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DESCRIPTIVE ANALYSIS OF CARBON EMISSION TRENDS, POTENTIAL CARBON TAX BURDEN, AND EMISSION DISCLOSURE LEVELS BASED ON GRI 305 INDICATORS: EVIDENCE FROM ENERGY-SECTOR COMPANIES LISTED ON THE INDONESIA STOCK EXCHANGE, 2022–2024

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Abstract: This study aims to analyze trends in carbon emission volume and intensity, estimate the potential carbon compliance burden under three policy scenarios, and evaluate the level of emission disclosure based on GRI 305 among energy-sector companies listed on the Indonesia Stock Exchange during 2022–2024. A descriptive approach was employed using secondary data from corporate sustainability reports. The sample comprised 39 companies and 117 observations selected through purposive sampling. Emission disclosure was assessed using the 2024 sustainability reports. The data were analyzed using descriptive statistics, scenario analysis, and quantitative content analysis. The scenario analysis included a full-rate scenario as the worst-case scenario, as well as cap-and-tax and cap-and-trade scenarios in which the emissions cap was derived through a top-down mechanism from the 2030 ENDC target using a Linear Reduction Factor and allocated through a grandfathering approach. The results show that carbon emissions tended to increase, particularly Scope 1 emissions, while Scope 2 emissions exhibited a more fluctuating pattern. This increase was accompanied by higher emission intensity, indicating that emissions relative to corporate revenue did not decline during the study period. Estimated carbon compliance costs differed substantially across scenarios. The full-rate scenario generated the highest aggregate burden of IDR 2.20 trillion, followed by the cap-and-trade (emission offset) scenario at IDR 434.90 billion, while the cap-and-tax scenario produced the lowest burden of IDR 273.81 billion. The average Carbon Emission Disclosure Index was 79.83%, with 56.4% of companies classified as well applied to fully applied. However, Scope 3 disclosure and several other emission indicators remained limited. These findings indicate that cap-based mechanisms may reduce the carbon compliance burden while also underscoring the link between fiscal exposure and reporting transparency, highlighting the need for more comprehensive emission disclosure to support the implementation of carbon pricing.

Keywords: Carbon Emissions; Carbon Tax; Carbon Pricing; GRI 305; Emission Disclosure; Energy Sector.

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INTRODUCTION

Climate change has evolved into a multidimensional issue affecting the environment, the economy, social life, and ecosystem sustainability. Rising concentrations of greenhouse gases resulting from human activities, particularly fossil-fuel use and industrial activities, are among the main factors accelerating global warming (Intergovernmental Panel on Climate Change [IPCC], 2023). These conditions require mitigation policies that not only promote measurable emission reductions but also internalize the social costs generated by carbon-emitting activities.

Indonesia faces a major challenge because it is highly vulnerable to climate change while also producing substantial greenhouse gas emissions. The energy sector is one of the main contributors to the national emissions profile. In 2023, energy-sector emissions reached 752,279.84 thousand tonnes CO_2e, accounting for more than half of total national emissions and far exceeding emissions from forestry and land use, the next-largest contributor (Badan Pusat Statistik, 2026). This dominance is associated with the high dependence of energy production and consumption on fossil fuels. Globally, CO_2 emissions from the energy sector also reached a record high of 37.8 gigatonnes in 2024 (International Energy Agency [IEA], 2025). These conditions make the energy sector strategically important in carbon-emission reduction policy.

As part of its commitment to the Paris Agreement, Indonesia's Enhanced Nationally Determined Contribution (ENDC) sets an emissions-reduction target of 31.89% through domestic efforts and 43.20% with international support by 2030. This target serves as a reference for developing national emission-mitigation policies, including the implementation of Carbon Economic Value (Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 2022). The current Carbon Economic Value framework is regulated under Presidential Regulation No. 110 of 2025, covering carbon allocation, carbon trading, performance-based payments, and carbon taxes or levies.

Indonesia's carbon-tax provisions are stipulated in Article 13 of Law No. 7 of 2021 on the Harmonization of Tax Regulations. The law sets a minimum rate of IDR 30,000 per tonne CO_2e, with implementation designed through a cap-and-tax mechanism under which tax is imposed on emissions exceeding a predetermined limit. In addition to the carbon tax, emissions control is also being developed through a cap-and-trade mechanism, allowing companies to meet carbon obligations through the trading of emission allowances or carbon credits. These different instrument designs indicate that the economic consequences of carbon policy are determined not only by a company's emissions volume but also by the emissions cap, tax rate, carbon price, and availability of trading instruments.

Despite the existence of a legal basis, carbon-tax implementation still faces challenges related to the readiness of technical regulations, emissions measurement, reporting and verification systems, cross-sector coordination, and potential impacts on energy costs and the wider economy. Elvani et al. (2025) identify limitations in technical regulations and emissions measurement systems as barriers to implementation in the oil and gas sector. Rahma et al. (2025) also show that broad carbon-tax implementation may raise prices across sectors and create regressive effects for low-income households. Its implementation should therefore be phased, grounded in verifiable emissions data, and accompanied by an assessment of distributional impacts.

Several studies have estimated the potential revenue from a carbon tax in Indonesia. Pratama et al. (2022) estimate that applying the minimum rate of IDR 30,000 per tonne CO_2e to the energy sector could generate state revenue of IDR 23.651 trillion. Meila et al. (2024) report a relatively similar estimate of IDR 23.280 trillion and emphasize the potential use of carbon-tax revenue to support climate-change mitigation. However, these studies rely on a national aggregate approach and

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therefore do not explain variations in emissions volume, emission intensity, and the distribution of potential carbon burdens at the firm level. They also do not compare the economic implications of the full-rate, cap-and-tax, and cap-and-trade scenarios. In practice, each instrument may produce different economic and environmental consequences depending on the tax rate, carbon price, and emissions-allocation mechanism used (Huang et al., 2024).

