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GHG Emission Volume, Carbon Disclosure Quality on Firm Value: The Moderating Role of Institutional Ownership

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Abstract

Growing global greenhouse gas emissions are exerting more pressure on companies to demonstrate responsibility regarding climate issues. This research examines the effect of GHG emission volume and carbon disclosure quality on firm value among energy companies listed on the Indonesia Stock Exchange during 2020-2024, with institutional ownership as a moderating variable. Using panel data from 65 firm-year observations across 13 purposively selected companies, GHG emissions volume, carbon disclosure quality, firm value, and institutional ownership were measured and analyzed using Moderated Regression Analysis with a Fixed Effects Model. Results show that GHG Emission Volume has a negative but statistically insignificant effect on firm value, whereas carbon disclosure quality has a positive and marginally significant effect in the moderated model. Institutional ownership exerts a positive and significant direct effect on firm value, yet fails to significantly moderate either the GHG emission volume-firm value or the carbon disclosure quality-firm value relationship. These findings imply that energy companies should prioritize carbon risk management alongside governance improvements, while regulators should incentivize higher-quality carbon reporting to enhance the value relevance of GRI-305 disclosures for domestic institutional investors. A robustness check using Tobin's Q confirms the consistency of the institutional ownership effect across alternative proxies for firm value.

JEL Classification: M41, Q56, G32, G34

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Introduction

One of the most significant threats to the current international financial system is climate change. The continuous buildup of greenhouse gas (GHG) levels in the atmosphere, driven largely by industrial operations and fossil fuel combustion, has pushed global average temperatures to 1.6 °C above pre-industrial levels in 2024, the first year on record to exceed the 1.5 °C threshold (Copernicus Climate Change Service, 2025). To prevent further ecological and economic disruption, the IPCC (2023) calls for a 43% reduction in GHG emissions by 2030 relative to 2019 levels, a target that underpins the legally binding Paris Agreement of 2015, which obligates each member state to establish nationally determined emission reduction targets through the Nationally Determined Contribution (NDC) mechanism (UNFCCC, 2015).

In Indonesia, this pressure converges most heavily on the energy sector. The sector accounted for 1.383 Gt CO2e or around 69.01% of national emissions in 2022 by Republic of Indonesia (2025), and is a primary driver behind Indonesia's position as the sixth-largest global GHG emitter in 2024 (Crippa et al., 2025). Given this scale of contribution, energy companies face the most immediate demand to demonstrate measurable carbon accountability, not only to regulators but also to capital market participants who increasingly treat emission performance as material financial information rather than a peripheral disclosure item.

This shift toward treating carbon information as financially material is reinforced by a series of Indonesian and international regulatory developments. The Financial Services Authority introduced POJK No.51/PJOK.03/2017, which obligates listed companies to disclose sustainability information, including carbon emissions, while Presidential Regulation No. 98 of 2021 introduces the legal basis for carbon pricing through the Economic Value of Carbon mechanism. The launch of IDXCarbon on September 26,2023, 2023, recorded a cumulative trading volume of 908.018 tons of CO2e worth IDR50.64 billion by the end of 2024 (Otoritas Jasa Keuangan, 2024). Domestically, the implementation of the Sustainable Finance Roadmap Phase II 2021-2025 further reinforces this trajectory by embedding sustainability principles across the broader national financial system, including environmental disclosure and emissions transparency (Otoritas Jasa Keuangan, 2021). At the international level, the adoption of IFRS S1 and IFRS S2 as of January 1, 2024, further raises expectations regarding the scope and credibility of corporate carbon disclosures (ISSB, 2023).

The regulatory and market developments have materially altered the information environment in which energy firms operate. From the perspective of signaling theory, firms that disclose high-quality carbon information or demonstrate lower GHG emission intensity signal stronger future cash flow sustainability and reduced transition risk exposure in market valuations. While institutional investors in Indonesia, dominated by state-owned entities, pension funds, and insurance companies with historically return-oriented mandates, remain empirically underexplored as governance actors in this carbon-valuation nexus, despite growing global ESG momentum reflected in commitments such as the Net Zero Asset Owner Alliance (2024), comprising 89 institutional investors managing USD 9.5 trillion in assets toward net-zero portfolios by 2050.

Many empirical studies examining the relationship between carbon disclosure and firm value have yielded mixed and inconclusive results. Alfayerds and Setiawan (2021); Noor and Ginting (2022); and Putri and Sebrina (2025) confirm that carbon disclosure significantly influences firm value among IDX-listed companies. Several other studies arrive at different conclusions, so a consensus in the empirical literature on this topic has not yet been fully reached. Afnilia and Astuti (2023); Fawzyputra et al. (2025); and Damanik et al. (2025) found that carbon emission disclosure does not have a significant impact on firm value. This persistent inconsistency is largely attributed to methodological limitations, particularly the use of simple checklist proxies that cannot adequately capture the dimensions of carbon disclosure quality.

This study identifies three research gaps that collectively justify its novelty. First, despite Indonesia's energy sector accounting for 69.01% of total national GHG emissions Republic of Indonesia (2025), the volume of GHG emissions, as a standalone independent variable in firm valuation models, remains understudied in the Indonesian context. Second, the moderating role of institutional ownership in the relationships between GHG emission volume and carbon disclosure quality and firm value has not been simultaneously examined

using a panel dataset of IDX-listed energy companies. Third, no prior study has applied a GRI 305-based scoring instrument to capture quantitative, qualitative, and forward-looking dimensions of carbon disclosure quality in this sector. The novelty of this study therefore rests on three contributions. Theoretically, it extends signaling theory and agency theory to an emerging market context where carbon pricing regulation remains nascent; methodologically, it replaces binary proxies with a GRI-305-based scoring instrument as a more comprehensive measure of disclosure quality; and contextually, it is the first to simultaneously position institutional ownership as a moderating variable within a single panel data framework covering IDX-listed energy companies.

