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Carbon Emission Disclosure Quality And GRI-Based Decarbonization Practices At ANTAM

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Abstract

This study assesses the quality of carbon emission disclosure and examines decarbonization practices at PT Aneka Tambang Tbk (ANTAM) using the GRI Standards as the benchmark for evaluation. A qualitative descriptive design with content analysis was applied to ANTAM's 2024 Annual Report, comprising 976 pages. Fourteen disclosure items derived from GRI 305 (Emissions), GRI 302 (Energy), GRI 3-3 (Management of Material Topics) and GRI 2-5 (External Assurance) were scored on a four-point ordinal scale, ranging from zero to three, producing a disclosure quality index. The results show an index of 26.19 %, categorised as low. Emissions are reported only in aggregate, namely 1.42 million tCO2e or a thirteen % decline year on year, without Scope 1, 2 and 3 disaggregation, emission intensity, ozone-depleting substances, or other significant air emissions. Conversely, decarbonization practices are relatively advanced, covering grid electricity transition, B35 biodiesel, solar road lighting, a decarbonization roadmap with a 2019 baseline, board-level key performance indicators, carbon risk registers, and 190,813 trees planted. The study identifies an accountability gap in which physical decarbonization performance is not matched by measurable and verifiable reporting.

Keywords: carbon emission disclosure; decarbonization; GRI Standards; content analysis; ANTAM.

INTRODUCTION

The mining sector is one of the largest contributors of greenhouse gas (GHG) emissions in the structure of the Indonesian economy, owing to the intensity of fossil energy use in extraction, haulage, and mineral processing activities. As a consequence,

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mining companies face mounting pressure from regulators, investors, rating agencies, and civil society not merely to reduce emissions physically, but also to account for those reductions through reporting that is measurable and verifiable. Indonesia's commitment to achieving Net Zero Emissions by 2060, reinforced through Presidential Regulation No. 98 of 2021 on the Implementation of Carbon Economic Value, positions carbon accounting and disclosure as key instruments in the transition toward a low-carbon economy.

In the domain of corporate reporting, the Financial Services Authority (Otoritas Jasa Keuangan) has, through Regulation No. 51/POJK.03/2017, required listed issuers to prepare Sustainability Reports covering environmental performance, including emissions. Yet this formal obligation does not by itself guarantee the quality of the information produced. The environmental accounting literature shows that carbon disclosure is frequently symbolic, dominated by qualitative narrative, and disproportionate to actual emission performance. Luo and Tang (2014) found that voluntary carbon disclosure does not always reflect the underlying carbon performance, while Hahn et al. (2015) emphasised that corporate climate transparency remains constrained by methodological inconsistency and low comparability across firms. Comyns (2016) further demonstrated that global oil and gas companies tend to disclose emissions selectively when such information favours their image. Talbot and Boiral (2018) reached a similar conclusion for the energy sector, showing that GHG reporting is often shaped by impression management rather than by the completeness of the underlying measurement.

The theoretical frameworks commonly used to explain this phenomenon are legitimacy theory, stakeholder theory, and signalling theory. Legitimacy theory views environmental disclosure as an effort by the firm to maintain its social contract with society when its activities have the potential to generate adverse impacts (Deegan, 2002). Stakeholder theory positions disclosure as a response to the information demands of groups that affect and are affected by the firm (Freeman, 1984). Signalling theory, meanwhile, explains that firms with sound environmental performance have an incentive to disclose information in detail in order to differentiate themselves from poor performers, a proposition supported empirically by Datt et al. (2019) and, in the Indonesian setting, by Ratmono et al. (2021). All three perspectives imply that the quality of disclosure, and not merely its existence, is the marker of whether a climate commitment is substantive or symbolic (Velte et al., 2020).

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The Global Reporting Initiative (GRI) Standards provide the most widely used international assessment framework for examining that quality. GRI 305: Emissions 2016 requires the disclosure of direct GHG emissions (Scope 1), energy indirect emissions (Scope 2), other indirect emissions (Scope 3), emission intensity, emission reductions, ozone-depleting substance emissions, and other significant air emissions, accompanied by the base year, emission factors, calculation methodology, and consolidation approach. GRI 302: Energy 2016 complements this with disclosures on energy consumption and energy intensity. It is the completeness of these attributes that distinguishes high-quality disclosure from mere narrative reporting. Recent evidence indicates that the substantive application of the GRI Standards is associated with real carbon mitigation outcomes rather than reputational effects alone (Luo & Tang, 2023), although the depth of application varies considerably across firms and jurisdictions (Choy, 2026; Özkan, 2025).

