstream industry, from state-owned enterprises (ANTM) through the major private companies (INCO, NCKL). These

companies are publicly listed on the Indonesia Stock Exchange (IDX), and thus their Sustainability Reports are prepared in accordance with OJK Regulation (POJK No. 51/2017) and international standards like GRI. This transparency is vital for providing reliable carbon-emission data required for the index-scoring process.

The variables are operationalized based on the Global Reporting Initiative (GRI) 305 standards for emissions:

1. Carbon Accounting Implementation: Measured by the identification of Scope 1 (direct), Scope 2 (indirect energy), and Scope 3 (value chain) emissions.
2. Emission Disclosure Transparency: Evaluated using a scoring index based on the completeness of carbon intensity data, reduction targets, and assurance by independent third parties.
3. Corporate Resilience Signal: Measured qualitatively by observing the company's strategic alignment with global green financing requirements and climate risk mitigation plans.

To ensure a consistent evaluation of transparency, this study uses a content index scoring system. Every sustainability report is scored against a checklist developed according to the GRI 305 (Emissions) and GRI 302 (Energy) standards. A binary score system is used: a score of '1' is assigned if the specific disclosure item is present in the report, and '0' is assigned if it is absent. Each company's total score is then computed to define a 'Carbon Disclosure Level,' enabling us to systematically compare transparency levels in the integrated nickel industry. The Index Scoring Framework is used as shown in Table 2.

Table 2 shows the Carbon Disclosure Index adopted in this study to measure the transparency of carbon accounting implementation. It is based on the Global Reporting Initiative (GRI) 305 and 302 standards, which serve as global benchmarks for emissions and energy reporting. This framework offers a structured and objective basis for assessing how integrated nickel companies communicate their environmental accountability by using a binary scoring system. A higher total score indicates a more mature carbon accounting system, reflecting the firm's readiness to mitigate climate-related risks and align with international green financing requirements. Systematic quantification is essential to bridge the gap between qualitative narratives in sustainability reports and the actual level of environmental transparency.

Table 2. Carbon Disclosure Index Scoring Framework

No	Disclosure Category (GRI Standards)	Assessment Criteria / Disclosure Items	Score (0/1)	Remarks
1	Scope 1 Emissions	The company reports quantitative data for direct emissions from its operations (smelters/mines).		
2	Scope 2 Emissions	The company reports quantitative data for indirect emissions from purchased electricity/energy.		
3	Scope 3 Emissions	The company reports emissions from the value chain (e.g., logistics, business travel, or supply chain).		
4	Emission Intensity	The company provides a ratio of emissions relative to its production volume (e.g., tCO2e per ton of nickel).		
5	Reduction Target	The company sets quantitative targets for emission reduction (e.g., 20% reduction by 2030).		
6	Carbon Policy & Regulation	The company discloses its strategy or mitigation plan regarding Indonesia's carbon tax or carbon pricing.		
7	Energy Mix & Efficiency	The company details its energy consumption profile (renewable energy vs. coal-fired power).		
8	External Assurance	The emission data has been verified or assured by an independent third-party auditor.		
TOTAL SCORE			**/ 8**	

The data analysis follows a four-step process:

1. Data Reduction: Filtering relevant information regarding carbon metrics from the reports.
2. Data Categorization: Grouping disclosures based on the Legitimacy and Stakeholder theories framework.
3. Data Comparison: Comparing the disclosure quality across different companies to identify industry benchmarks.
4. Inference and Conclusion: Concluding how carbon accounting serves as a strategic tool for economic resilience in the nickel sector.

IV. Results and Discussion

1. Analysis of Trends in Carbon Disclosure (2022–2024)

Considering the carbon disclosure index data from Figure 2 and Table 3, we find that in this part of the data set, the patterns in the carbon disclosure practices for nine nickel-listed Indonesian companies are significant in the 2022-2024 years. Contrary to the prediction of a slow trend increasing, the disclosure scores are surprisingly uniform, with the companies sustaining a standard level over the three years. This is in line with the prevailing nature of development of sustainability accounting in the nickel industry in Indonesia, where the companies holding excellent international engagements, such as PT Aneka Tambang Tbk (ANTM), achieving a perfect score of 8/8, have shown the best disclosure performance. International alignment with global standards, such as the Global Reporting Initiative (GRI) and the Task Force on Climate-related Financial Disclosures (TCFD), often necessary to join international joint ventures and supply chain partnerships, also helps lead to such enhanced performance for internationally connected companies.