This study aims to examine the effects of GHG emissions volume and carbon disclosure quality on firm value, and to test the moderating role of institutional ownership on both relationships, among energy sector companies listed on the IDX for the period 2020 to 2024. These findings are expected to contribute at three levels. To the academic literature by providing empirical evidence on the relevance of carbon information in equity valuation under nascent regulatory conditions; to institutional investors by offering evidence-based guidance for evaluating the financial materiality of GHG data in portfolio decisions; and to regulators by providing grounded evidence to inform the design of more effective carbon disclosure mandates and pricing mechanisms that increase the financial interpretability of environmental information for market participants.

Literature Review

Theoretical Foundation

This study is primarily grounded in signaling theory (Spence, 1973). Signaling theory explains how firms convey credible information to reduce information asymmetry with external stakeholders, and this mechanism directly underlies the relationships between GHG emission volume, carbon disclosure quality, and firm value. Agency theory Jensen and Meckling (1976) serves as a supporting theoretical lens for explaining the moderating role of institutional ownership. Agency theory is applied here because institutional ownership functions as a governance mechanism that monitors management behavior and shapes how carbon-related signals are interpreted and priced by the market. The two theories are therefore used in a complementary manner. Signaling theory explains why the volume of emissions and disclosure quality carry information, while agency theory explains why the strength of that signal depends on the ownership structure that oversees management.

The Effect of GHG Emission Volume on Firm Value

Signaling theory Spence (1973) provides the foundational lens for understanding how GHG emission volume influences firm value, as information functions as a credible signal that resolves information asymmetry between firms and external parties. Han et al. (2023) extend this argument to the carbon context, showing that higher GHG emissions volumes send a negative signal to capital markets as investors anticipate higher compliance costs, regulatory sanctions, and a long-term decline in competitiveness.

This signal is particularly salient in Indonesia's energy sector. Energy sector firms are inherently high-emission operations due to the nature of extraction and combustion-based production processes. Regulatory requirements such as POJK No. 51/POJK.03/2017 and IFRS S2 have also increased investor demand for verifiable environmental disclosure in this sector. As a result, reported emission volume becomes a more material factor in investor decision-making for energy firms than for firms in lower-emission industries, where regulatory and market scrutiny of emission levels remains comparatively limited.

Choi and Luo (2021) operationalize GHG emissions volume by taking the natural logarithm of a firm's total absolute emissions, which are classified into Scope 1 direct emissions and Scope 2 indirect emissions under the GHG Protocol Corporate Standard. Park et al. (2024) later confirm this approach, reinforcing that the magnitude of reported emissions, not merely their disclosure, carries direct market consequences. As reported emission volume increases, negative market perception intensifies, ultimately suppressing firm value.

H1: *GHG emission volume has a negative effect on firm value*

The Effect of Carbon Disclosure Quality on Firm Value

Signaling theory Spence (1973) explains that high-quality carbon disclosure requires significant resources and managerial commitment, making it a costly and therefore credible signal of managerial competence. This credibility operates through a specific mechanism of information asymmetry. Without detailed disclosure, investors can only rely on industry-level assumptions to estimate a firm's transition risk. High-quality disclosure narrows this gap by providing firm-specific information on emission sources and reduction targets, allowing risk to be priced more precisely through a lower risk premium rather than a generalized industry discount. The study operationalized carbon disclosure quality using the GRI 305-1 to 305-5, while excluding 305-6 and 305-7, as they cover pollutants beyond the GHG scope.

Luo et al. (2023) find that carbon assurance enhances disclosure quality by strengthening the credibility of reported carbon information. Cao et al. (2022) find that carbon disclosure quality is positively associated with enterprise value among Chinese listed firms, an effect more pronounced in non-heavy-pollution industries, where disclosure serves as a stronger differentiating signal, in a market where disclosure remains voluntary and unevenly adopted across industries. Matthews et al. (2025) further examined FTSE 350 firms and found that voluntary carbon disclosers exhibit a significantly stronger positive effect of carbon disclosure regulation on market value than non-disclosers, in a market that is moving toward mandatory disclosure regulation. Although these three studies point in a consistent direction, their context are not interchangeable, and Indonesia's energy sector sits closer to the first context, since disclosure here is still largely voluntary and unevenly practiced despite intense regulatory scrutiny, and studies on this relationship within the sector remain limited.

H2: *Carbon disclosure quality has a positive effect on firm value*

Moderation of Institutional Ownership on the Effect of GHG Emission Volume on Firm Value

Agency theory Jensen and Meckling (1976) explains that the separation of ownership and control creates a conflict of interest, which produces information asymmetry that could allow managers to understate emissions to avoid sanctions and stakeholder pressure. Institutional investors serve as a monitoring mechanism through concrete channels rather than general oversight alone. Safiullah et al. (2022) identify shareholder activism as a proximate monitoring channel, tracing a specific pathway whereby institutional ownership reduces emissions primarily by pushing firms to lower energy consumption. This capacity is especially relevant in the energy sector, where emissions volume is directly tied to core operations. Nguyen et al. (2025) support this view, finding that the influence of ownership type on carbon disclosure behavior varies with industry environmental exposure, making the monitoring role more consequential in high-emission sectors such as energy.

Cohen et al. (2023) find that companies with CDP-registered institutional investors are more likely to make climate disclosures, and that these disclosures result in lower corporate carbon emissions. Safiullah et al. (2022) add that this effect depends on investor type, with active, long-horizon investors more effective than inactive ones. Together, these findings show that institutional ownership lowers emissions through identifiable channels, not merely through its presence.

The direction of this moderation is not fully settled in the literature, and this matters for how the hypothesis is framed. Institutional investors may treat high emission volume as evidence of poorly controlled operational risk, which would strengthen the negative market reaction; however, it is also plausible under agency theory that investors with strong monitoring capacity may instead read high reported emissions as transparency about a risk already being managed, which would weaken rather than strengthen the negative effect. This study follows the dominant view that monitoring pressure intensifies negative reactions to poor environmental performance, while acknowledging the alternative pathway as a boundary condition worth testing empirically.

