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The Effect of Energy Intensity, Environmental Performance, Environmental Costs, and Firm Size on Carbon Emission Disclosure (A Study of Energy Sector Companies Listed on the Indonesia Stock Exchange in 2025)

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Abstract

This study examines the effects of energy intensity, environmental performance, environmental costs, and firm size on carbon emission disclosure among energy-sector companies listed on the Indonesia Stock Exchange in 2025. A quantitative design using secondary corporate data was applied to a population of 91 energy-sector companies, from which 40 companies were selected through purposive sampling. Energy intensity was measured as total energy consumption divided by revenue, environmental performance was measured using PROPER ratings, environmental costs were measured as environmental costs divided by net income after tax, and firm size was measured using the natural logarithm of total assets. The data were analyzed using descriptive statistics and multiple linear regression with IBM SPSS version 26 after normality, multicollinearity, heteroscedasticity, and autocorrelation testing. The results show that environmental performance does not significantly affect carbon emission disclosure. Energy intensity has a significant negative effect, whereas environmental costs and firm size have significant positive effects on carbon emission disclosure. Simultaneously, the four independent variables significantly explain carbon emission disclosure, with an R-square value of 0.654, indicating that 65.4% of the variation in disclosure is explained by the model. The study contributes to sustainability accounting research by incorporating energy intensity as an operational determinant of carbon emission disclosure in the Indonesian energy sector.

Keywords: *carbon emission disclosure, energy intensity, environmental costs, environmental performance, firm size.*

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INTRODUCTION

Climate-related disclosure has become an increasingly material component of corporate accountability as firms are expected to explain not only their financial performance but also the environmental consequences of their operating models. This issue is particularly salient for the energy sector, where production, processing, and distribution activities are structurally associated with intensive energy consumption and significant greenhouse gas exposure. Recent accounting and sustainability research has consequently shifted from treating carbon reporting as a peripheral corporate social responsibility practice toward examining it as a measurable element of environmental accountability, market transparency, and corporate sustainability strategy (Reichelstein, 2024; Syam et al., 2024; Di Vaio et al., 2024). Carbon disclosure also functions as an information mechanism through which firms communicate their carbon performance, environmental commitments, and responses to stakeholder scrutiny, while differences in disclosure quality may affect how investors and other stakeholders evaluate corporate environmental risk (Cohen et al., 2023; Houten & Wedari, 2023). The relevance of this issue is amplified in carbon-intensive industries because firms with substantial operational footprints face stronger expectations to document how energy use and environmental consequences are identified, measured, and communicated. Research on Indonesian corporations has similarly shown that carbon disclosure remains heterogeneous across firms and industries, reinforcing the need to examine the organizational characteristics and environmental factors associated with variations in disclosure practices (Nilasakti et al., 2024; Putri & Arieftiara, 2023).

The contemporary literature has developed several lines of inquiry concerning the determinants and consequences of carbon emission disclosure. One stream emphasizes corporate characteristics and governance-related conditions, showing that firm size, ownership structure, leverage, board characteristics, and external visibility can shape the extent of environmental transparency (Desai, 2022; Cahyaningsih & Rahmadiah, 2024; Puteri & Handayani, 2026; Zhu et al., 2024). A second stream concentrates on environmental performance and carbon-related operational outcomes, positioning carbon performance, environmental management systems, environmental performance, and green strategies as relevant dimensions for explaining disclosure behavior (Puteri & Inawati, 2023; Yuliana & Wedari, 2023; Wahyuningrum et al., 2024; Xia, 2026). A third stream has broadened the discussion toward the economic consequences of carbon disclosure by examining associations with financial performance, market value, firm value, and other organizational outcomes (Bedi, 2024; Houten & Wedari, 2023; Putri & Wirakusuma, 2025). Recent studies have also integrated green investment, research and development, environmental costs, digital transformation, and sustainability-oriented innovation into the carbon disclosure literature, indicating that environmental transparency is increasingly understood as part of a broader system of corporate resource allocation and sustainability management rather than an isolated reporting decision (Albert, 2025; Fidiano & Dewi, 2026; Majidah et al., 2025).