Figure 2. Carbon Disclosure Index of 9 Indonesian Nickel Companies (2022-2024)

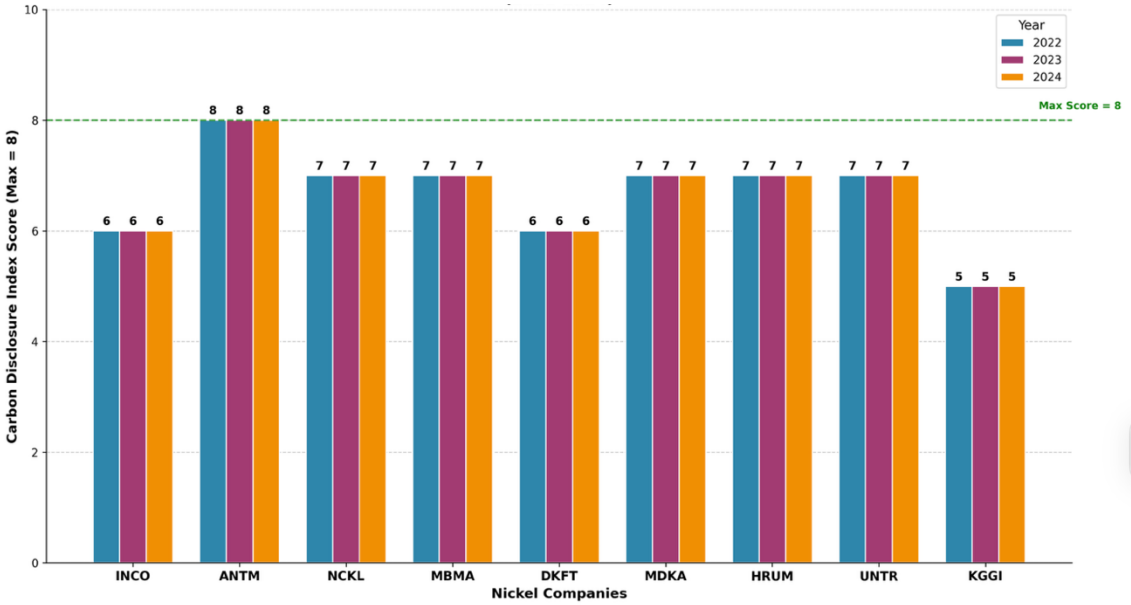

Table 3. Carbon Disclosure Binary Scoring Matrix (2022-2024)

Disclosure Category	Assessment Criteria	INCO			ANTM			NCKL			MBMA			DKFT			MDKA			HRUM			UNTR			KGGI		
		2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024
Scope 1 Emissions	Direct emissions from owned or controlled sources.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scope 2 Emissions	Indirect emissions from the generation of purchased energy.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scope 3 Emissions	Indirect emissions in the value chain (logistics, supply chain).	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emission Intensity	Emissions relative to production volume (e.g., tCO2e/ton).	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Reduction Target	Specific quantitative targets for reducing emissions.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carbon Policy & Regulation	Strategy regarding carbon tax or pricing regulations.	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
Energy Mix & Efficiency	Energy consumption profile (Renewables vs. Fossil fuels).	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
External Assurance	Verification of emission data by independent third parties.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0

Note: (1) Indicates data is explicitly disclosed in public reports; (0) Indicates absence of disclosure.