H3: *Institutional ownership strengthens the negative effect of GHG emission volume on firm value*

Moderation of Institutional Ownership on the Effect of Carbon Disclosure Quality on Firm Value

The interpretive capacity of investors plays a decisive role in translating the quality of carbon disclosure into tangible firm value outcomes, and institutional ownership is widely recognized as a governance mechanism that sharpens this capacity. Agency theory by Jensen and Meckling (1976) supports this view by arguing that institutional investors, given their significant stakes and long-term orientation, are well positioned to monitor management behavior, evaluate how well a firm manages its environmental threats, and examine the degree of information disclosed.

Fuadah et al. (2022) find that public and foreign ownership positively influence ESG disclosure quality among IDX-listed firms, which reinforces firm value through stakeholder confidence, while a recent study by Rachmadhika and Firmansyah (2025) provides more direct evidence from Indonesia's energy sector, finding that institutional ownership significantly moderates the disclosure-value relationship by reducing the negative valuation consequences disclosure can otherwise produce. Whereas the former's findings apply broadly across industries, the latter offers a sector-specific mechanism more directly relevant here. In the energy sector, disclosure signals are more heavily scrutinized due to environmental exposure, so institutional investors are more likely to treat disclosure quality as an active screening criterion rather than background information, supporting the expectation that institutional ownership strengthens the effect of disclosure quality on firm value in this sector.

H4: *Institutional ownership strengthens the positive effect of carbon disclosure quality on firm value*

Research Model

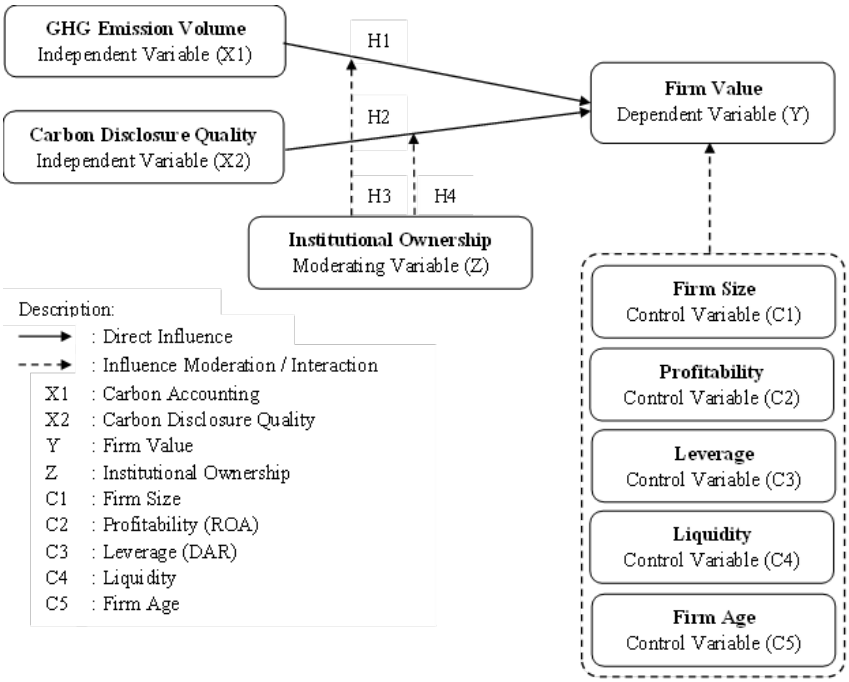

Figure 1. Research Model

Source: Developed by the authors, 2026

Method

A quantitative methodology based on a panel data design is used in the investigation. Secondary data were collected from the official IDX website (www.idx.co.id) and the official websites of each company in the sample. Using the sustainability report as the main document is very important because it is an official document that contains greenhouse gas (GHG) emissions data, serving as the basis for measuring the two independent variables examined in this study. Stock price and book value of equity data were taken from audited financial statements, while institutional ownership data were taken from the shareholder composition section in each company's annual report. The observation period from 2020 to 2024 was

selected because, during this time, the implementation of PJOK No.51/PJOK.03/2017 was uniformly applied across all listed companies, supported by regulatory pressure to standardize sustainability reporting formats, thereby making emissions data across companies more consistent for panel analysis. In addition, the launch of IDX Carbon on 23 September 2026 has made greenhouse gas emissions data more economically relevant to investors.

Population and Sample

For the years 2020–2024, all 92 energy businesses trading on the IDX were included in this study's population. Purposive sampling, in which specific criteria pertinent to the study aims were considered throughout the sampling process, was used to choose the samples. The established criteria are as follows:

1. Energy companies listed on the Indonesia Stock Exchange during 2020-2024.
2. Energy sector companies publishing annual reports and sustainability reports consecutively during the observation period.
3. Energy sector companies disclosing information about GHG in an explicit and measurable way between 2020 and 2024, including at least Scope 1 and Scope 2 emissions.

According to these criteria, 13 companies are eligible to participate in this study, yielding 65 observations from the balanced panel data.

Table 1. Sample Selection Process

Selection stage	Number of companies
Energy companies listed on the Indonesia Stock Exchange during the 2020-2024.	92
Deduction: Failure to consistently publish annual reports and sustainability reports during the observation period.	33
Deduction: Failure to explicitly and measurably disclose GHG emissions, at a minimum Scope 1 and Scope 2	46
Final sample of companies	13
Number of Observations (13 companies x 5 years)	65

Source: Developed by researcher, 2026

The sampling criteria used in this study may introduce selection bias, as only companies that explicitly disclose Scope 1 and Scope 2 emissions were included in the final sample. Consequently, the sample is likely to be skewed toward firms with relatively mature carbon reporting practices, while energy companies that have not yet disclosed measurable emissions are systematically excluded. The findings of this study should therefore be interpreted within the context of firms exhibiting higher carbon transparency, and generalization to the broader population of energy companies in Indonesia should be made with caution.