Firm-level analysis has become increasingly feasible as emissions data are more widely available through sustainability reports. Financial Services Authority Regulation No. 51/POJK.03/2017 requires issuers and public companies to disclose sustainability performance, including environmental aspects and greenhouse gas emissions. This requirement is reinforced by Financial Services Authority Circular Letter No. 16/SEOJK.04/2021. In practice, many companies use GRI 305: Emissions as a reference for disclosing direct emissions, energy indirect emissions, other indirect emissions, emission intensity, and emission-reduction initiatives (Global Reporting Initiative, 2016).

Although an increasing number of companies publish sustainability reports, the quality, depth, and comparability of emissions disclosures remain inconsistent. Hanafi et al. (2025) identify variation in environmental disclosure among Indonesian energy-sector companies. Khoesnadi and Meiden (2025) show that, of the ten companies examined, only three had high-quality disclosure, with the most pronounced weaknesses found in Scope 3 and GRI 305-6 and GRI 305-7. Poliyama et al. (2026) report a similar pattern among IDX LQ45 Low Carbon Leaders companies. The recurrence of this pattern suggests a persistent disclosure gap, although the evidence is not yet sufficient to generalize it as a sector-wide characteristic without broader sample coverage.

Previous studies generally treat carbon-tax estimation and emissions disclosure as separate research objects. Consequently, empirical evidence that integrates emissions trends, emission intensity, potential carbon burden, and disclosure levels at the firm level remains limited. This study addresses that gap using actual data disclosed in the sustainability reports of energy-sector companies listed on the Indonesia Stock Exchange during 2022–2024.

Specifically, this study aims to analyze trends in carbon-emission volume and intensity, estimate and compare potential carbon burdens under full-rate, cap-and-tax, and cap-and-trade scenarios, and evaluate emission disclosure based on GRI 305 indicators. The study contributes an integrated view of emissions performance, economic exposure to carbon policy, and the quality of environmental transparency at the firm level. The findings are expected to inform the development of carbon-tax, carbon-trading, and sustainability-reporting policies in Indonesia.

LITERATURE REVIEW

Externality Theory and Pigouvian Tax

Externality theory explains that economic activity may impose costs on parties not directly involved in a transaction. When these costs are not reflected in market prices, producers consider only private costs, causing output and emissions to potentially exceed the socially optimal level (Hackett, 2006; Tietenberg & Lewis, 2018). In an environmental context, carbon emissions constitute a negative externality because their impacts on health, ecosystems, and climate change are not fully borne by the firms generating the emissions.

One instrument for internalizing these costs is a Pigouvian tax, which is imposed on polluting activities according to the magnitude of the external damage they create. A carbon tax is a form of Pigouvian tax because it imposes a cost on each unit of emissions and is therefore expected to encourage energy efficiency, reduce fossil-fuel use, and promote the adoption of low-carbon technologies.

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Environmental taxes may also generate a double dividend, consisting of both lower emissions and public revenue that can be used to support the energy transition and climate-change mitigation (Goulder, 1995). In this study, externality theory provides the basis for explaining carbon taxation and estimating the potential carbon burden on companies.

Legitimacy Theory

Legitimacy theory holds that corporate continuity depends on the alignment of a company's activities with societal values, norms, and expectations. Companies require social acceptance to maintain access to resources, markets, and stakeholder support (Dowling & Pfeffer, 1975).

When corporate activities generate substantial environmental impacts, companies may face a legitimacy gap. One strategy for obtaining or maintaining legitimacy is to transparently disclose social and environmental information in corporate reports (Suchman, 1995; O'Donovan, 2002).

For energy-sector companies, disclosure of emission volumes, emission intensity, emission sources, and emission-reduction programs can demonstrate environmental responsibility. However, disclosure may also be selective, emphasizing information that supports a positive corporate image. In this study, legitimacy theory is used to explain variation in corporate emissions disclosure based on GRI 305 indicators.

Carbon Tax and Carbon Economic Value Instruments

Carbon-emission control in Indonesia is implemented through the Carbon Economic Value framework regulated by Presidential Regulation No. 110 of 2025, which replaced Presidential Regulation No. 98 of 2021. The regulation governs carbon allocation, carbon trading, performance-based payments, carbon taxes or levies, and monitoring, reporting, and evaluation systems. Within this framework, the government establishes an emissions limit or cap for each entity, which forms the basis for two compliance mechanisms: cap-and-tax and cap-and-trade.

Under the cap-and-tax mechanism, tax is imposed on emissions exceeding the established limit. The carbon tax itself is regulated under Article 13 of Law No. 7 of 2021, with a minimum rate of IDR 30.00 per kilogram CO_2e or IDR 30,000 per tonne CO_2e, while taking into account the carbon price in the carbon market. Under the cap-and-trade mechanism, entities whose emissions exceed their allocation may meet their obligations through the trading of emission allowances or the use of carbon units without incurring tax, provided that the shortfall is covered through the carbon-market mechanism.

Accordingly, cap-and-tax and cap-and-trade are equivalent compliance instruments within the Carbon Economic Value framework, but they operate through different channels: direct fiscal charges under cap-and-tax and a market mechanism under cap-and-trade. These differences form the basis for the analytical scenarios developed in this study.