Despite this expanding body of research, the determinants of carbon emission disclosure remain empirically and conceptually unsettled. Studies conducted in Indonesia continue to test environmental performance and firm size as explanatory variables, yet the persistence of these variables across successive studies indicates that their relationship with disclosure has not produced a sufficiently stable explanatory framework across samples, sectors, and research designs (Rahmah et al., 2024; Lumbantungkup & Alam, 2026; Widianingsih, 2025). Research focused specifically on the Indonesian energy sector has strengthened contextual understanding by examining environmental performance, media exposure, environmental management systems, ownership, green investment, and board characteristics, but these models continue to emphasize institutional and organizational determinants rather than the efficiency of energy use itself (Nurjanah & Mulyandini, 2024; Puteri & Inawati, 2023; Fidiano & Dewi, 2026; Khairunnisa & Wilasittha, 2026). Environmental costs have also received increasing attention as an indicator of corporate environmental commitment, although existing work more frequently positions such costs in relation to corporate performance or combines them with other sustainability variables rather than integrating them with energy-use efficiency in a single disclosure model (Majidah et al., 2025; Valencia & Arsjah, 2025). The principal research gap therefore lies in the limited integration of operational energy intensity with environmental performance, environmental costs, and firm size as simultaneous determinants of carbon emission disclosure, particularly within listed Indonesian energy companies. Existing carbon accounting studies provide substantial insight into carbon measurement, reporting architecture, and disclosure determinants, but they leave relatively limited evidence on whether the intensity with which firms consume energy relative to their economic activity is associated with the breadth of carbon information they disclose (Reichelstein, 2024; Izzo et al., 2026).

This gap has both scientific and practical consequences. From an accounting perspective, limiting explanatory models to organizational scale, environmental ratings, governance structures, or conventional financial characteristics may understate the role of operational resource efficiency in shaping environmental transparency. Energy intensity captures a dimension that is conceptually different from environmental performance because it reflects the amount of energy required to generate economic activity, whereas environmental performance indicators generally represent broader environmental outcomes or institutional assessments. The distinction is relevant because companies may exhibit similar formal environmental performance while operating with substantially different levels of energy dependence. Carbon disclosure research increasingly recognizes that reporting quality must be interpreted alongside actual carbon performance and transition behavior rather than treated solely as a symbolic reporting practice (Xia, 2026; Albert, 2025). Evidence concerning the interaction between disclosure, environmental performance, and corporate outcomes also suggests that stakeholders may respond differently to environmental information depending on the underlying environmental characteristics of the firm (Ma, 2023; Bedi, 2024; Ardelia & Paramita, 2026). For Indonesian energy companies, a model that simultaneously considers energy intensity, environmental performance, environmental expenditure, and corporate scale can provide a more

differentiated basis for assessing whether carbon disclosure corresponds to the operational and organizational conditions that generate environmental accountability pressures (Riantono & Sunarto, 2022; Wahyuningrum et al., 2024).

The present study positions itself within the carbon accounting and sustainability disclosure literature by combining four determinants that represent distinct dimensions of corporate environmental accountability: energy intensity as an operational efficiency characteristic, environmental performance as an observable environmental achievement, environmental costs as a resource commitment to environmental management, and firm size as a proxy for organizational scale and public visibility. Its novelty lies primarily in introducing energy intensity into an explanatory model of carbon emission disclosure for energy-sector companies listed on the Indonesia Stock Exchange in the 2025 reporting period, while simultaneously retaining environmental performance, environmental costs, and firm size as established but empirically contested determinants. This specification extends studies that have concentrated on carbon performance, environmental management systems, green strategies, governance, ownership structures, or media exposure by explicitly incorporating the relationship between energy consumption and economic activity into the disclosure model (Yuliana & Wedari, 2023; Cahyaningsih & Rahmadiah, 2024; Putri & Arieftiara, 2023). It also complements recent Indonesian evidence concerning environmental cost allocation and carbon transparency by testing whether financial commitment to environmental management remains explanatory when evaluated alongside operational energy intensity (Majidah et al., 2025; Valencia & Arsjah, 2025). The focus on a single recent reporting period and a carbon-intensive sector provides a specific empirical setting in which environmental accountability, energy dependence, corporate scale, and disclosure incentives can be examined under comparable industrial conditions rather than across heterogeneous sectors.