Table 2. Research Variable and Their Operations

Variable	Indicator and Measurement	Source
Firm Value Dependent variable (Y)	Reflects investor perception of firm value. $$PBV = \frac{Market\ Price\ per\ Share}{Book\ Value\ per\ Share}$$ Robustness poxy: $$Tobin's = \frac{(Market\ Capitalization + Total\ Debt)}{Total\ Assets}$$	Santra et al. (2023); Rachmadhika and Firmansyah (2025)
GHG Emission Volume Independent variable (X1)	Total operational GHG emissions, signaling environmental risks exposure. $$GHGEV = Ln\ (Total\ Scope\ 1\ + Scope\ 2\ GHG\ Emissions)$$	Bolton and Kacperczyk (2023)

Variable	Indicator and Measurement	Source
Carbon Disclosure Quality Independent variable (X2)	GRI-305 based disclosure index (305-1 to 305-5), scored 0-2 per item. $$CDQ = \sum \frac{Actual\ GRI\ 305\ Disclosure}{Maximum\ Score}$$	Luo et al. (2023)
Institutional Ownership Moderating variable (Z)	Proportion of share held by institutional investors, reflecting monitoring capacity. $$IO = \frac{Number\ of\ Shares\ Held\ by\ Institutions}{Total\ Shares\ Outstanding} \times 100\%$$	Brilliani et al. (2023)
Firm Size Control Variable (C1)	Controlled for its known influence on environmental disclosure behavior. $$SIZE = Ln\ (Total\ Assets)$$	Maryana and Carolina (2021)
Profitability Control Variable (C2)	Controlled as profitable firms tend to disclose more voluntarily. $$ROA = \frac{Net\ Income}{Total\ Asset} \times 100\%$$	Park et al. (2024)
Leverage Control Variable (C3)	Controlled as highly leveraged firms face greater creditor scrutiny. $$DAR = \frac{Total\ Debt}{Total\ Asset}$$	Maryana and Carolina (2021)
Liquidity Control Variable (C4)	Controlled as short-term solvency may influence firm valuation. $$CR = \frac{Current\ Assets}{Current\ Liabilities}$$	Li (2024)
Firm Age Control Variable (C5)	Controlled as older firms tend to have more predictable performace. $$\boldsymbol{AGE = Ln(Observation\ Year - IPO\ Year)}$$	Cao et al. (2022)

Source: Developed by the researchers, 2026

The scoring system used for each disclosure of the GRI-305 items included in the CDQ index is detailed in Table 3 below. The content analysis of the sustainability reports for each sampled firm was conducted independently by the researchers. To ensure consistency in coding all firm-year observations, a coding guide specifying the requirements for obtaining each score was developed before conducting the analysis.

Table 3. GRI-305 Carbon Disclosure Quality Scoring Scheme

GRI Item	Disclosure Dimension	Score 0	Score 1	Score 2
GRI 305-1	Direct emissions (Scope 1)	Not Disclosed	Qualitative description only	Quantitative data and qualitative
GRI 305-2	Energy indirect emissions (Scope 2)	Not Disclosed	Qualitative description only	Quantitative data and qualitative
GRI 305-3	Other indirect emissions (Scope 3)	Not Disclosed	Qualitative description only	Quantitative data and qualitative
GRI 305-4	GHG emission intensity	Not Disclosed	Qualitative description only	Quantitative data and qualitative
GRI 305-5	Reduction of GHG emissions	Not Disclosed	Qualitative description only	Quantitative data and qualitative

Note: The scoring system has three levels. A score of 0 indicates no disclosure, 1 indicates qualitative disclosure, and 2 indicates both quantitative and qualitative information. The maximum score is 10. Table 1 provides the CDQ index formula.

Data Analysis Technique

Hypothesis testing in this study was conducted by applying Moderated Regression Analysis (MRA) as the main analytical instrument, chosen because it allows researchers to test whether a third variable can statistically change the direction or strength of the influence between two other variables through the

formation of interaction variables explicitly included in the regression equation (Aiken & West, 1991; Memon et al., 2019). The entire estimation and testing process in this study was carried out using EViews 13.

The analysis process starts with determining the best estimation model through a series of consecutive steps. The Common Effect Model (CEM) and Fixed Effect Model (FEM) are compared using the Chow test. For further evaluation of the estimators' consistency, the test for comparison between the two models will continue using the Hausman test, which compares FEM and Random Effect Model (REM). Should the Chow test indicate a preference for CEM, additional tests will be conducted using the Lagrange Multiplier test to compare CEM and REM (Wooldridge, 2020; Baltagi, 2021). This selection procedure is conducted once for the baseline specification, and the resulting estimation technique is applied consistently to both Model 1 and Model 2, since the addition of the institutional ownership interaction term in Model 2 does not alter the underlying panel data structure these tests evaluate. Once the estimation technique is determined, the analysis proceeds with Moderated Regression Analysis (MRA) to examine the moderating role of institutional ownership. Model feasibility is assessed using a simultaneous F-test and partial t-test at the 95% confidence level. Partial t-tests for individual coefficients are evaluated at three significance levels, namely 1%, 5%, and 10%, with the lowest level included to capture marginally significant relationships. The estimated regression equation model is:

Model 1:

$$PBV_{it} = \alpha + \beta_1 GHGEV_{it} + \beta_2 CDQ_{it} + \beta_3 IO_{it} + \beta_4 SIZE_{it} + \beta_5 ROA_{it} + \beta_6 DAR_{it} + \beta_7 CR_{it} + \beta_8 AGE_{it} + \varepsilon_{it} \quad (1)$$