PT Aneka Tambang Tbk (ANTAM) is a relevant object of study. As a member of the MIND ID Group managing nickel, gold, and bauxite commodities, ANTAM is a constituent of the IDX LQ45 Low Carbon Leaders Index, received six PROPER awards in 2024, and explicitly states that it operates a decarbonization programme guided by a roadmap with a 2019 base year. On the other hand, the ASEAN Corporate Governance Scorecard assessment reproduced in ANTAM's 2024 Annual Report records that the Company has not disclosed specific quantitative sustainability targets and has not explained the internal review process for its Sustainability Report. The contrast between active decarbonization activity and weakness on the reporting side constitutes the research gap.

Prior research in Indonesia has generally tested the determinants of carbon emission disclosure quantitatively using dichotomous indices, and has therefore been unable to distinguish narrative disclosure from quantitative disclosure supported by methodology. Studies of state-owned enterprises (Yustina et al., 2024), non-financial firms (Wahyuningrum et al., 2026), and mining and basic-industry firms (Widhiastuti & Safitri, 2023; Tarigan et al., 2025) consistently focus on the antecedents of disclosure extent rather than on the informational quality of the disclosed content, and Fransisca et al. (2024) note that the disclosure indicators used in the Indonesian context still require refinement to capture measurement attributes. This study fills that gap by employing a graded ordinal scale, following the argument of Saha et al. (2019) that the quality of carbon disclosure must be separated analytically from its volume, and by simultaneously mapping actual decarbonization practices so that the alignment between action and

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reporting can be examined. The objectives of this study are, first, to measure the quality of ANTAM's carbon emission disclosure based on the GRI Standards; second, to map the decarbonization practices implemented by ANTAM and classify them according to the mitigation hierarchy; and third, to analyse the gap between decarbonization practice and disclosure quality together with its implications for corporate climate accountability.

RESEARCH METHOD

This study adopts a qualitative descriptive approach using content analysis. Content analysis was selected because it enables replicable and valid inferences to be drawn from texts within their context (Krippendorff, 2019), making it suitable for assessing disclosure quality in corporate reports. The specific type applied is directed content analysis, in which coding categories are derived beforehand from a theoretical framework, in this case the GRI Standards, before being applied to the text. This design follows the approach used in GRI-based content analyses of corporate sustainability reporting (Özkan, 2025; Choy, 2026).

The data are secondary data in the form of public documents, collected through documentary study. The unit of analysis is the 2024 Annual Report of PT Aneka Tambang Tbk, comprising 976 pages and published by the Company in June 2025. The sample was selected purposively on the consideration that ANTAM is a state-owned mining issuer listed in a low-carbon-oriented index on the Indonesia Stock Exchange that explicitly claims to operate a decarbonization programme, and is therefore relevant for testing the alignment between practice and reporting. The recording units are sentences and tables containing information on emissions, energy, climate, and decarbonization.

The research instrument is a checklist consisting of fourteen disclosure items. Seven items are drawn from GRI 305: Emissions 2016 (305-1 to 305-7), five from GRI 302: Energy 2016 (302-1 to 302-5), one from GRI 3-3 concerning the management of material topics, and one from GRI 2-5 concerning external assurance. The GRI 302 items are included because energy consumption is the principal driver of Scope 1 and Scope 2 emissions in the mining industry, while GRI 3-3 and GRI 2-5 are included to capture the governance and information-reliability dimensions, the latter being an aspect that the assurance literature identifies as decisive for the credibility of emission figures (Green & Zhou, 2013; Datt et al., 2022).

Assessment was carried out using a four-level ordinal scale ranging from zero to three, as presented in Table 1. The use of a graded rather than a dichotomous scale is

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intended to distinguish disclosure that is merely narrative from quantitative disclosure that is complete with a base year, methodology, and verification, consistent with the quality-versus-volume distinction developed by Saha et al. (2019).

Table 1. Assessment Rubric for Carbon Emission Disclosure Quality Based on the GRI Standards

Score	Category	Assessment Criteria
0	Not disclosed	The item is not found at all in the document, or is mentioned only as a cross-reference without substantive information.
1	General narrative	The item is disclosed only as a qualitative statement, commitment, or programme description without numerical data.
2	Partially quantitative	The item is disclosed with numerical data, but without disaggregation, base year, emission factors, or an explanation of the calculation methodology.
3	Fully quantitative	The item is disclosed with disaggregated numerical data, accompanied by base year, methodology and emission factors, and inter-period comparison and/or third-party verification.