This study therefore aims to examine the effects of energy intensity, environmental performance, environmental costs, and firm size on carbon emission disclosure among energy-sector companies listed on the Indonesia Stock Exchange in 2025. Energy intensity is positioned to capture the operational dimension of energy dependence, environmental performance represents the quality of corporate environmental management outcomes, environmental costs reflect the allocation of financial resources to environmental responsibility, and firm size represents the organizational scale associated with broader public and stakeholder exposure. The study is expected to contribute theoretically to sustainability accounting research by expanding the explanatory framework of carbon emission disclosure beyond conventional organizational and environmental determinants through the incorporation of energy intensity. Its methodological contribution lies in testing these four determinants simultaneously within a relatively homogeneous industrial setting and a recent reporting period. The practical contribution concerns the provision of empirical evidence that may assist corporate management, investors, regulators, and other stakeholders in evaluating whether the extent of carbon information disclosed by energy companies is associated with their operational energy profile, environmental management characteristics, environmental expenditure, and organizational scale.

RESEARCH METHODS

This study employed a quantitative design using secondary corporate data to examine the effects of energy intensity, environmental performance, environmental costs, and firm size on carbon emission disclosure. The unit of analysis was energy-sector companies listed on the Indonesia Stock Exchange during the 2025 reporting period. The population consisted of 91 energy-sector companies, from which 40 companies were selected through purposive sampling. Sample eligibility required companies to be listed in the energy sector in 2025; publish an annual report and/or sustainability report containing the information required for the study; receive a PROPER rating from the relevant environmental authority during the study period; disclose at least one item related to carbon emissions, either explicitly or implicitly; report energy consumption; and disclose environmental costs. The sample-selection records show that 18 companies were excluded because the required annual or sustainability reporting information was unavailable, 28 companies did not disclose environmental costs, and five companies did not report energy consumption, resulting in a final sample of 40 companies. Data were obtained from the companies' annual reports, sustainability reports, and financial information for the 2025 period. Four independent variables were examined.

Energy intensity was measured as total energy consumption divided by revenue, environmental performance was measured using the company's PROPER rating, environmental costs were measured as environmental costs divided by net income after tax, and firm size was measured using the natural logarithm of total assets. Carbon emission disclosure served as the dependent variable and was identified from corporate reporting information; the available methodological information does not specify a separate item-level scoring formula or disclosure-index construction, so no additional measurement procedure is introduced beyond that documented in the study.

The data were processed and analyzed using IBM SPSS version 26. Descriptive statistics were first used to summarize the distribution of the research variables through their minimum, maximum, mean, and standard deviation values. Multiple linear regression was then applied to estimate the relationship between the four independent variables and carbon emission disclosure. Prior to regression analysis, the dataset was subjected to the assumption tests documented in the study. Normality was assessed using the Kolmogorov–Smirnov test, multicollinearity was evaluated using tolerance and variance inflation factor values, heteroscedasticity was examined through the significance values generated by the heteroscedasticity test reported in the analysis, and autocorrelation was evaluated using the Durbin–Watson statistic. The regression model was specified as ($Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + e$), where (Y) represents carbon emission disclosure, (X_1) environmental performance, (X_2) energy intensity, (X_3) environmental costs, and (X_4) firm size. The simultaneous effect of the independent variables was evaluated using the F-test, while the individual effect of each independent variable was examined using the t-test at a significance level of 0.05. The coefficient of determination was used to assess the proportion of variation in carbon emission disclosure explained by the regression model. The use of documented corporate reports, explicit purposive-sampling criteria, fixed operational measures for the independent variables, and formal statistical assumption testing provides the basis for maintaining consistency and analytical rigor in the estimation procedure.

RESULTS AND DISCUSSION

Descriptive Characteristics and Statistical Adequacy of the Research Model

The empirical analysis was based on 40 energy-sector companies listed on the Indonesia Stock Exchange that satisfied the purposive-sampling criteria for the 2025 reporting period. These observations were retained because the required information concerning carbon emission disclosure, energy consumption, environmental costs, financial position, and environmental performance was available in the companies' annual reports, sustainability reports, or related corporate financial information. Focusing on a relatively homogeneous industrial group reduces cross-industry variation while preserving meaningful differences in environmental exposure and reporting practices among individual firms. Previous studies indicate that carbon disclosure within high-emission industries remains heterogeneous because corporate environmental characteristics, organizational resources, and disclosure incentives differ materially across firms (Houten & Wedari, 2023; Nilasakti et al., 2024).