Model 2:

$$PBV_{it} = \alpha + \beta_1 GHGEV_{it} + \beta_2 CDQ_{it} + \beta_3 IO_{it} + \beta_4 (GHGEV \times IO)_{it} + \beta_5 (CDQ \times IO)_{it} + \beta_6 SIZE_{it} + \beta_7 ROA_{it} + \beta_8 DAR_{it} + \beta_9 CR_{it} + \beta_{10} AGE_{it} + \varepsilon_{it} \quad (2)$$

Description:

PBV_{it} = Firm Value of company *i* in year *t*
α = constant
$\beta_1 - \beta_{10}$ = Regression Coefficient
$GHGEV_{it}$ = GHG Emission Volume for company *i* in year *t*
CDQ_{it} = Carbon Disclosure Quality for company *i* in year *t*
IO_{it} = Institutional Ownership for company *i* in year *t*
$SIZE_{it}$ = Firm Size for company *i* in year *t*
ROA_{it} = Profitability for company *i* in year *t*
DAR_{it} = Leverage for company *i* in year *t*
CR_{it} = Liquidity for company *i* in year *t*
AGE_{it} = Firm Age for company *i* in year *t*
ε_{it} = error term

Result and Discussion

Table 4 presents the descriptive statistics for all variables across 65 firm-year observations from 13 energy sector companies listed on the IDX over the period 2020-2024. Firm value (PBV) has a mean of 0.905 (SD = 0.478), indicating that sampled firms are, on average, valued below book value, with a positive skewness of 1.289, suggesting a few firms with exceptionally high market valuations. Meanwhile, Tobin's Q, employed as an alternative measure of firm value, has a mean of 0.943 (SD = 0.234), corroborating the undervaluation pattern observed in PBV. GHG emission volume (GHGEV) records a mean of 13.349 in natural log form (SD = 1.390), reflecting the high emission intensity inherent to energy sector operations, while carbon disclosure quality (CDQ) has a mean of 0.695 (SD = 0.203), implying that firms disclose approximately 69.5% of expected carbon-related information. Institutional ownership (IO) is high at 81.081% (SD = 14.924), aligning with the concentrated ownership structure typical of Indonesian energy firms. Regarding control variables, firm size (SIZE) has a mean 31.044 (SD = 1.044), profitability (ROA) records a mean of 7.360% with substantial dispersion (SD = 9.260), leverage (DAR) has a mean of 0.520 (SD = 0.204), liquidity (CR) shows wide variation

with a mean of 170.933 (SD = 85.489), and firm age (AGE) records a mean 2.938 in logarithm form (SD = 0.379). These figures collectively indicate considerable cross-sectional heterogeneity among the sampled firms.

Table 4. Descriptive Statistical Test

	Mean	Median	Max	Min	Std. Dev.	Skew.	Kurtosis	N
PBV	0.905	0.737	2.623	0.229	0.478	1.289	4.886	65
TOBIN'S Q	0.943	0.919	1.642	0.509	0.234	0.709	3.729	65
GHGEV	13.349	13.628	15.562	10.404	1.390	-0.515	2.506	65
CDQ	0.695	0.700	1.000	0.300	0.203	-0.442	2.192	65
IO	81.081	86.227	100.000	39.940	14.924	-0.812	2.690	65
SIZE	31.044	31.131	32.765	28.660	1.044	-0.497	2.687	65
ROA	7.360	5.149	45.427	-9.839	9.260	1.556	6.508	65
DAR	0.520	0.529	0.961	0.169	0.204	0.053	2.181	65
CR	170.933	157.629	447.546	26.956	85.489	1.154	5.105	65
AGE	2.938	2.944	3.526	2.079	0.379	-0.136	2.065	65

Source: EViews 13 (Data processed, 2026)

Table 5. Panel Data Selection Test Result

No	Test	Statistic	Prob.	Decision
1	Chow Test (Common vs Fixed)	F = 2.697 (Cross-section F)	0.008	Fixed Effect Model
2	Hausman Test (Fixed vs Random)	Chi-square = 15.895	0.044	Fixed Effect Model

Source: EViews 13 (Data processed, 2026)

Chow test yields an F-statistic of 2.697 (p = 0.008), rejecting the Common Effect Model in favor of the Fixed Effect Model. Subsequently, the Hausman test produces a Chi-square statistic of 15.895 (p = 0.044), rejecting the Random Effect Model. Collectively, these results confirm that the Fixed Effect Model (FEM) is the most appropriate specification, accounting for unobserved firm-specific heterogeneity that remains constant over time.

Table 6. Multicollinearity Test

Variable	R^2 Auxiliary	VIF
GHGEV	0.0338	1.512
CDQ	0.5200	2.082
IO	0.3838	1.623
SIZE	0.5694	2.322
ROA	0.4537	1.831
DAR	0.5296	2.126
CR	0.5049	2.020
AGE	0.2868	1.402

Source: E-views 13 (Data processed, 2026)

The multicollinearity test using the variance inflation factor (VIF) shows that all variables have VIF values ranging from 1.402 to 2.322, well below the conventional threshold of 10 Hair et al. (2022), confirming the absence of multicollinearity among the independent variables. The Durbin-Watson statistic of 2.229 further indicates no serial autocorrelation in the residuals, as the value falls within the acceptable range of 1.5 to 2.5.

Results of the cross-sectional dependence test are summarized in Table 7. All four test statistics generate p-values higher than 0.05, and in particular, the Pesaran CD cross-sectional dependence test gives 0.938 (p = 0.348). Together, these findings suggest the absence of cross-sectional dependence between the panel data

sets; hence, there is no systematic correlation in the residual terms across firms. Therefore, only White's diagonal-robust standard errors will be sufficient for the treatment of heteroskedasticity problems.