Source: Data processed, 2026

The Disclosure Quality Index (DQI) is computed by comparing the total actual score against the maximum score, namely fourteen items multiplied by the highest score of three, yielding a maximum of forty-two, expressed as a %age. Results are interpreted using four categories: low for values below 40 %, moderate for 40 to below 60 %, high for 60 to below 80 %, and very high for values of 80 % or above.

Decarbonization practices were analysed separately through thematic coding. Each identified initiative was classified according to the emission mitigation hierarchy, namely energy efficiency, fuel substitution, energy source transition, carbon sequestration, and carbon governance. Data validity was maintained through source triangulation, comparing statements in the Performance Highlights, Management Report, Management Discussion and Analysis, Corporate Governance, and Social and

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Environmental Responsibility sections of the same document. Coding reliability was tested through re-coding by the researcher at two different points in time (intra-rater reliability), with a high level of agreement.

It should be emphasised that this study restricts its unit of analysis to the 2024 Annual Report. The findings therefore represent the quality of carbon emission disclosure in the principal reporting channel most widely accessed by investors, and not the totality of the Company's disclosure, part of which is redirected to the Sustainability Report.

RESULTS AND DISCUSSION

Profile of ANTAM's Carbon Emission Disclosure in 2024

The examination shows that carbon emission information in ANTAM's 2024 Annual Report is dispersed across several sections and presented in a highly condensed form. In the Environmental Performance Highlights, the Company reports total emissions of 1.42 million tonnes of CO2eq with a note of a 13 % decrease compared with the previous year, together with total energy consumption of 12.39 million gigajoules, down 23 %. On the basis of these figures, 2023 emissions can be inferred to have been in the region of 1.63 million tonnes of CO2eq. However, no multi-year emissions table, no separation of Scope 1, 2 and 3, and no explanation of the emission factors, consolidation approach, or organisational boundary applied were found.

The second quantitative disclosure appears in the section on concrete steps toward Net Zero Emission, which states that the transfer of electricity supply at the Kolaka Nickel Mining Business Unit from diesel and steam power plants to the PLN Sulselrabar grid reduced greenhouse gas emissions by 53,000 tonnes CO2e during 2024, and lowered energy-demand intensity by approximately 25 to 28 %. That figure of 53,000 tonnes CO2e is equivalent to about 3.7 % of total 2024 emissions, so the remaining annual reduction of roughly 210,000 tonnes CO2e is not fully explained in the document. This condition indicates a disconnect between the aggregate figure and initiative-level attribution.

Apart from these two figures, all other emission information is narrative in character. The Company states that it has formulated a decarbonization roadmap with a 2019 base year and runs a range of emission reduction initiatives, but discloses no reduction target in absolute or intensity terms, no target year, and no interim trajectory. The Social and Environmental Responsibility section explicitly redirects the discussion of environmental impact to the Environment and Climate Change chapter of the 2024

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Sustainability Report, without reproducing the core data in the Annual Report. This practice of redirecting references weakens the completeness of information in the document that regulation designates as the principal report to shareholders.

Disclosure Quality Assessment Based on the GRI Standards

The assessment of the fourteen disclosure items produces the scores presented in Table 2. The highest scores were obtained by emission reduction (GRI 305-5), reduction of energy consumption (GRI 302-4), energy consumption within the organisation (GRI 302-1), and management of material topics (GRI 3-3), each scoring two. Conversely, seven of the fourteen items scored zero because no disclosure whatsoever was found.

Table 2. Assessment Results for the Quality of ANTAM's Carbon Emission and Energy Disclosure, 2024

GRI Code	Disclosure Item	Score	Findings in ANTAM's 2024 Annual Report
305-1	Direct (Scope 1) GHG emissions	1	Only aggregate total emissions of 1.42 million tonnes CO2eq; no Scope 1 separation, emission factors, gases covered, base year, or consolidation approach.
305-2	Energy indirect (Scope 2) GHG emissions	1	Implicit through the narrative on switching electricity supply to the PLN grid; no separate Scope 2 figure and no location-based versus market-based distinction.
305-3	Other indirect (Scope 3) GHG emissions	0	No value-chain emission disclosure found, even though ANTAM exports to more than twenty destination countries.
305-4	GHG emissions intensity	0	No ratio of emissions to production, revenue, or another metric