Carbon Emissions and Emission Intensity

Carbon emissions are releases of greenhouse gases that contribute to global warming and are generally expressed in tonnes of carbon dioxide equivalent, or tonnes CO_2e (Intergovernmental Panel on Climate Change [IPCC], 2023). Corporate emissions are typically measured using activity data, emission factors, and global warming potential values.

The Greenhouse Gas Protocol divides corporate emissions into three scopes. Scope 1 comprises direct emissions from sources owned or controlled by the company. Scope 2 comprises indirect emissions from purchased energy such as electricity, heat, or steam. Scope 3 comprises other indirect emissions from the company's upstream and downstream value chain (World Resources Institute & World Business Council for Sustainable Development, 2004).

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In addition to absolute volume, carbon performance can be assessed through emission intensity, defined as the ratio of emissions to an activity indicator such as revenue or production. Emission intensity enables an assessment of carbon efficiency because an increase in absolute emissions is not necessarily accompanied by an increase in intensity.

Emission-intensity analysis is also related to the concept of decoupling. Absolute decoupling occurs when economic activity increases while emissions decline, whereas relative decoupling occurs when both activity and emissions increase but emissions grow more slowly. Conversely, rising emission intensity indicates that growth in economic activity has not yet been decoupled from growth in emissions.

Sustainability Reporting and GRI 305 Disclosure

Sustainability reports are used by companies to communicate their economic, social, governance, and environmental performance to stakeholders. In Indonesia, the obligation for issuers and public companies to prepare sustainability reports is regulated by Financial Services Authority Regulation No. 51/POJK.03/2017 and reinforced by Financial Services Authority Circular Letter No. 16/SEOJK.04/2021.

One of the standards widely used for emissions disclosure is GRI 305: Emissions. The standard comprises seven indicators: Scope 1, Scope 2, and Scope 3 emissions; emission intensity; emission reductions; ozone-depleting substances; and NOx, SOx, and other significant air emissions (Global Reporting Initiative, 2016).

Adequate disclosure not only reports total emissions but also explains the methodology, organizational boundaries, emission factors, gas types, and base year. This information helps investors and regulators evaluate carbon exposure, climate risk, and the quality of a company's environmental management (Choi et al., 2013). Accordingly, the level of GRI 305 disclosure is used as a measure of corporate environmental transparency and accountability.

Previous Studies and Research Gap

Carbon-tax research in Indonesia remains dominated by a national aggregate approach. Pratama et al. (2022) estimate potential carbon-tax revenue from the energy sector at IDR 23.651 trillion, while Meila et al. (2024) estimate IDR 23.280 trillion. However, neither study shows the distribution of potential carbon burdens at the firm level.

Huang et al. (2024) find that carbon taxes, cap-and-trade, and mixed policies can produce different economic and environmental effects. The relative advantages of each scheme are influenced by tax rates, carbon prices, and emissions allocation. However, their study uses a hypothetical model and does not employ actual data from Indonesian energy-sector companies.

Regarding implementation, Elvani et al. (2025) show that carbon-tax implementation continues to face limitations in technical regulation, measurement, reporting, and verification systems, as well as emissions-data availability. Rahma et al. (2025) also find that broad carbon-tax implementation may raise prices and generate distributional impacts, making a phased approach more realistic.

With respect to disclosure, Hanafi et al. (2025) find that energy companies exhibit a relatively high level of reporting compliance, although variation remains across indicators. Khoesnadi and Meiden (2025), Poliyama et al. (2026), and Veisi (2025) show that Scope 1 and Scope 2 disclosures are more consistent than disclosures of Scope 3, ozone-depleting substances, and other air emissions.

Based on previous research, three main gaps can be identified. First, carbon-tax estimates continue to rely on aggregate data and therefore do not capture variation in burdens across companies. Second, comparisons of full-rate, cap-and-tax, and cap-and-trade scenarios using actual

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emissions data remain limited. Third, analyses of emissions trends, potential carbon burdens, and GRI 305 disclosure are generally conducted separately.

This study addresses these gaps by integrating an analysis of trends in emission volume and intensity, simulations of three carbon-policy scenarios, and an evaluation of GRI 305 disclosure among energy-sector companies listed on the Indonesia Stock Exchange during 2022–2024.

Research Conceptual Framework

The study's conceptual framework links three main aspects. First, emissions from energy-sector companies are viewed as a negative externality and analyzed through changes in emissions volume and intensity to identify the direction of carbon performance and the state of decoupling.

Second, based on externality theory and the concept of a Pigouvian tax, corporate emissions may generate economic consequences through carbon charges. These consequences are estimated using the full-rate, cap-and-tax, and cap-and-trade scenarios.

Third, legitimacy theory is used to explain corporate transparency through the level of disclosure across the seven GRI 305 indicators. The disclosure measurement is then mapped against the potential carbon burden to illustrate the relationship between carbon exposure and corporate transparency.

Thus, this study integrates emissions performance, the economic consequences of carbon policy, and the quality of environmental reporting at the firm level.

METHOD

According to Sugiyono (2023), descriptive statistics are used to describe collected data as they are. On this basis, the present study adopts a descriptive approach to characterize carbon-emission trends, estimate potential carbon compliance burdens, and evaluate the level of emissions disclosure among energy-sector companies without testing causal relationships or drawing inferential generalizations. The burden estimates are simulation-based because cap parameters for the non-power-generation energy sector and broad carbon-tax implementation were not yet in force during the study period.