Table 7. Cross-Sectional Dependence Test

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	91.823	78	0.136
Pesaran scaled LM	1.107		0.268
Bias-corrected scaled LM	-0.518		0.604
Pesaran CD	0.938		0.348

Source: EViews 13 (Data processed, 2026)

Table 8. Panel Data Regression Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	19.804	10.693	1.852	0.071
GHGEV	-0.012	0.081	-0.149	0.882
CDQ	0.858	0.558	1.537	0.132
IO	0.017	0.010	1.649	0.106
SIZE	-0.714	0.404	-1.764	0.085*
ROA	0.013	0.009	1.515	0.137
DAR	2.095	1.096	1.911	0.063*
CR	0.000	0.009	0.325	0.746
AGE	0.075	1.089	0.069	0.945
R-squared	0.536	Mean dependent var		0.905
Adjusted R-squared	0.326	S.D. dependent var		0.477
F-statistic	2.546	Durbin-Watson stat		2.229
Prob(F-statistic)	0.005			

Source: EViews 13 (Data processed, 2026)

The following panel data regression equation was derived from the estimation results of the Fixed Effects Model (FEM) in Model 1:

$$PBV = 19.804 - 0.012GHGEV + 0.858CDQ + 0.017IO - 0.714SIZE + 0.013ROA + 2.095DAR + 0.000CR + 0.075AGE + \varepsilon$$

Statistically, the F-statistic = 2.546 and the p-value = 0.005, indicating joint significance of the results. The Adjusted R-squared of the regression equation is 0.326. In other words, the set of independent variables explains 32.6% of the variation of the firm value. The DW statistic is 2.229; thus, there is no evidence of serial correlation. GHG emission volume (GHGEV) is negatively related to firm value, but the effect is not statistically significant (β = -0.012, p = 0.882). This indicates that the absolute magnitude of GHG emissions does not significantly affect the market valuation of firms in Indonesia's energy sector, possibly because investors are tolerant of emission-intensive businesses common in the industry. Carbon disclosure quality (CDQ) is positively associated with firm value, but this effect is not statistically significant (β = 0.858, p = 0.132). Although the effect is consistent with signaling theory, the positive effect of CDQ on firm value is not statistically significant due to the small sample size. Institutional ownership (IO) also shows a positive but insignificant direct effect on firm value (β = 0.017, p = 0.106). This means that the concentration of shares held by institutional investors does not significantly affect firm valuation in the regression model. Size of the firm (SIZE) has a negative marginal effect (β = -0.714, p = 0.085), whereas the debt-to-assets ratio (DAR) has a positive marginal significance (β = 2.095, p = 0.063); the remaining controls, ROA, CR, and AGE, show no significant effects on firm value.

The overall model demonstrates a satisfactory fit, with a statistically significant F-statistic (F = 2.506, p = 0.005) and an Adjusted R-squared of 0.341, indicating that 34.1% of the variance in firm value is explained by the independent variables in the model. The Durbin-Watson statistic of 2.203 indicates the absence of significant autocorrelation in the model, as the value lies close to 2. Regarding the main exploratory variables, the variable GHG emission volume (GHGEV_c) has a negative beta coefficient (β = -0.033) that is not

statistically significant (p = 0.784). This implies that GHG emissions volume, measured as the percentage of the reported amount of GHG emissions relative to total industry emissions, does not significantly affect the market valuation of firms in the sample. The variable CDQ_c has a positive beta coefficient (= 0.923, p = 0.088), which is significant at the 10% level. It provides some supporting evidence for signaling theory. Institutional ownership (IO_c) appears to be the only variable statistically significant at the 5% level among the main variables (= 0.024, p = 0.038), with the positive coefficient suggesting that firms with greater institutional investor presence tend to attract higher market valuations.

Table 9. Moderated Regression Analysis (MRA) Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	24.802	12.541	1.978	0.054
GHGEV_c	-0.033	0.121	-0.276	0.784
CDQ_c	0.923	0.529	1.744	0.088*
IO_c	0.024	0.012	2.143	0.038**
GHGEVc_IOc	0.002	0.007	0.276	0.784
CDQc_IOc	0.043	0.032	1.353	0.183
SIZE	-0.862	0.459	-1.877	0.067*
ROA	0.014	0.009	1.473	0.148
DAR	2.566	1.274	2.014	0.050**
CR	0.000	0.001	0.358	0.722
AGE	0.436	1.142	0.382	0.705
R-squared	0.568	Mean dependent var		0.905
Adjusted R-squared	0.341	S.D. dependent var		0.477
F-statistic	2.506	Durbin-Watson stat		2.203
Prob(F-statistic)	0.005			

Source: EViews 13 (Data processed, 2026)

Neither of the interaction terms has shown any statistical significance. The GHGEV_c x IO_c interaction is positive (= 0.002, p = 0.784) but fails to present significant information that can indicate the conditional impact of institutional ownership. Similarly, the CDQ_c x IO_c interaction is positive (= 0.043) but not statistically significant (p = 0.183). These non-significant interaction effects should be interpreted with caution given the limited sample size in this study. With only 13 firms observed over 5 years, statistical power may be limited, potentially obscuring moderating effects that might otherwise emerge with a larger sample. In considering the controls, firm size (SIZE) has a negative effect significant at the 10% level (= -0.862, p = 0.067), while leverage (DAR) shows a positive and significant effect (= 2.566, p = 0.050). Other controls, such as ROA, CR, and AGE, have not shown statistically significant effects on firm value (p = 0.148, p = 0.722, and p = 0.705, respectively).

The association between GHG emissions volume and institutional ownership holdings on firm value is demonstrated by Figure 2. The curves are nearly parallel, implying that institutional ownership does not affect the association between GHG emissions volume and firm value, regardless of whether institutions own the firm to a lesser or greater extent. This result is confirmed by the insignificant interaction term shown in Table 9 (= 0.002, p = 0.784).

The interaction effect of the quality of carbon disclosure and institutional ownership on firm value is depicted in Figure 3. Even though the slope for high institutional ownership seems to be steeper compared to the slope of low institutional ownership, indicating a strong relationship between the quality of carbon disclosure and firm value at high institutional ownership, the pattern lacks statistical significance (β = 0.043, p = 0.183) and should therefore be interpreted with caution.