Descriptive statistics provide the initial empirical profile of the five variables included in the regression model. Environmental performance recorded values between 0 and 5, with a mean of 1.3250 and a standard deviation of 1.88635, indicating substantial variation in PROPER-based environmental performance across the sampled firms. Energy intensity ranged from 0.00 to 0.74, with a mean of 0.0185 and a standard deviation of 0.11635, showing that the relationship between energy consumption and corporate revenue differed markedly across companies. Such variation is analytically relevant because environmental performance and operational energy dependence represent distinct dimensions of corporate environmental characteristics and should not be treated as interchangeable indicators (Puteri & Inawati, 2023; Wahyuningrum et al., 2024).

Environmental costs show particularly wide dispersion, with a minimum value of -0.01, a maximum of 44.02, a mean of 2.7977, and a standard deviation of 9.44837. The magnitude of the standard deviation relative to the mean indicates considerable differences in the proportion of environmental expenditure relative to net income after tax among the sampled companies. Firm size also varies considerably, ranging from 17.70 to 32.57, with an average of 27.6831 and a standard deviation of 4.07430, indicating the presence of firms with materially different asset scales. Corporate scale and environmental resource allocation have repeatedly been identified as relevant determinants

of sustainability and carbon-reporting practices because they affect both reporting capability and stakeholder visibility (Bedi, 2024; Majidah et al., 2025).

Carbon emission disclosure ranges from 0.17 to 0.94, with a mean value of 0.6583 and a standard deviation of 0.19674. This distribution indicates that carbon-related reporting was present among the selected firms but differed substantially in breadth, suggesting that participation in the same industrial sector does not produce uniform carbon transparency. Table 2 presents the original descriptive statistics used to characterize the distribution of the research variables and should remain part of the empirical presentation because it provides the quantitative basis for subsequent regression analysis. Heterogeneity in corporate carbon disclosure is consistent with evidence from Indonesian listed companies showing that disclosure intensity remains sensitive to firm-specific environmental and organizational characteristics (Putri & Arieftiara, 2023; Widianingsih, 2025).

Table 1. Descriptive Statistics

Variable	Minimum	Maximum	Mean	Standard Deviation
Environmental Performance	0.00	5.00	1.3250	1.88635
Energy Intensity	0.00	0.74	0.0185	0.11635
Environmental Costs	-0.01	44.02	2.7977	9.44837
Firm Size	17.70	32.57	27.6831	4.07430
Carbon Emission Disclosure	0.17	0.94	0.6583	0.19674

Source: Research data processed by the researchers, 2026.

The regression model was subsequently evaluated through the assumption tests documented in the original analysis. The normality test employed the Kolmogorov–Smirnov procedure and produced an Asymp. Sig. (2-tailed) value of 0.200, which exceeds the 0.05 decision threshold adopted in the study. This result indicates that the regression residuals satisfied the normality criterion used by the authors and allowed the analysis to proceed to the remaining diagnostic procedures. Statistical diagnostics are necessary in multivariate carbon-disclosure studies because coefficient interpretation can be affected when fundamental regression assumptions are not adequately evaluated (Desai, 2022; Reichelstein, 2024).

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		40
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.18614104
Most Extreme Differences	Absolute	.104
	Positive	.058
	Negative	-.104
Test Statistic		.104
Asymp. Sig. (2-tailed)		.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Recorded result used in the analysis: **Asymp. Sig. (2-tailed) = 0.200**.

Figure 1. Normality Test

Source: Research data processed by the researchers, 2026.

Multicollinearity was assessed to determine whether the four independent variables contained excessive linear interdependence that could distort the estimated regression coefficients. The original analysis applied the criteria of tolerance values above 0.10 and variance inflation factor values below 10, and each predictor satisfied these thresholds. Table 4 should be preserved in its original form

because the underlying SPSS output contains the variable-specific tolerance and VIF information used to support this diagnostic conclusion. The absence of problematic multicollinearity is important because environmental performance, energy intensity, environmental costs, and firm size conceptually capture different dimensions of corporate behavior and must remain statistically distinguishable for their individual coefficients to be meaningfully interpreted (Wahyuningrum et al., 2024; Di Vaio et al., 2024).