The population comprised energy-sector companies listed on the Indonesia Stock Exchange during 2022–2024. The sample was selected using purposive sampling based on the criteria that companies were continuously listed, published sustainability reports, and disclosed Scope 1 and Scope 2 emissions in tonnes CO_2e. These criteria yielded 39 companies and 117 observations.

Secondary data were obtained from corporate sustainability and annual reports, Law No. 7 of 2021, Presidential Regulation No. 110 of 2025, the 2022 ENDC, and IDXCarbon trading and project data. The study variables comprised Scope 1 emissions, Scope 2 emissions, emission intensity, estimated carbon compliance burden, and the Carbon Emission Disclosure Index (CEDI). Emission intensity was calculated as total Scope 1 and Scope 2 emissions divided by corporate revenue, expressed in tonnes CO_2e per IDR billion.

The potential carbon compliance burden was estimated for Scope 1 emissions under three scenarios. Scenario 1 (full rate) calculates $TP_{i,t} = E1_{i,t} \times \tau$, where τ is IDR 30,000 per tonne CO_2e. This scenario serves as an upper-bound benchmark or worst-case scenario. Scenario 2 (cap-and-tax) imposes tax on emissions exceeding the company's cap. Scenario 3 (cap-and-trade using an emission-offset approach) applies the same cap, but excess emissions are first covered through the purchase of SPE-GRK certificates; any remaining emissions that cannot be offset are subject to tax.

The cap-setting procedure in this study follows a top-down approach within an emissions-trading design framework, whereby the national emissions-reduction target is translated into emissions limits allocated to regulated entities (Partnership for Market Readiness [PMR] &

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International Carbon Action Partnership [ICAP], 2021). The emissions-reduction target (ΔE) was calculated as the difference between the projected 2030 BAU emissions of the energy sector, at 1,669 million tonnes CO_2e, and the unconditional ENDC target of 1,311 million tonnes CO_2e, yielding ΔE of 358 million tonnes CO_2e, or 21.45% of BAU. This percentage was distributed over an eight-year reduction period (2022–2030) to derive a Linear Reduction Factor (LRF) of 2.68125% per year. The total sample cap was then derived from the aggregate historical average Scope 1 emissions of all sample companies during 2022–2024 and allocated through grandfathering according to each company's share of historical emissions (Pang & Duan, 2016; PMR & ICAP, 2021). In the equations, E_hist denotes the aggregate historical average Scope 1 emissions of the sample, while $E\_hist_{,i}$ denotes the historical average Scope 1 emissions of company i.

$$\Delta E = E\_BAU{,}2030 - E\_ENDC{,}2030 = 358 \text{ million tonnes } CO_2e$$
$$LRF = (\Delta E \ / \ E\_BAU{,}2030) \div (2030 - 2022) = 2.68125\% \text{ per year}$$
$$Cap\_total_{,t} = E\_hist \times [1 - LRF \times (t - 2022)]$$
$$Cap_{i,t} = (E\_hist_{,i} \ / \ E\_hist) \times Cap\_total_{,t}; \ \ EKP_{i,t} = MAX(0, E1_{i,t} - Cap_{i,t})$$

Under the cap-and-tax scenario, the burden is calculated as $BP_{i,t} = EKP_{i,t} \times \tau$. Under the offset scenario, the purchased volume is $MIN(EKP_{i,t}, V\_SPE)$, while the remaining obligation is $MAX(0, EKP_{i,t} - V\_SPE)$. Market parameters were drawn from three SPE-GRK projects listed on IDXCarbon through November 2024, with a total listed volume of 1,777,141 tonnes CO_2e and an average transaction price of IDR 47,650.07 per tonne CO_2e (Bursa Efek Indonesia, 2024). Because IDXCarbon only began operating in September 2023, prices and volumes for 2022–2023 were assumed to be equal to those observed in November 2024. The entire listed volume was assumed to be available and independently usable by each company; therefore, the simulation does not model competition among buyers, price changes, or market liquidity.

The level of emissions disclosure was measured through quantitative content analysis of the 2024 sustainability reports. The instrument consisted of **37 disclosure items** based on GRI 305-1 through GRI 305-7. Each item was assigned a score of 1 if disclosed and 0 if not disclosed, and the scores were then converted into a CEDI percentage using an unweighted index (Hossain, 2003; Milne & Adler, 1999).

The CEDI values were then mapped against the estimated carbon burden using a scatter plot. The median values of both variables were used to divide companies into four groups: high burden–high disclosure, high burden–low disclosure, low burden–low disclosure, and low burden–high disclosure.

RESULTS AND DISCUSSION

Overview of the Research Sample

Using purposive sampling, 39 energy-sector companies met all sample criteria. Over the 2022–2024 observation period, 117 observations were analyzed. The sample companies represented seven subindustries based on the Indonesia Stock Exchange Industrial Classification (IDX-IC). The sample distribution by subindustry is presented in Table 1.

Table 1. Sample Distribution by Subindustry

Subindustry	Number of Companies	Share (%)
Coal Production	21	53.85%
Coal Distribution	1	2.56%
Oil, Gas, and Coal Services and Equipment	7	17.95%
Oil and Gas Drilling Services	2	5.13%

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Subindustry	Number of Companies	Share (%)
Oil and Gas Storage and Distribution	5	12.82%
Oil and Gas Production and Refining	2	5.13%
Alternative Energy Equipment	1	2.56%
Total	**39**	100.00%

Source: Authors' calculations (2026).