In Indonesia's mining sector, quality and comprehensive coverage in carbon reporting have significant heterogeneity. Table 3 presents a comparative quantitative evaluation of carbon emission disclosure in line with GRI 305 standards. Khoesnadi & Meiden (2025) find that stakeholder pressure, national reporting systems, and internal corporate strategies highly impact the quality of disclosure performance, and that most companies do not disclose Scope 3 emissions. This is consistent with our findings that new entrants and locally focused companies have lower scores of transparency. This study has highlighted a gap (in most cases) in how Scope 3 emissions are included, along with a lack of leveraged external assurance mechanisms. Although all nine companies report their Scope 1 and Scope 2 emissions, which represent actual operating impacts and purchased energy used, respectively, only ANTM and NCKL report their Scope 3 value chain emissions. This selective disclosure characteristic highlights that while fundamental carbon accounting standards are gaining traction, advanced financial disclosure of climate risks, including the extent of regulatory liability due to the delayed roll-out of Indonesia's carbon tax, is nascent.

The adoption of carbon taxation in Indonesia is confronted with significant institutional and technological obstacles that have direct implications for corporate disclosure practices. Regulated under Law Number 7 of 2021 concerning the Harmonization of Tax Regulations, the carbon tax implementation encounters substantial obstacles, including the absence of technical regulations, limited emission measurement systems, and unclear mechanisms for revenue allocation (Simanullang & Sari, 2026). A sluggish roll-out of CO2 pricing mechanisms generates uncertainty among mining companies as regards their financial exposure in the future, explaining the reluctance behind carbon policy disclosure. It has been shown that coal companies subjected to the implementation of carbon taxes could have an increase of 42.5% probability of default, highlighting the materiality of climate-related financial risks to Indonesia's extractive sectors (Usman et al., 2025). The gap between regulatory intent and operational readiness has become one of the most worrisome uncertainties for Indonesian mining managers (Pinem & Anggoro, 2025).

The adoption of carbon accounting by Indonesian nickel pioneers (including PT Vale Indonesia (INCO) and PT Trimegah Bangun Persada (NCKL)) is evidence of a strategic shift from traditional financial reporting toward proactive environmental disclosure mechanisms. According to previous studies, carbon emission disclosure has dual functions in the form of a symbolic mirror of corporate ethical awareness and moral responsibility toward environmental matters: it serves as both a tool for corporate legitimation and trust development and a technique for mitigating informational distortion. Thus, firms are now accountable to stakeholders that involve more than just shareholders (Stakeholder Theory), such as global electric vehicle manufacturers and green finance institutions. Carbon transparency becomes the essential "Green Passport" of market access and partnership opportunities at the strategic level as Indonesia's strategic position deepens in the global EV battery supply chain.

The disclosure of Scope 1, 2, and 3 emissions explicitly helps minimize information asymmetry between companies and stakeholders, thereby increasing investor confidence and enabling the allocation of capital to sustainable enterprises. Research investigating the link between carbon information disclosure and corporate financial performance in heavily polluting industries illustrates that carbon disclosure can enhance performance through reduced debt financing costs and higher institutional investor shareholding (Xu et al., 2025). The relationship between corporate governance structures and firm performance is mediated by the disclosure of data on carbon emissions in Indonesian mining companies; thus, the idea that transparency can be used as a proxy for management quality has been reinforced (Kurnia et al., 2025). UK non-financial companies also provide evidence that ESG disclosure reduces market uncertainty, and carbon disclosure compounds this negative relationship, in accordance with Signaling Theory (Moussa & Elmarzouky, 2024).

Due to the EU Carbon Border Adjustment Mechanism (CBAM) and the changing sustainability criteria of Western markets, Indonesian nickel companies face particularly acute stakes. Failing strong carbon accounting risks pushing Indonesian nickel into the category of "dirty nickel," which could potentially cut it off from premium market segments or cause substantial border adjustment fees. Under the geopolitical context of mounting material concerns, the USA and EU have begun to deploy material diplomacy to obtain access to resource-rich countries, focusing on allied countries' proven sustainability credentials (Jetin, 2023). Companies involved in supply chains for critical raw materials are also exposed to an intersection of sustainability, competitive pressures, and geopolitical risk, which marks a transformative new form of supply chain governance (Maltais et al., 2026) with regulatory initiatives like the Corporate Sustainability Due Diligence Directive.