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GRI Code	Disclosure Item	Score	Findings in ANTAM's 2024 Annual Report
			denominator found; only energy-demand intensity for a single business unit is available.
305-5	Reduction of GHG emissions	2	Disclosed quantitatively as 53,000 tonnes CO2e from the electricity transition and a 13 % year-on-year decline, but without an explicit base year and calculation methodology.
305-6	Emissions of ozone-depleting substances	0	No disclosure of production, imports, or exports of ozone-depleting substances found.
305-7	NOx, SOx, and other significant air emissions	0	No conventional air emission data found, even though ferronickel smelting is a significant source.
302-1	Energy consumption within the organisation	2	Total energy consumption of 12.39 million GJ is disclosed, but without a breakdown by fuel type, purchased electricity, and the renewable share.
302-2	Energy consumption outside the organisation	0	No disclosure of energy consumption in the supply chain or among mining contractors found.
302-3	Energy intensity	1	Only a statement of a 25 to 28 % decline in energy-demand intensity at the Kolaka Nickel Business Unit; no corporate-level ratio and no clear denominator.

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GRI Code	Disclosure Item	Score	Findings in ANTAM's 2024 Annual Report
302-4	Reduction of energy consumption	2	A 23 % year-on-year decline in energy consumption is disclosed together with supporting initiatives, but without quantitative attribution per initiative.
302-5	Reductions in energy requirements of products and services	0	No disclosure found regarding the energy footprint of ferronickel, gold, or bauxite products.
3-3	Management of the material topic of emissions	2	An environmental policy, the ANTAM Green Standard, a 2019-based decarbonization roadmap, Board of Directors performance indicators, and a carbon risk register are present; but without quantitative targets and materiality thresholds.
2-5	External assurance of emission information	0	No statement of independent assurance over emission and energy data found in the 2024 Annual Report.
Total	**—**	**11**	**Maximum score 42**

Source: Data processed, 2026

The recapitulation of scores by disclosure group is presented in Table 3. The overall Disclosure Quality Index is 26.19 %, which falls into the low category. The GRI 305 group, which constitutes the core of emission disclosure, records the lowest index at 19.05 %.

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Table 3. Recapitulation of the Disclosure Quality Index by Standard Group

Standard Group	Number of Items	Actual Score	Maximum Score	Index (%)
GRI 305: Emissions	7	4	21	19.05
GRI 302: Energy	5	5	15	33.33
GRI 3-3 and GRI 2-5	2	2	6	33.33
Total	**14**	**11**	**42**	**26.19**

Source: Data processed, 2026

These findings are consistent with Bae Choi et al. (2013), who noted that firms tend to disclose emissions at an aggregate level without scope disaggregation, and with Depoers et al. (2016), who demonstrated systematic inconsistency between emissions reported in corporate reports and those reported to the Carbon Disclosure Project. The low score on GRI 305-3 is likewise in line with Comyns (2016), who found that Scope 3 emissions are the least frequently disclosed item because of measurement complexity and the sensitivity of the resulting figures; Hettler and Graf-Vlachy (2024) show in their systematic review that Scope 3 reporting remains the weakest link in corporate carbon accounting, even though it is precisely this scope that opens the way to supply-chain decarbonization. Within the legitimacy theory framework, a disclosure pattern that foregrounds an emission reduction figure of 53,000 tonnes CO2e while omitting scope disaggregation can be read as a symbolic legitimation strategy, that is, displaying achievement without opening the calculation basis that would allow third parties to verify it. Talbot and Barbat (2020), in their assessment of the credibility of sustainability reports in the mining sector, identify a comparable pattern in which selective quantitative claims are presented without traceable measurement infrastructure.

Mapping of Decarbonization Practices

In contrast to the quality of its disclosure, ANTAM's decarbonization practice is relatively comprehensive. Thematic coding identified eleven initiatives that can be grouped into five mitigation hierarchy categories, as presented in Table 4.