Table 2. Multicollinearity Test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.284	.223		1.271	.212		
	Kinerja Lingkungan	.019	.017	.185	1.119	.271	.936	1.068
	Energy Intensity	-.028	.367	-.017	-.077	.939	.543	1.842
	Biaya Lingkungan	.000	.005	.015	.066	.947	.526	1.901
	Ukuran Perusahaan	.013	.008	.261	1.586	.122	.944	1.059

a. Dependent Variable: CED

Decision criterion documented in the manuscript: **Tolerance > 0.10 and VIF < 10 for each independent variable**.
Source: Research data processed by the researchers, 2026.

The heteroscedasticity test provides additional evidence concerning the stability of the residual variance across observations. The recorded significance values were 0.640 for environmental performance, 0.851 for energy intensity, 0.123 for environmental costs, and 0.392 for firm size, each exceeding the 0.05 criterion specified in the original analysis. These values support the conclusion that the test did not detect heteroscedasticity among the four predictors under the decision rule employed by the study. Maintaining relatively stable residual variance strengthens the interpretability of the subsequent inferential tests concerning corporate carbon disclosure determinants (Syam et al., 2024; Izzo et al., 2026).

Table 3. Heteroscedasticity Test

Variable	Significance	Criterion	Decision
Environmental Performance	0.640	> 0.05	No heteroscedasticity detected
Energy Intensity	0.851	> 0.05	No heteroscedasticity detected
Environmental Costs	0.123	> 0.05	No heteroscedasticity detected
Firm Size	0.392	> 0.05	No heteroscedasticity detected

Source: Research data processed by the researchers, 2026.

Autocorrelation was examined using the Durbin–Watson statistic reported in the original model output. The analysis produced a Durbin–Watson value of 1.833, while the documented upper-bound value for 40 observations and four independent variables was 1.7209; the complementary upper limit was calculated as 2.2791. The observed statistic lies between these two boundaries, satisfying the decision rule (DU < DW < 4-DU) adopted in the manuscript. Table 6 and Table 7 are therefore retained because together they provide the model statistic and the reference boundary used to evaluate autocorrelation, a diagnostic step that supports the reliability of the regression specification (Reichelstein, 2024; Desai, 2022).

Table 4. Autocorrelation Test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.331[a]	.110	.008	.11827	1.833

a. Predictors: (Constant), Ukuran Perusahaan, Kinerja Lingkungan, Energy Intensity, Biaya Lingkungan

b. Dependent Variable: RES2

Recorded Durbin–Watson statistic: **1.833**.

Source: Research data processed by the researchers, 2026.

Table 5. Durbin–Watson Upper-Bound Reference

Parameter	Value
Number of observations (N)	40
Number of independent variables (K)	4
DU	1.7209
4 − DU	2.2791
Durbin–Watson	1.833
Decision rule	1.7209 < 1.833 < 2.2791

Source: Durbin–Watson upper-bound.

The combined descriptive and diagnostic evidence indicates that the dataset contains substantial empirical variation while meeting the statistical conditions applied before multiple linear regression. Differences in energy intensity and environmental costs are particularly pronounced, while variation in PROPER performance, firm size, and carbon disclosure demonstrates that companies operating within the same energy sector are not environmentally or organizationally homogeneous. The normality, multicollinearity, heteroscedasticity, and autocorrelation assessments provide the statistical basis for proceeding to coefficient estimation without introducing additional transformations or analytical procedures that were not part of the original study. Such multidimensional variation is consistent with carbon-accounting research that conceptualizes disclosure behavior as a product of operational, financial, environmental, and organizational characteristics rather than a single corporate attribute (Yuliana & Wedari, 2023; Zhu et al., 2024).

The descriptive structure also clarifies why a multivariate specification is required to evaluate carbon emission disclosure among the sampled companies. Environmental performance captures externally assessed environmental standing, energy intensity represents operational dependence on energy relative to economic output, environmental costs reflect financial commitment to environmental activities, and firm size represents organizational scale. Their different empirical distributions suggest that no single indicator adequately represents the environmental accountability profile of an energy-sector company. Studies examining Indonesian carbon reporting similarly emphasize the need to combine environmental and corporate determinants when explaining disclosure variation, particularly in industries with substantial environmental exposure (Nurjanah & Mulyandini, 2024; Riantono & Sunarto, 2022).