In this study, we establish that firms with higher disclosure scores—specifically ANTM with comprehensive eight-criterion disclosure—are deliberately building defensive shields against carbon-heavy product-driven protectionist trade policies. The necessity of harmonized ESG disclosure guidance in shaping corporate environmental behavior has been proven by international evidence, where companies

listed on exchanges with ESG guidance are found to decrease their carbon emissions significantly, but particularly, they do so largely through the reduction of Scope 1 emissions (Yan et al., 2026). Comprehensive carbon disclosure thus becomes not just a compliance exercise for Indonesian nickel producers, but rather a competitive imperative for ensuring access to international markets in an increasingly decarbonizing global economy. Although the implementation costs of improved sustainability reporting are high, they are offset by a growth in market valuations and the trust of stakeholders in firms that deliver on these emerging international standards effectively (Pratama et al., 2025).

2. Legitimacy and Stakeholder Pressures: A Dual-Lens Interpretation

We interpret the results of this study that are considered through the dual lenses of Legitimacy Theory and Stakeholder Theory, giving a deeper understanding of the motivations behind corporate transparency in Indonesia's nickel mining sector. These theoretical frameworks have been extensively applied in sustainability accounting research (Del Gesso & Lodhi, 2025). Thus, the relationship between these theoretical frameworks helps to elucidate the different levels of carbon disclosure quality among Indonesian nickel companies from 2022 to 2024.

2.1 Legitimacy Strategy as a Social License to Operate

In addition, the high level of transparency observed in Scope 1 and Scope 2 emissions among all nine nickel companies in Indonesia is a deliberate pursuit of retaining a “social license to operate” (SLO). The SLO concept is recognized as fundamental to the natural resource development lexicon, capturing the continuous and evolving consent of stakeholders and being about more than merely fulfilling regulatory norms (Meding et al., 2026). Given the high energy intensity of smelting operations—particularly with Indonesia’s reliance on coal-fired power for nickel processing—these companies face significant public and regulatory scrutiny.

Studies on various mining companies listed on the Australian Stock Exchange show that the level of communication on environmental protection, emissions, carbon footprint, and climate change differs by the size of a mining company, with larger firms performing considerably more extensive disclosures (Miklosik & Evans, 2021). This result is consistent with the data showing that PT Aneka Tambang Tbk (ANTM), one of Indonesia’s largest and most established nickel producers, achieved the highest disclosure index score of 8/8 across all three years examined. These firms also leverage their proactive role in disclosures to reduce negative perceptions and to narrow the Legitimacy Gap between industrial expansion and environmental preservation.

Recent mining research describes the notion of the Legitimacy Trilemma to characterize the tension between legal, economic, and sociopolitical forms of legitimacy that resource extraction firms must manage (Meding et al., 2026). Communication should move from rhetorical intent to verifiable results to achieve lasting legitimacy. This is why Indonesian nickel companies have universally adopted disclosure of Scope 1 and 2 emissions (which include direct operational emissions and purchased electricity) as the most tangible and verifiable metrics of environmental accountability. The data show that all nine companies (INCO, ANTM, NCKL, MBMA, DKFT, MDKA, HRUM, UNTR, and KGGI) maintained consistent disclosure of these core emission categories throughout the 2022-2024 period.

Carbon accounting serves as a defensive means to demonstrate that nickel downstreaming does not automatically equal environmental destruction. It has been shown by various studies that environmental penalties also play a meaningful role in improving carbon disclosure practices, especially as an amplification through social media scrutiny, which builds public pressure and demonstrates the role of external stakeholders in promoting transparency (Shao et al., 2024). This legitimacy-seeking behavior in Indonesian nickel firms aligns with more general tendencies highlighted in this study, indicating that firms with stronger financial capacity and better environmental performance exhibit more transparent carbon disclosure, while larger firms respond more robustly to pressure for environmental accountability (Pratama & Gantino, 2026).

The core of the analysis shows a "Nickel Dilemma", which is the industrial downstreaming process; though profitable, it is inherently energy-intensive and remains tethered to captive coal-fired power plants. This creates a significant Legitimacy Gap. Firms must comply with the constraints and norms imposed by their own cultures as articulated by Legitimacy Theory (Aristawati & Rohmiatun, 2026), and sustainability reporting can increase firm value if their disclosures are credible, consistent, and material. To fill this gap, companies use carbon accounting as a “narrative tool,” to redirect public attention from “current coal dependency” toward “future technological transition.”