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Table 4. Mapping of PT Aneka Tambang Tbk's Decarbonization Practices, 2024

Mitigation Category	Identified Initiatives	Disclosed Performance Indicators
Energy source transition	Transfer of electricity supply at the Kolaka Nickel Business Unit from diesel and steam power plants to the PLN Sulselrabar grid; Power Purchase Agreement with PT PLN (Persero) with a capacity of 150 MVA for the Pomalaa Ferronickel Plant.	Emission reduction of 53,000 tonnes CO2e; decline in energy-demand intensity of 25–28 %.
Fuel substitution	Use of B35 biodiesel in mine operational vehicles.	Not disclosed quantitatively.
Renewable energy	Use of solar panels for mine road lighting at several business units.	Neither installed capacity nor electricity generated is disclosed.
Energy efficiency	Use of more environmentally friendly exploration equipment; energy efficiency programmes in development projects; relocation of Wartsila diesel engines between business units.	Total energy consumption down 23 % year on year.
Carbon sequestration	Planting of 190,813 trees, comprising 99,218 trees on former mining land and 91,595 trees outside former mining land; cumulative reclamation of disturbed land.	Reclamation of 1,461.83 ha out of 2,905.49 ha of disturbed land, or 50.31 %; no carbon sequestration estimate.
Carbon governance	Decarbonization roadmap with a 2019 base year and its update	Performance indicator weight of 2.00 with achievement of

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Mitigation Category	Identified Initiatives	Disclosed Performance Indicators
	by the Board of Commissioners in December 2024; Board of Directors performance indicator on carbon emission reduction relative to total business-as-usual emissions; social and environmental risk register covering failure to achieve emission reduction targets; ANTAM Green Standard and ISO 14001:2015 certification.	110 %; six PROPER awards; environmental funds and investment of IDR 158.33 billion.

Source: PT Aneka Tambang Tbk 2024 Annual Report, processed 2026

This mapping shows that ANTAM has placed decarbonization at a strategic level rather than treating it merely as an operational environmental programme. The indicator of carbon emission reduction against business-as-usual emissions has been integrated into the performance contract of the Board of Directors with a weight of 2.00 and an achievement of 110 %, while failure to reach the emission reduction target is recorded as corporate risk number ten, mitigated through roadmap updates and monitoring of emission reduction calculations. This integration signals the presence of a carbon management control system as conceptualised by Bui and de Villiers (2017) and elaborated by Mikes and Metzner (2023), who distinguish firms that embed decarbonization within formal control and incentive structures from those that respond reactively. Nevertheless, Schenzle and Busch (2026) caution that the presence of such structures does not guarantee the effectiveness of the decarbonization strategy unless the underlying targets and boundaries are made explicit and publicly testable.

The Gap between Decarbonization Practice and Disclosure Quality

A comparison of Table 2 and Table 4 reveals the principal finding of this study, namely the existence of an accountability gap. Eleven decarbonization initiatives have been implemented, yet only two of them are accompanied by quantitative indicators and

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none is accompanied by a traceable calculation methodology. Table 5 summarises the forms this gap takes.

Table 5. The Gap between Decarbonization Practice and the Quality of Its Disclosure

Dimension	Condition of Practice	Condition of Disclosure
Measurement basis	The decarbonization roadmap uses a 2019 base year and business-as-usual projections.	The base year and business-as-usual assumptions are not disclosed in the Annual Report, so the 110 % achievement cannot be tested.
Emission scope	Initiatives target direct combustion emissions and purchased electricity emissions.	Emissions are presented in aggregate without separation of Scope 1, 2, and 3.
Targets	Board of Directors performance indicators and internal emission reduction targets exist.	No public quantitative target with a target year; a similar finding is recorded in the ASEAN Corporate Governance Scorecard assessment.
Attribution	Eleven initiatives are running across business units.	Only 53,000 tonnes CO2e is attributed, while approximately 210,000 tonnes CO2e of the annual reduction is left unexplained.
Reliability	An ISO 14001:2015 environmental management system and PROPER assessment have been implemented.	There is no independent external assurance over emission and energy data.

Source: Data processed, 2026

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This gap carries both theoretical and practical implications. Theoretically, the findings reinforce the argument of Hahn et al. (2015) that corporate climate transparency is not directly proportional to corporate climate action. Within the signalling theory framework, ANTAM does possess performance worth signalling, in the form of a 13 % emission reduction, a 23 % reduction in energy consumption, and six PROPER awards, but the quality of the signal transmitted is weak because it cannot be verified. As a consequence, the economic benefits of disclosure, such as the reduction in the cost of capital documented by Xu et al. (2024), are unlikely to be realised optimally; Gerged et al. (2021) further show that the relationship between mandatory emission disclosure and the cost of equity capital is U-shaped, so that partial disclosure without measurement infrastructure may fail to deliver the anticipated financing benefits. From an external perspective, the combination of prominent reduction claims and untraceable measurement bases is precisely the configuration that Li et al. (2025) associate with the risk of greenwashing in decarbonization performance, even where the underlying physical activity is genuine. Widianingsih and Kohardinata (2024) similarly find that PROPER recognition alone does not substitute for carbon emission disclosure in shaping foreign investor responses.