The sample was dominated by the coal production subindustry, with 21 companies (53.85%). Seven companies belonged to the oil, gas, and coal services and equipment subindustry, while five operated in oil and gas storage and distribution. Companies that did not publish complete sustainability reports or did not disclose Scope 1 and Scope 2 emissions in tonnes CO_2e were excluded from the sample.

Descriptive Statistics

The descriptive statistics indicate substantial variation in emissions volume and disclosure levels among energy-sector companies. Summary statistics for emissions and CEDI are presented in Table 2, while estimated carbon burdens under the three scenarios are presented in Table 3.

Table 2. Descriptive Statistics of Emissions and CEDI

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Scope 1 Emissions (tonnes CO_2e)	117	31.88	5,710,288	627,491.90	1,057,587.48
Scope 2 Emissions (tonnes CO_2e)	117	2.88	453,017	23,880.99	54,660.16
CEDI (%)	39	48.65	100.00	79.83	15.60

Source: Authors' calculations (2026).

Table 3. Descriptive Statistics of Estimated Carbon Burden

Scenario	N	Minimum (IDR)	Maximum (IDR)	Mean (IDR)
Full Rate	117	956,400	171,308,640,000	18,824,756,856
Cap-and-Tax	117	0	52,698,058,400	2,340,270,510
Cap-and-Trade (Emission Offset)	117	0	83,702,202,785	3,717,134,990

Source: Authors' calculations (2026).

Scope 1 emissions averaged 627,491.90 tonnes CO_2e, with a standard deviation of 1,057,587.48 tonnes CO_2e. A standard deviation greater than the mean indicates substantial variation in direct emissions across companies. Descriptively, Scope 1 emissions were also far higher than Scope 2 emissions.

Scope 2 emissions averaged 23,880.99 tonnes CO_2e, with a standard deviation of 54,660.16 tonnes CO_2e. Emission intensity ranged from 0.054 to 3,865.506 tonnes CO_2e per IDR billion of revenue, with a standard deviation of 608.515. This range indicates substantial differences across companies in emissions efficiency relative to revenue.

Estimated carbon burdens also differed markedly across scenarios. The full-rate scenario produced the highest average burden at IDR 18,824,756,856. The average burden under the cap-and-tax scenario was IDR 2,340,270,510, whereas cap-and-trade generated an average compliance cost of IDR 3,717,134,990.

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The minimum value of IDR 0 under the cap-and-tax and cap-and-trade scenarios indicates that some companies had actual emissions that did not exceed their emissions cap. The cap-and-trade cost was higher than the cap-and-tax cost because the carbon-certificate price used in the simulation exceeded the minimum carbon-tax rate.

The CEDI results show an average disclosure level of 79.83%. This indicates that energy-sector companies generally disclosed most of the information required under GRI 305, although the completeness of disclosure still varied across companies.

DISCUSSION

Carbon-Emission and Emission-Intensity Trends

Across the 39 sample companies, aggregate Scope 1 emissions increased from 19,993,028.20 tonnes CO_2e in 2022 to 26,589,305.85 tonnes CO_2e in 2023 (+32.99%) and 26,834,217.69 tonnes CO_2e in 2024 (+0.92%). Although the rate of increase slowed, there was no indication of an overall decline in emissions during the observation period. At the subindustry level, the pattern was uneven: Coal Production recorded the largest increase (9.4 million to 17.4 million tonnes CO_2e), consistent with the expansion of national coal production and exports (687 million tonnes in 2022 and a projected 695 million tonnes in 2023; Kementerian ESDM, 2023), whereas Oil & Gas Production and Refining and Coal Distribution declined consistently. At the firm level, heterogeneity was high, as reflected in standard deviations exceeding the mean. MEDC and BUMI consistently ranked among the largest emissions contributors, while HRUM, TCPI, and COAL—all part of the coal value chain—recorded sharp increases in particular years (HRUM increased almost 44-fold in 2023–2024). This indicates that the aggregate increase in this subindustry was driven by a small number of companies undergoing the most aggressive expansion rather than by a uniform trend across the subindustry.

In contrast to Scope 1, Scope 2 emissions fluctuated, declining from 861,460.98 tonnes CO_2e in 2022 to 720,155.38 tonnes CO_2e in 2023 (−16.40%), before surging to 1,212,459.44 tonnes CO_2e in 2024 (+68.36%). This fluctuating pattern is consistent with the nature of Scope 2 as indirect emissions from electricity consumption, which are more sensitive to changes in energy demand arising from capacity expansion or shifts in business structure than Scope 1 emissions, which more directly follow production volumes. At the subindustry level, the largest increase occurred in Oil & Gas Production and Refining (more than doubling), while Oil & Gas Storage and Distribution and Coal Distribution declined, consistent with differences in electricity intensity across value chains. At the firm level, heterogeneity was also high: 88% of observations were below 50,000 tCO_2e, with a median of 5,102 and a mean of 23,881 tCO_2e. The aggregate increase in 2024 was largely driven by one observation: HRUM rose from 4,655 to 453,017 tonnes CO_2e (>97-fold), consistent with the consolidation of subsidiaries into downstream nickel processing through electricity-intensive RKEF smelters (PT Harum Energy Tbk., 2025). This finding highlights that the current carbon-tax scope, which focuses on Scope 1, does not yet capture emissions surges arising from business transformation toward electricity-intensive activities.