The carbon reporting index findings of this research support this strategic behavior. For the carbon disclosure statistics presented in Figure 2 and Table 3, all nine analyzed Indonesian nickel companies (INCO, ANTM, NCKL, MBMA, DKFT, MDKA, HRUM, UNTR, and KGGI) demonstrated full disclosure

(score = 1) for Scope 1 and Scope 2 emissions in all three years (2022–2024), all of which show that they are universally committed to reporting both direct emissions of smelters and mines and indirect emissions from purchased electricity. This universal compliance with basic emissions reporting reflects what researchers call strategic disclosure mechanisms, where companies use specific environmental metrics to justify their ongoing "social license to operate" amidst global climate scrutiny. Uniform disclosure of Energy Mix & Efficiency across all companies further evidences the fact that companies strategically highlight their energy consumption profiles (e.g., the proportion of renewable energy to coal-fired power) as a legitimacy-building narrative.

The empirical pattern becomes more nuanced when examining Scope 3 emissions and carbon policy disclosure. The disclosure index reveals that only ANTM and NCKL consistently reported Scope 3 value chain emissions across all three years, while most firms—including INCO, MBMA, DKFT, MDKA, HRUM, UNTR, and KGGI—maintained zero disclosure on this category. This selective disclosure pattern indicates that firms strategically emphasize certain environmental metrics while omitting others that might expose the broader carbon footprint of their supply chains. Carbon accounting at present suffers from problems of lack of standardization, transparency, and comparability, especially in Scope 3 emissions (both upstream and downstream emissions) (Bonelli & Coqueret, 2024; Csutora & Harangozo, 2017). This is particularly relevant for sectors such as nickel and EVs, when supply chains are complex, and emissions are spread across several stages (Alsaleh & Farooq, 2026; Becker, 2025).

Research on carbon information disclosure in heavily polluting industries confirms that enhanced corporate carbon disclosure can significantly improve financial performance by reducing the degree of information asymmetry and obtaining government support (Xu et al., 2025). By disclosing granular carbon intensity data—which all 9 firms reported at full compliance—companies can demonstrate that High-Pressure Acid Leaching (HPAL) technology offers a lower carbon footprint for battery-grade nickel compared to Rotary Kiln-Electric Furnace (RKEF) methods used for stainless steel. The transition to LNG or hydropower, as detailed in recent sustainability reports, serves as empirical evidence provided to stakeholders that the firm is actively mitigating its environmental impact.

2.2 Stakeholder Response and Market Signaling Mechanisms

Data disclosure over nickel sulfate synthesis — the backbone of the EV battery world — is another clear response to global stakeholders' "green demands." Carbon emission disclosure serves multiple purposes: on one hand, representing corporate ethical consciousness and moral accountability to the ecological impacts, while simultaneously acting as a strategic tool in establishing legitimacy, enhancing reputation, reducing information asymmetry, and sending positive signals to investors and the market. This dual function is most evident in the Indonesian nickel industry, where companies seek to situate themselves in the international electric vehicle supply chain while being sensitive to local sustainability.

European and North American EV brands have become more demanding of traceable and low-carbon raw materials. Research on the global EV battery supply chain establishes that environmental considerations are at the crux of buyers' choices as producers demand extensive documentation of carbon footprints throughout manufacturing (Vegh et al., 2024). The idea of battery passports for tracking lithium-ion battery components has been suggested for material traceability and has been identified as a mechanism for sustainable supply chain assurance for critical minerals. Indonesian nickel companies are adapting to these demands by improving their carbon disclosure practices as a method of keeping access to premium markets.