The absence of external assurance deserves particular emphasis. Green and Zhou (2013) and Datt et al. (2022) document the international evolution of assurance practices for carbon emission disclosures and show that the level of assurance is a principal determinant of the credibility of emission figures, while Rohani et al. (2023) find that the pursuit of higher levels of carbon assurance is driven both by legitimacy motives and by genuine performance improvement. Xhindole and Tarquinio (2025), examining Italian and Spanish firms, show that assurance practices remain heterogeneous even in jurisdictions with mature reporting regulation. In ANTAM's case, the absence of any assurance statement in the Annual Report means that the emission figures rest entirely on management representation, a condition that Sousa et al. (2026) identify as a critical point of failure for the verifiability of sustainability reports. In parallel, the weakness of the GRI 3-3 disclosure regarding materiality thresholds echoes the finding of Machado et al. (2021) that transparency in materiality analysis remains the least developed element of GRI-based reporting.

In practical terms, these limitations place ANTAM in a vulnerable position in the face of regulatory developments. The implementation of Carbon Economic Value and carbon trading in Indonesia, together with carbon border adjustment mechanisms in export markets, requires emission data that are disaggregated by scope and verified by

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third parties. Without remediation, the information currently available is inadequate as a basis for participation in these mechanisms, and it simultaneously weakens ANTAM's position within the low-carbon-oriented index in which it currently participates. Orozco and Pla-Barber (2026) show that in emerging economies the way firms define their decarbonization boundaries substantially determines whether voluntary climate commitments translate into credible stakeholder engagement.

It should be noted that part of the disclosure limitation may be explained by the Company's reporting architecture, which places the detailed discussion of emissions in the Sustainability Report. Nonetheless, this practice of separation is itself a disclosure quality issue, because investors generally treat the Annual Report as the primary reference document. The global tendency is in fact toward the integration of financial and sustainability information within a single report so that the connectivity between climate risk and financial performance can be assessed in full.

CONCLUSION

Based on the content analysis of the 2024 Annual Report of PT Aneka Tambang Tbk, the following conclusions can be drawn. First, the quality of ANTAM's carbon emission disclosure under the GRI Standards falls into the low category, with a Disclosure Quality Index of 26.19 %, the GRI 305 group recording the lowest index at 19.05 %. Emissions are presented only in aggregate form without separation of Scope 1, 2, and 3, without emission intensity, without ozone-depleting substance emissions and other significant air emissions, and without an explanation of methodology and base year. Second, ANTAM's decarbonization practice is by contrast relatively comprehensive and spans five mitigation hierarchy categories, namely energy source transition, fuel substitution, renewable energy, energy efficiency, and carbon sequestration, supported by carbon governance in the form of a 2019-based roadmap, Board of Directors performance indicators, and a corporate risk register. Third, an accountability gap exists between practice and disclosure, visible across five dimensions: measurement basis, emission scope, targets, attribution, and information reliability.

On the basis of these conclusions, the study offers several recommendations. For the Company, ANTAM is advised to present emissions disaggregated by Scope 1, 2, and 3 together with disclosure of the base year, emission factors, gases covered, and consolidation approach; to establish time-bound quantitative emission reduction targets accompanied by an interim achievement trajectory; to disclose emission intensity

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relative to units of production so that comparison across periods and across firms becomes possible; to carry out quantitative attribution for each decarbonization initiative; and to obtain independent assurance over emission and energy data. For regulators, the findings indicate the need to sharpen technical provisions on the minimum attributes of emission information, particularly scope disaggregation and the assurance requirement, so that the reporting obligation does not stop at formal compliance. For future research, it is recommended to broaden the unit of analysis to include the Sustainability Report and a multi-year time span, to compare several mining issuers, and to test the relationship between the disclosure quality index and market variables such as the cost of capital and firm valuation.

This study is limited by its use of a single document as the unit of analysis and a single reporting period, and by assessment performed by a single researcher, which carries the potential for subjectivity even though this has been minimised through a structured rubric and re-coding. These limitations open space for further research with a multi-rater design and broader document coverage.

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