Aggregate emission intensity increased from 29.01 tonnes CO_2e per IDR billion in 2022 to 43.61 in 2023 (+50.4%) and 46.67 in 2024 (+7.0%). The sharp increase between 2022 and 2023 coincided with a steep decline in the benchmark coal price (HBA), from US$305.21/tonne to US$117.38/tonne (a decline of more than 60% within a year). Because intensity is calculated relative to net revenue, the commodity-price correction reduced the denominator faster than absolute emissions declined, causing the ratio to rise even though this does not necessarily indicate a deterioration in underlying environmental performance. This pattern was most evident in Coal Production, the subindustry most exposed to HBA volatility, while five of the other seven subindustries remained relatively

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stable. Nevertheless, four company observations (DEWA, ADRO, PGAS, and PTBA) displayed the opposite pattern—total emissions increased while intensity declined—confirming that a reduction in intensity does not always reflect successful absolute emission reduction but may instead result from revenue growing faster than emissions. For ADRO, PTBA, and PGAS, this pattern was associated with business diversification and downstream expansion (the Adaro Energy 4.0 transformation, downstream coal processing into artificial graphite, and expansion of LNG trading and gas infrastructure), whereas for DEWA it was more closely related to operational energy-efficiency initiatives, including the use of solar panels and fleet renewal of heavy equipment.

Trend classification shows that the fluctuating group was the largest category for both Scope 1 and Scope 2, as presented in Table 4.

Table 4. Classification of Corporate Emission Trends, 2022–2024

Trend Classification	Scope 1	Share (%)	Scope 2	Share (%)
Consistently Increasing	14 companies	35.90%	14 companies	35.90%
Consistently Decreasing	10 companies	25.60%	6 companies	15.40%
Fluctuating	15 companies	38.50%	19 companies	48.70%
Total	**39 companies**	100.00%	**39 companies**	100.00%

Source: Authors' calculations (2026).

Table 4 shows that companies with consistently declining emissions accounted for only 25.6% of the sample for Scope 1 and 15.4% for Scope 2. Thus, most companies did not exhibit a stable emission-reduction pattern during the study period.

From the perspective of externality theory, this pattern is consistent with a setting in which the social costs of emissions have not yet been fully internalized into corporate cost structures (Hackett, 2006). As long as carbon pricing is not broadly implemented, market demand, commodity prices, and operational expansion remain key contextual drivers of changes in emissions (Huang et al., 2024). Accordingly, these findings are better interpreted as a descriptive picture of energy-sector emissions before broad carbon-tax implementation rather than as a test of the relative magnitude of each factor's influence. This context is consistent with the ex-ante simulation study by Rahma et al. (2025), which uses a Social Accounting Matrix approach to project the impact of carbon taxation on sectoral prices and household living costs, given that the policy has not yet been implemented on a binding, economy-wide basis in Indonesia. The similarity in context indicates that the present results can be viewed as a snapshot of pre-implementation conditions and as a useful starting point for future carbon-pricing policy design.

4.2.2. Analysis of Potential Carbon Tax Burden under Alternative Policy Scenarios

The simulation results show that policy design produces substantial differences in carbon burdens. A comparison of the three scenarios is presented in Table 5.

Table 5. Comparison of Estimated Carbon Burden under Three Scenarios

Metric	Full Rate (Upper-Bound Benchmark)	*Cap-and-Tax*	Cap-and-Trade (Emission Offset)
Total emissions / emissions subject to obligation, 2022–2024 (tonnes CO_2e)	73,416,551.74	9,127,054.98	9,127,054.98

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Metric	Full Rate (Upper-Bound Benchmark)	*Cap-and-Tax*	Cap-and-Trade (Emission Offset)
Estimated burden, 2022 (IDR)	599,790,845,950	27,691,383,649	43,983,210,766
Estimated burden, 2023 (IDR)	797,679,175,553	113,057,234,536	179,572,831,688
Estimated burden, 2024 (IDR)	805,026,530,700	133,063,031,475	211,348,751,392
Total estimated burden, 2022–2024 (IDR)	**2,202,496,552,202**	**273,811,649,659**	**434,904,793,845**
Mean per observation (IDR)	18,824,756,856	2,340,270,510	3,717,134,990
Minimum (IDR)	956,400	0	0
Maximum (IDR)	171,308,640,000	52,698,058,400	83,702,202,785

Source: Authors' calculations (2026).

The Full-Rate Scenario, used as the worst-case scenario, produced the highest estimate (IDR 2.20 trillion) because all Scope 1 emissions were subject to the tax rate without any deduction. The burden under this scenario was concentrated among a small number of large companies: the five companies with the highest estimates were MEDC, BUMI, DOID, TCPI, and TOBA, four of which belong to the Coal Production subindustry. This is consistent with MEDC and BUMI also being recorded as the largest Scope 1 emissions contributors throughout the study period.

The Cap-and-Tax Scenario produced a much lower estimate (IDR 273.81 billion, approximately 12.4% of the full-rate scenario) because tax was imposed only on the 9.13 million tonnes CO_2e exceeding the cap; emissions remaining within the allocated limit were not subject to the obligation. This mechanism creates an incentive that is absent under the Full-Rate Scenario: companies that reduce emissions faster than the annual cap-reduction rate (2.68% per year, derived from the 2030 Enhanced NDC target) can become fully exempt from tax in that year, as observed for several sample companies.

The Cap-and-Trade Scenario generated a higher cost than Cap-and-Tax (IDR 434.90 billion), even though the emissions base subject to the obligation was identical, because the SPE price on IDXCarbon (IDR 47,650.07/tonne) exceeded the minimum carbon-tax rate (IDR 30,000/tonne). Across all 39 sample companies and all three observation years, the volume of SPE units available in the market (1,777,141 tonnes CO_2e) was never exceeded by the requirement of any single company-year. Consequently, all obligations could be met through SPE purchases without any residual direct tax. However, because the market price of SPE units was higher than the tax rate, the total compliance cost under this scheme exceeded that of Cap-and-Tax, indicating that, at the current SPE price level, the economic incentive to choose the offset route remains relatively weak.