Based on the signaling theory, Indonesian nickel companies are applying carbon accounting as an advanced signaling tool. ESG disclosure operates as a strategic signaling mechanism that lowers information asymmetry and increases stakeholder confidence, and digital transparency improves the value relevance of sustainability disclosures by ensuring that the non-financial information is available, timely, and trustworthy (Nasution et al., 2026). The disclosure index in Table 3 shows the heterogeneity of signaling strategies: only ANTM and NCKL report Scope 3 value chain emissions, whereas INCO and KGGI restrict their disclosure to direct and purchased energy emissions. Carbon disclosure has been shown to amplify the negative relationship between ESG disclosure and market uncertainty, a finding that resonates with Signaling Theory and underscores the role of ESG and carbon disclosure in reducing cost of capital, enhancing firm value, and boosting investor confidence (Moussa & Elmarzouky, 2024). By providing high-quality emission data, Indonesian nickel companies are not merely reporting numbers; they are securing their position within the global EV supply chain and attracting green financing from investors who prioritize ESG performance.

Studies on heavily polluting sectors in China show that corporate carbon disclosure can significantly improve corporate financial performance, with the main effect realized through reducing debt financing

costs and increasing the proportion of institutional investors' shareholding (Xu et al., 2025). These results could be easily connected and applied to the Indonesian setting, since nickel-mining firms with higher disclosure scores can receive preferential financing terms from sustainability-related lenders. As financial markets evolve with increasing sophistication in evaluating sustainability indicators, Indonesia's nickel companies investing in complete carbon accounting structures have a favorable opportunity to gain access to capital markets. By alleviating information asymmetry, third-party green certification has been shown to reduce financing costs significantly, while its credibility effects are especially pronounced in publicly offered bonds and for non-listed enterprises (Wang, 2025).

Strategically situated as it is in the global EV battery supply chain, Indonesia faces both opportunities and pressures for nickel producers. Such geopolitical rivalries between major powers are transforming global capital flows, especially in relation to critical mineral supply chains key to electric vehicle development (Zulkifli et al., 2025). Indonesia, the world's largest producer of nickel, has become a strategic pivot in this global realignment, with companies challenged to prove environmental credentials to attract foreign direct investment and maintain market access. With the automotive industry moving towards electrification, a sustainable supply chain (from mine to vehicle end-of-life) needs to be developed across the production process with environmentally friendly industrial processes (Vegh et al., 2024). Such an imperative pushes the Indonesian nickel companies to raise the transparency level as a competitive differentiator. Firms failing to perform well in managing their environmental performance run the risk of their companies being tagged "dirty nickel producers" and potentially facing exclusion from prestigious Western markets or facing severe fines according to the EU's Carbon Border Adjustment Mechanism (CBAM).

The disclosure of carbon policy and regulatory strategy – visible in only six of the nine companies analyzed (ANTM, MBMA, MDKA, HRUM, UNTR) – suggests varying levels of strategic preparedness for changing international trade conditions. Studies show that critical minerals play a crucial role in maintaining the supply chain required to switch to a carbon-free energy society, and that nickel is in great demand for batteries used for electric vehicles (Reich & Simon, 2025). Firms that take the initiative to discuss carbon policy as part of their disclosure response are more likely to recognize, and be ready to act on, international regulatory needs. Additionally, the importance of providing external assurance in increasing the trustworthiness of disclosure is also another aspect of the legitimacy-stakeholder framework. The findings of this study suggest that all companies except KGGI have received external assurance for emission data over 2022-2024. The presence of corporate governance mechanisms, in particular, environmental committees, which consist of their attributes, such as size, chairperson independence, and meeting frequency, contributes to the improvement of carbon emission disclosure and environmental performance (Budianto et al., 2025). This set of governance mechanisms enables credible environmental information to be created in a stable fashion capable of sustained stakeholder scrutiny. Currently, more than ever, Indonesian nickel companies are forming sustainability committees and using third-party verifiers to affirm the credibility of their carbon disclosures.

3. Preemptive Accounting: Building Resilience Against Regulatory Volatility

One of the interesting observations in this study is the 'Strategic Proactivity' of nickel businesses towards Indonesia's delayed carbon tax implementation. Whereas many sectors have taken a passive "wait and see" approach, integrated nickel companies have been institutionalizing internal carbon pricing and rigorous emission tracking. The carbon disclosure indicator confirms the above observation, with the Carbon Policy & Regulation disclosure item indicating a clear strategic split in strategic behavior. The carbon tax mitigation strategies of the companies ANTM, MBMA, MDKA, HRUM, and UNTR exhibited consistent disclosure throughout 2022–2024, whereas INCO, NCKL, DKFT, and KGGI did not disclose such strategies across the entire observation period. This is analyzed through the lens of Strategic Resilience. Not only do these firms expect a legal obligation by implementing carbon accounting in advance, but they are also "de-risking" their financial structures.