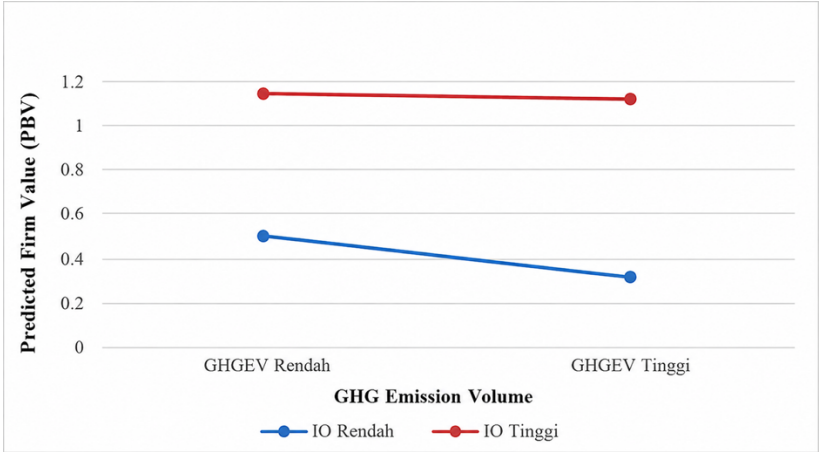

Figure 2. Interaction Effect of GHG Emission Volume and Institutional Ownership on Firm Value

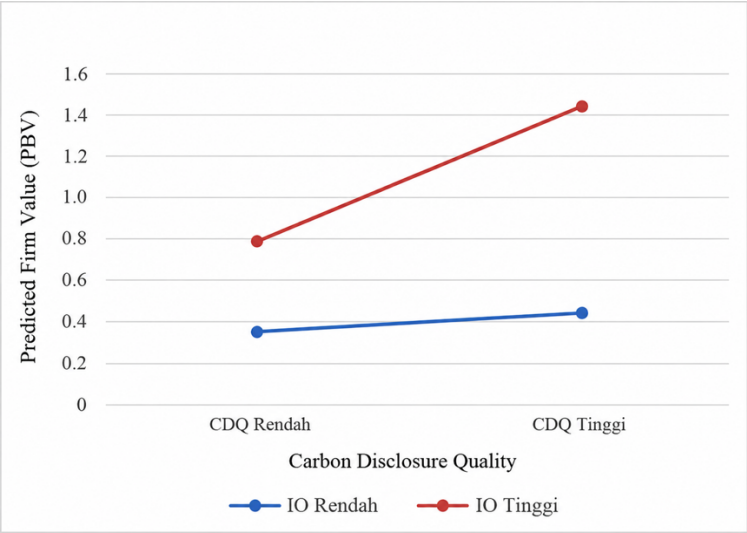

Figure 3. Interaction Effect of Carbon Disclosure Quality and Institutional Ownership on Firm Value

Table 10. Robustness Check

Variable	Coefficient	Prob.
C	5.533	0.293
GHGEV	0.003	0.992
CDQ	-1.463	0.145
IO	0.007	0.025**
GHGEVc_IOc	0.002	0.994
CDQc_IOc	0.021	0.156
SIZE	-0.145	0.377
ROA	0.008	0.046**
DAR	0.554	0.176
CR	0.001	0.724
AGE	-0.366	0.434
R-squared	0.633	
Adjusted R-squared	0.440	
F-statistic	3.287	
Prob(F-statistic)	0.004	

Source: EViews 13 (Data processed, 2026)

Firm value was reformulated into Tobin's Q for a robustness test using a Fixed Effects model specification with White diagonal robust standard errors. The robustness model is statistically significant as a whole, with an F-statistic (F = 3.287 p = 0.004), and explains 44% of the variation in firm value as measured by Tobin's Q (Adjusted R-squared = 0.440), a relatively higher explanatory power compared to the main model PBV, reflecting the conceptual difference between PBV as market perception relative to book value and Tobin's Q as market value relative to asset replacement const. Institutional ownership (IO) still showed a positive and significant relationship with firm value (= 0.007, p = 0.025), consistent with its significance in the PBV model and reinforcing the robustness of this finding despite differing coefficient scales across proxies. In contrast, carbon disclosure quality proves sensitive to proxy choice, weakly significant in the PBV model, but insignificant in the Tobin's Q model (= -1.463, p = 0.145), while GHG emission volume remains insignificant across both models. The interaction terms (GHGEV_c x IO_c) and (CDQ_c x IO_c) still showed no statistical significance on the effect on firm value (= 0.002, p = 0.994; β = 0.021, p = 0.156, respectively), confirming that institutional ownership does not moderate the GHGEV or CDQ relationship with firm value. Among the controls, only ROA is significant (β = 0.008, p = 0.046), while SIZE, DAR, CR, and AGE show no significant effects.

Discussion

The Effect of GHG Emission Volume on Firm Value

Based on the findings of Models 1 and 2, there is an inverse but statistically insignificant relationship between the volume of GHG emissions and firm value. The finding shows that hypothesis 1 (H1) is not supported, as the volume of carbon emissions does not have a significant effect on the valuation of energy firms listed on the IDX. These results corroborate those of Afnilia and Astuti (2023), who provide no evidence of a significant effect of emission volume on firm value. This result is consistent with the possibility that emission volume has not yet been systematically incorporated into valuation practices in carbon-emitting industries, although this interpretation should be tempered by the absence of direct evidence on how individual investors actually process such information. In terms of signaling theory, information about emission volume can effectively signal firms' performance in an industry to investors only in a conducive, government-regulated environment. Inadequate regulation on carbon prices in the Indonesian context limits the financial importance of emission volumes in the valuation process. Additionally, according to Choi and Luo (2021), the effect of carbon emissions on valuation is significant only in jurisdictions with stringent carbon laws.