All three schemes essentially represent forms of Pigouvian taxation with different coverage of the tax base, and the results underscore a trade-off among breadth of coverage, cost certainty, and market flexibility. The magnitude of the Full-Rate Scenario estimate is consistent with projections by Pratama et al. (2022) and Meila et al. (2024), who estimate that Indonesia's energy-sector carbon-tax revenue could exceed IDR 23 trillion in 2025 if the full tax base were applied, highlighting the much greater fiscal leverage of this approach relative to cap-based schemes. Conversely, a phased approach such as Cap-and-Tax is more consistent with the Swedish precedent discussed by

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Purwienanti and Purwanto (2023), which suggests that sustained carbon taxation can reduce emissions without constraining economic growth, and with Rahma et al. (2025), who recommend focusing carbon taxation in Indonesia on high-emitting sectors or entities to minimize increases in living costs. Such an approach is also more realistic given the current limitations of monitoring, reporting, and verification (MRV) systems and verified emissions data in Indonesia (Elvani et al., 2025). Meanwhile, the cost difference between Cap-and-Tax and Cap-and-Trade confirms the finding of Thamrin et al. (2025) that carbon taxation provides cost certainty but does not guarantee emissions reductions, whereas carbon trading constrains emissions more directly but exposes participants to market-price fluctuations. This is consistent with Huang et al. (2024), who argue that the relative advantage of the two instruments depends on the position of the market carbon price relative to the applicable tax rate.

Thus, cap-based mechanisms—both Cap-and-Tax and Cap-and-Trade—have the potential to reduce the carbon-tax burden relative to the Full-Rate Scenario. However, their effectiveness still depends on credible cap setting, allocation methods that do not create incentives to preserve historical emissions, and an adequate MRV system (Elvani et al., 2025; PMR & ICAP, 2021). The three scenarios in this study are not intended to recommend a specific cap level for government adoption; rather, they are designed to map the sensitivity of compliance burdens to alternative instrument designs. The results therefore illustrate trade-offs among schemes rather than support a single policy recommendation.

Level of Emissions Disclosure Based on GRI 305

The measurement results show that the average Carbon Emission Disclosure Index among energy-sector companies was 79.83%, with a median of 81.08%. This indicates that most companies disclosed the majority of information required by GRI 305, although the completeness of disclosure still varied. The distribution of companies by disclosure category is presented in Table 6.

Table 6. Distribution of Emissions Disclosure Levels

Category	Score Range	Number of Companies	Share (%)
Fully Applied	100%	10	25.60%
Well Applied	76%–99%	12	30.80%
Partially Applied	41%–75%	17	43.60%
Limited Disclosure	1%–40%	0	0.00%
Not Applied	0%	0	0.00%
Total		**39**	100.00%

Source: Authors' calculations (2026).

Table 6 shows that 10 companies were classified as Fully Applied, 12 as Well Applied, and 17 as Partially Applied. No companies were classified as Limited Disclosure or Not Applied.

The relatively high disclosure level can be explained through legitimacy theory. Energy-sector companies face public and regulatory pressure because their activities have material environmental impacts. Emissions disclosure is one way for companies to demonstrate accountability and maintain social legitimacy (Suchman, 1995). This finding is consistent with Hanafi et al. (2025), who report relatively high sustainability-reporting compliance among energy companies.

Nevertheless, disclosure levels still vary across individual GRI 305 indicators, as shown in Table 7.

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Table 7. Disclosure Level for Each GRI 305 Indicator

Indicator	Disclosure Item	Number of Companies	Disclosure Rate
GRI 305-1	Direct GHG emissions or Scope 1	39	100.00%
GRI 305-2	Energy indirect GHG emissions or Scope 2	39	100.00%
GRI 305-3	Other indirect GHG emissions or Scope 3	20	51.28%
GRI 305-4	GHG emissions intensity	39	100.00%
GRI 305-5	Reduction of GHG emissions	38	97.44%
GRI 305-6	Emissions of ozone-depleting substances	12	30.77%
GRI 305-7	NOx, SOx, and other significant air emissions	24	61.54%

Source: Authors' calculations (2026).

GRI 305-1, GRI 305-2, and GRI 305-4 were disclosed by all companies, while GRI 305-5 was disclosed by 97.44% of companies. By contrast, GRI 305-3, GRI 305-6, and GRI 305-7 had lower disclosure rates.

The low level of Scope 3 disclosure is associated with the complexity of data collection across the value chain because these emissions arise from activities of parties outside the company's direct control, such as suppliers or customers. Reporting therefore requires the involvement of external stakeholders who may not always cooperate or possess adequate emissions-recording systems (Hettler & Graf-Vlachy, 2024). Ozone-depleting substances and other air emissions, meanwhile, are not always considered material because they are more relevant to certain subindustries, such as mining, than to other energy subindustries, as also found in the mining sector by Khoesnadi and Meiden (2025).

This pattern indicates that companies are more consistent in disclosing information that is easy to measure and directly related to core operations, whereas indicators requiring additional data or considered less material tend to be omitted. This finding is consistent with Poliyama et al. (2026), who suggest that the gap is systemic rather than merely a characteristic of the present sample.