Studies show that the carbon emissions trading policy greatly enhances the ESG performance of heavy-polluting companies by reducing external financing constraints and promoting green technological innovation (Dai & He, 2025). This research supports the findings of the present study that early adopters of carbon management systems experience a reduced cost of equity since they offer a clearer risk profile to investors. For example, in the Indonesian context, this proactivity is protective against "regulatory shocks." The previous studies have shown that ESG disclosure has a positive and statistically significant impact across all performance indicators, from Tobin's Q to Return on Assets to Return on Equity, which reinforces disclosure as one pathway for making firms more transparent, reducing information asymmetry, and increasing stakeholder trust (Hamdouni, 2025). When the domestic carbon tax gets implemented, firms like

these will have already calibrated their operating costs, eliminating potentially large financial shocks that would destabilize their downstream investments.

This proactive accounting approach is evident in the universal adherence to emissions intensity disclosure: all nine firms reported tCO2e per ton of nickel production throughout the observation period. Equally, the 100 percent adoption of quantitative reduction targets by all sectoral companies suggests a whole sector commitment to emission management that is not limited to compliance with rules and regulations. Regulations such as emissions intensity disclosure can strengthen resilience by promoting technological innovation and low-carbon energy systems (Frankovic & Kolb, 2024; Zhao & Jiang, 2024). For instance, in the nickel and EV sectors, the incorporation of carbon accounting approaches into decision-making frameworks can bolster transparency, align sustainability goals with operational objectives, and strengthen adaptive mechanisms against climate-related risks (Islami et al., 2025; Rana et al., 2025). This is particularly relevant for sectors such as nickel and EVs, when supply chains are complex, and emissions are spread across several stages (Alsaleh & Farooq, 2026; Becker, 2025). Legitimacy theory suggests that this transition involves moving from symbolic strategies to substantive strategies designed to enable changes in companies' own operating policies and increase their contribution to sustainable development goals. The proactive alignment implies that carbon accounting is a prerequisite for financial sustainability that turns a potential regulatory threat into a managed transition that increases the firm's long-term competitive advantage.

A major emerging theme from the content analysis of this study is the growing importance of the digitalization of carbon data to improve its reliability and traceability. Traditional carbon accounting (which can be characterized by the reliance on manual data acquisition and periodic estimation) has historically been criticized for its lack of precision and its susceptibility to human error or "greenwashing." The External Assurance disclosure item that offers great evidence of this is the Carbon Disclosure Index. As is clear from this data, eight out of nine firms (INCO, ANTM, NCKL, MBMA, DKFT, MDKA, HRUM, and UNTR) all carried out full external assurance verification through 2022–2024, with KGGI not having third-party audit verification in all three years. This near-universal adoption of external assurance showcases the acknowledgement on the part of the sector that credibility involves independent verification mechanisms.

To protect themselves from greenwashing risks, Indonesia's highest-profile integrated nickel companies have established integration of real-time emission monitoring systems (CEMS) and Internet of Things (IoT) sensors in their smelting sites. Studies of blockchain for ESG reporting show that blockchain technologies manage to automate the process of reporting effectively by reducing mistakes, ensuring data truthfulness, and guaranteeing accountability (Singh et al., 2025). Switching to an automated method of data collection enables companies to represent their environmental footprint as one's 'live' footprint, which is highly beneficial to their Legitimacy for foreign auditors.