The Effect of Carbon Disclosure Quality on Firm Value

Carbon disclosure quality is found to have no statistically significant effect on the firm value in Model 1, indicating that H2 is not supported. Such a result may reflect the limited extent to which GRI-305-based carbon disclosure quality has been embedded into valuation practices within Indonesia's energy capital market, though this remains an inference from aggregate market pricing rather than direct evidence of investor decision-making. According to Fawzyputra et al. (2025), Indonesian energy sector companies exhibit a similar phenomenon, whereby carbon disclosures do not have a significant impact on valuations due to industry- and location-specific conditions that hinder investors from considering disclosure quality in the valuation process. However, according to Jiang et al. (2021), voluntary carbon disclosure quality is positively and statistically significant for the value of firms in developing countries, indicating that it is only the degree of maturity of the regulatory and investment system and not the quality of disclosures that makes valuations possible. The CDQ coefficient remains positive across both models and is marginally significant in the moderated model after mean-centering. However, this conditional effect represents the estimated impact when institutional ownership is at its mean, rather than indicating an unconditional direct relationship.

Moderation on Institutional Ownership on the Effect of GHG Emission Volume on Firm Value

Institutional ownership does not significantly moderate the relationship between GHG emission volume and firm value, indicating that hypothesis 3 (H3) is not supported. This finding is consistent with the interpretation that institutional investors in the Indonesian energy sector may not systematically factor absolute emission levels into their valuation assessments, a conclusion drawn from the absence of a significant interaction effect rather than from direct evidence of investor reasoning. Consequently, the monitoring function anticipated by agency theory has not yet emerged in this context. This outcome can be

attributed to structural characteristics of institutional ownership in Indonesia, where dominant investor types, including state-owned entities, pension funds, and insurance companies, prioritize stable financial returns over scrutiny of environmental performance. This pattern is plausible in the absence of a strong ESG-oriented investment mandate, though the study cannot directly confirm whether institutional investors differentiate firm value based on emission volumes. Additionally, the absence of mandatory carbon pricing in Indonesia means that GHG figures carry limited financial interpretability for investors, making it difficult for even motivated institutional shareholders to price emission data into their valuation decisions. To the authors' knowledge, no prior empirical study has directly examined this moderating relationship in the Indonesian energy sector, making this finding a meaningful contribution to the existing literature.

Moderation of Institutional Ownership on the Effect of Carbon Disclosure Quality on Firm Value

Institutional ownership does not have any significant effect on the carbon disclosure quality-firm value relationship. Therefore, hypothesis 4 (H4) cannot be supported by the results of this study. While the interaction term shows a positive relationship, consistent with agency theory, the significance of this relationship is not significant for firm value. Based on agency theory, the conditional moderating effect of institutional ownership depends on shareholders' ability and willingness to assess disclosure quality and take appropriate action based on their assessments. In the Indonesian capital market, however, these assumptions are not fully satisfied; as reported by Rachmadhika and Firmansyah (2025), the relationship between carbon disclosure and firm value is significantly moderated by institutional ownership in the Indonesian energy sector. This relationship, although consistent, appears to depend on how disclosure is measured and the observation period used. Altogether, the findings imply that, to function as an effective governance mechanism, institutional ownership requires sophisticated investors and a strong regulatory system, which currently do not exist in the Indonesian energy capital market.

Additional Finding: Direct Effect of Institutional Ownership

Taken together, the pattern across all four hypotheses points toward a broader characteristic of Indonesia's energy sector capital market rather than four isolated results. Neither GHG emissions volume nor carbon disclosure quality has a significant effect on firm value in the baseline model, and institutional ownership neither strengthens nor weakens these relationships. This pattern is more consistent with a market in which carbon-related information has not yet reached the threshold of financial materiality required for investors to price it systematically, a condition plausibly linked to Indonesia's still-developing carbon pricing infrastructure and the recent implementation of mandatory disclosure regulation. At the same time, institutional ownership's significant direct effect on firm value, independent of its moderating role, suggests that, in this context, institutional investors continue to reward governance-related characteristics of firms more broadly, rather than carbon-specific performance in particular. Collectively, these findings imply that carbon information in Indonesia's energy sector currently functions less as a risk or legitimacy signal actively priced by the market, and more as a compliance artifact whose financial relevance has yet to be established.

Control Variable

Firm size is found to have a negative and significant relationship to firm value. The finding above shows that larger companies are less valued than their smaller counterparts in Indonesia's energy sector, which can be attributed to their organizational complexity and limited prospects for further growth. The positive and significant relationship between leverage and firm value shows that leverage can mitigate excessive managerial discretion and serve as a commitment mechanism by management towards investors. Profitability, liquidity, and age do not affect firm value during the study period.

Conclusions and Recommendations

This study analyzed the interaction of GHG emissions volume, carbon disclosure quality, and firm value of IDX-listed companies in the energy sector during 2020 to 2024, using institutional ownership as a moderating variable. Using Moderated Regression Analysis within a Fixed Effects Model framework on 65 observations from 13 companies provides evidence that, in the limited context of this small study, GHG emissions volume did not correlate with firm value. In the moderated model, carbon disclosure quality exhibited marginal

significance (10%). Institutional ownership positively and significantly influenced firm value, but did not moderate the effects of GHG emission volume and carbon disclosure quality on firm value. Due to the limited sample of 13 energy sector companies with complete data on scope 1 and scope 2 emissions, these results may not represent the entire energy sector or the other sectors in Indonesia and should be interpreted with caution.

The study has several limitations. First, because of limited sample size, the model may have omitted some significant moderating effects. Second, the analysis was limited to firms with full emissions datasets. Because these firms are more transparent, this likely resulted in selection bias. Third, the relationships among the study's variables may be affected by the instability of the post-pandemic recovery, given the study's 2020-2024 time frame. Future research should focus on the remaining sectors with complete emissions datasets, use more sophisticated carbon disclosure measurement tools, and evaluate differences among the various types of institutional investors as more refined and significant moderating variables to improve the study's overall validity and applicability.

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