Mapping Carbon Burden and Disclosure Level

Mapping the estimated carbon burden under the full-rate scenario against CEDI values shows that high carbon exposure is not always accompanied by a high level of disclosure. Companies are distributed across four quadrants without forming a clear linear pattern.

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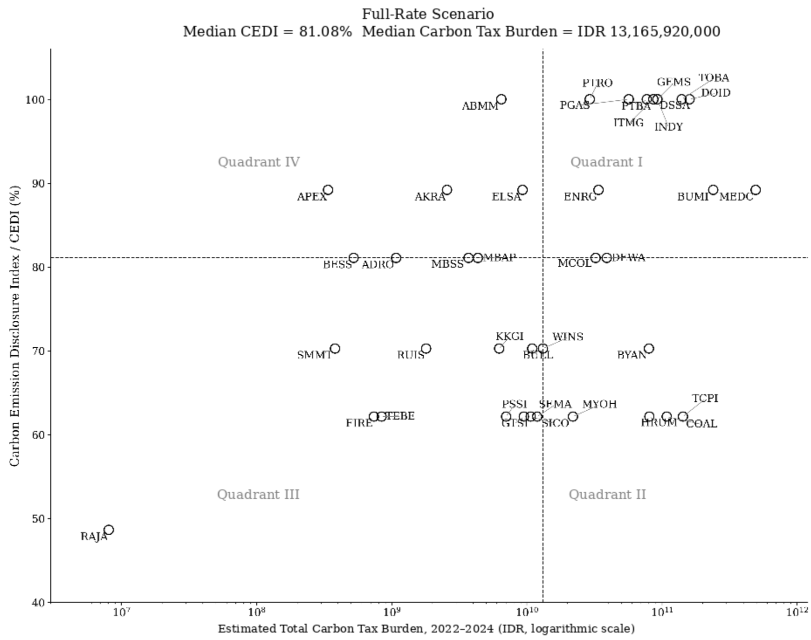

Figure 1. Mapping of Estimated Carbon Tax Burden and Carbon Emission Disclosure Index

Source: Authors' calculations (2026).

The high-burden, high-disclosure group displays a pattern consistent with legitimacy theory, namely high fiscal exposure accompanied by high transparency. The high-burden, low-disclosure group is the most relevant for regulators because it may represent a legitimacy gap—substantial environmental impact combined with limited information accountability. The low-burden, low-disclosure group reflects companies that have not yet faced substantial fiscal or legitimacy pressure to expand their emissions disclosure. The low-burden, high-disclosure group demonstrates disclosure beyond what would be expected from its fiscal-risk exposure and may be interpreted as an anticipatory legitimacy strategy as well as a signal of governance quality to investors.

This mapping suggests that carbon pricing and disclosure standards can function as complementary instruments in climate governance: carbon pricing creates an economic incentive to reduce emissions, while disclosure strengthens accountability regarding emission sources and management strategies.

CONCLUSION

This study shows that, among 39 energy-sector companies during 2022–2024, Scope 1 emissions tended to increase while Scope 2 emissions fluctuated. The increase was accompanied by rising emission intensity, indicating that emissions relative to corporate revenue did not decline during the study period. Firm-level emissions dynamics were highly heterogeneous, with fluctuating patterns being the most dominant, suggesting that emissions trajectories were shaped more by company-specific characteristics than by a uniform sector-wide pattern.

The simulation of three policy scenarios produced substantial differences in the estimated burden. The Full-Rate Scenario, serving as the upper-bound benchmark, generated the highest estimate (IDR 2.20 trillion), followed by Cap-and-Trade (IDR 434.90 billion), while Cap-and-Tax produced the lowest estimate (IDR 273.81 billion). Cap-based mechanisms substantially reduced the burden because obligations applied only to emissions above historical allocations. The cost difference between Cap-and-Tax and Cap-and-Trade was determined by the position of the SPE-GRK price relative to the minimum tax rate rather than by limitations in carbon-credit volume.

The level of GRI 305 disclosure was relatively high, with an average CEDI of 79.83%. Indicators related to core operational activities were almost fully disclosed, whereas Scope 3, ozone-depleting substances, and other air emissions remained less frequently disclosed because of measurement complexity and limited relevance for some subindustries. Mapping CEDI against potential carbon burden shows that disclosure transparency does not necessarily increase with fiscal exposure, as some companies exhibited high exposure but low disclosure.

Overall, the findings indicate that carbon pricing and disclosure standards have the potential to operate as complementary rather than substitutive instruments in firm-level climate governance. For regulators, the results support consideration of phased carbon-pricing implementation that prioritizes the largest emitters, improvements in cap-allocation methods, and stronger disclosure guidance and MRV systems. For energy-sector companies, the findings underscore the importance of expanding the completeness of emissions disclosure at an early stage, given that future sustainability-reporting standards are likely to demand greater transparency. For investors, the combination of disclosure indicators and fiscal carbon exposure may provide an additional basis for assessing transition risk and corporate climate governance.

This study has several limitations. Estimates of the potential carbon burden are based on scenario simulations constructed from the policy parameters and provisions in effect at the time of the study. The results are therefore illustrative and do not represent the actual burden that would arise under full carbon-tax implementation, particularly because the final policy design may still change. The Cap-and-Trade simulation also uses SPE-GRK prices and volumes recorded on IDXCarbon during the study period; consequently, the results cannot be generalized to carbon-market conditions in other periods. Future studies are encouraged to apply inferential quantitative approaches once the carbon tax is formally implemented and to examine alternative cap-allocation methods such as benchmarking.

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