In addition, the use of Blockchain technology for carbon tracking is being discussed for the purpose of ensuring that emission data remains immutable and transparent from the mine site through to the final battery component. Literature highlights the place of attestation approaches and permissioned blockchains in ESG applications, which receives increasing attention regarding their potential to address reporting challenges (Caldarelli, 2025). The combined effect of regulatory engagement, third-party verification, internal controls, and nascent technologies in an ecosystem of anti-greenwashing is known to create "a synergistic set of deterrents that collectively shape the integrity and credibility of sustainability disclosure practices" (Sneideriene & Legenzova, 2025). This technological shift is motivated by demand for "traceable and clean" minerals from global EV manufacturers as per Stakeholder Theory. Evidence of the external assurance adoption consistency evident in the disclosure index—maintained at full compliance by eight firms across three consecutive years—suggests that Indonesian nickel companies are not only improving internal operational efficiency but also provide a high-fidelity "signal" of accountability that meets the most stringent global transparency standards.

The empirical results also indicate heterogeneous patterns of adoption that merit further research. Firms such as ANTM and NCKL show thorough disclosure across the 8 categories (total rating of 8/8), while KGGI and INCO's selective level of disclosure has 5/8 and 6/8 scores, respectively, indicating divergent commitment to fully disclose carbon in the 8 categories. AI-enabled ESG compliance auditing has been demonstrated to be capable of replicating auditor judgments and significantly reducing workload while performing audits, stressing the way in which lightweight digital tools can allow auditors, regulators, boards, and investors to screen and compare sustainability reports in a way that does not compromise professional judgment (Alotaibi & Alwathnani, 2025). Such variability in comprehensiveness in disclosure correlates with the theory that digitalization and carbon data reliability adoption are not uniform across firms but rather reflect firm-specific factors such as governance structure, stakeholder pressures, and strategic positioning within the global EV supply chain.

V. Conclusion

This study concludes that for the Indonesian nickel industry, carbon accounting has evolved from a voluntary transparency measure into a critical strategic asset. Amidst the pressure of global supply chains and the looming implementation of CBAM, the ability to quantify and disclose carbon intensity is the 'green signal' that determines market access. While coal-dependency remains a significant challenge, proactive carbon disclosure serves as a buffer against regulatory shocks, ensuring that the downstreaming of nickel contributes not only to national economic growth but also to long-term global sustainability resilience.

Despite its strategic insights, this study possesses several limitations that should be acknowledged. First, the sample size is restricted to publicly listed integrated nickel companies, which may not fully represent the carbon accounting practices of smaller, private smelters or those operating within enclosed industrial estates. Second, the qualitative nature of the content analysis relies heavily on the quality of self-reported data in sustainability reports, which may be susceptible to "greenwashing" or selective disclosure. Lastly, because Indonesia's carbon tax and domestic carbon exchange are still in their nascent stages of implementation during the 2022–2024 period, the long-term financial impact of these regulations could not be fully quantified in this research.

To build upon the findings of this study, future research should consider the following directions. First, future studies could employ quantitative methods, such as panel data regression, to test the empirical correlation between carbon disclosure scores and firm performance (e.g., Tobin's Q or Cost of Equity) across a broader range of mining sectors. Second, a comparative analysis between Indonesia's nickel industry and other major nickel-producing nations, such as Canada or Australia, would provide deeper insights into how different regulatory environments influence carbon accounting maturity. Third, subsequent research could incorporate primary data through in-depth interviews or surveys with corporate carbon accountants and environmental engineers to better understand the internal technical barriers to emissions tracking. Finally, investigating the specific role of digital technologies, such as blockchain or IoT-based carbon monitoring, in enhancing the reliability of carbon data within the downstream sector would be a highly relevant area of exploration.

Indonesian policymakers should expedite carbon tax implementation with clear timelines and sector-specific guidelines, as current regulatory uncertainty creates an uneven playing field. Further, regulators should mandate phased Scope 3 emissions disclosure beginning with material categories such as upstream supply chain emissions and downstream logistics, aligning Indonesian standards with international frameworks (ISSB, EU CSRD) to facilitate access to global green financing. Moreover, standardized digital verification protocols incorporating blockchain-based traceability should ensure data immutability. Finally, policy instruments such as tax incentives, concessional financing, and expedited permitting should accelerate the transition from coal-fired captive power to renewable energy sources, as universal Energy Mix & Efficiency disclosure indicates industry readiness to track and report energy transition progress.

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