The observed variation in carbon emission disclosure provides the dependent-variable dispersion required to evaluate whether the four predictors are associated with differences in reporting behavior. A minimum disclosure value of 0.17 compared with a maximum of 0.94 indicates a wide gap between firms with limited carbon information and those reporting substantially broader information, despite all observations meeting the sample-selection requirements. This difference supports the empirical relevance of examining disclosure determinants rather than assuming that regulatory exposure or sector membership produces equivalent reporting practices across firms. Previous evidence likewise demonstrates that corporate carbon transparency varies according to

organizational capacity, environmental characteristics, and sustainability strategy, creating a strong empirical foundation for the regression analysis that follows (Cohen et al., 2023; Houten & Wedari, 2023).

Regression Estimation and Hypothesis Testing

The multiple linear regression analysis was used to estimate the relationship between environmental performance, energy intensity, environmental costs, firm size, and carbon emission disclosure among the 40 sampled energy-sector companies. The regression specification follows the model established in the research method, with carbon emission disclosure positioned as the dependent variable and the four corporate characteristics as independent variables. The estimated equation reported in the manuscript is (Y = 0.142 + 0.013X_1 - 1.084X_2 + 0.009X_3 + 0.018X_4 + e), where (X_1) represents environmental performance, (X_2) energy intensity, (X_3) environmental costs, and (X_4) firm size. A multivariate specification is appropriate for carbon-disclosure research because reporting behavior can be simultaneously associated with environmental, operational, and organizational characteristics rather than a single determinant (Desai, 2022; Wahyuningrum et al., 2024).

Table 6. Multiple Linear Regression Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.142	.137		1.042	.305
	Kinerja Lingkungan	.013	.011	.128	1.245	.221
	Energy Intensity	-1.084	.142	-.875	-7.628	.000
	Biaya Lingkungan	.009	.002	.444	3.821	.001
	Ukuran Perusahaan	.018	.005	.368	3.658	.001

a. Dependent Variable: CED

Regression equation:
[Y = 0.142 + 0.013X_1 - 1.084X_2 + 0.009X_3 + 0.018X_4 + e]

Source: Research data processed by the researchers, 2026.

The regression coefficients in Table 8 show different directions across the explanatory variables. Environmental performance has a positive coefficient of 0.013, environmental costs have a positive coefficient of 0.009, and firm size has a positive coefficient of 0.018, while energy intensity has a negative coefficient of -1.084. The coefficient signs indicate the direction of association while holding the remaining variables constant, but statistical significance must be evaluated before substantive conclusions are drawn about each predictor. Carbon-disclosure studies similarly emphasize that coefficient direction and statistical significance should be interpreted jointly because corporate characteristics may show apparent associations that are not sufficiently strong to support inferential conclusions (Cahyaningsih & Rahmadiah, 2024; Rahmah et al., 2024).

The original manuscript also contains two graphical normality outputs positioned after the regression table and before the inferential tests. These visual diagnostics form part of the original SPSS output and should remain in the results presentation because they complement the Kolmogorov–Smirnov assessment reported previously. The visual material should be retained exactly as generated in the original analysis rather than reconstructed, since graphical patterns such as histogram shape and probability-plot alignment cannot be reproduced reliably from textual values alone. Diagnostic visualization is commonly used as a supplementary assessment of regression residual behavior alongside formal statistical tests (Reichelstein, 2024; Syam et al., 2024).

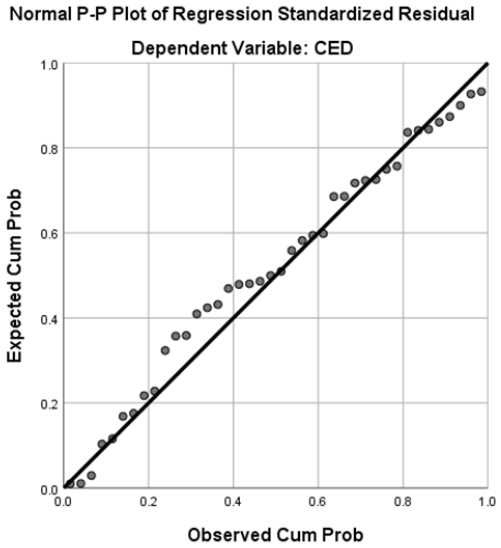


Figure 2. Normal P–P Plot of Regression Standardized Residual
Source: Research data processed by the researchers, 2026.

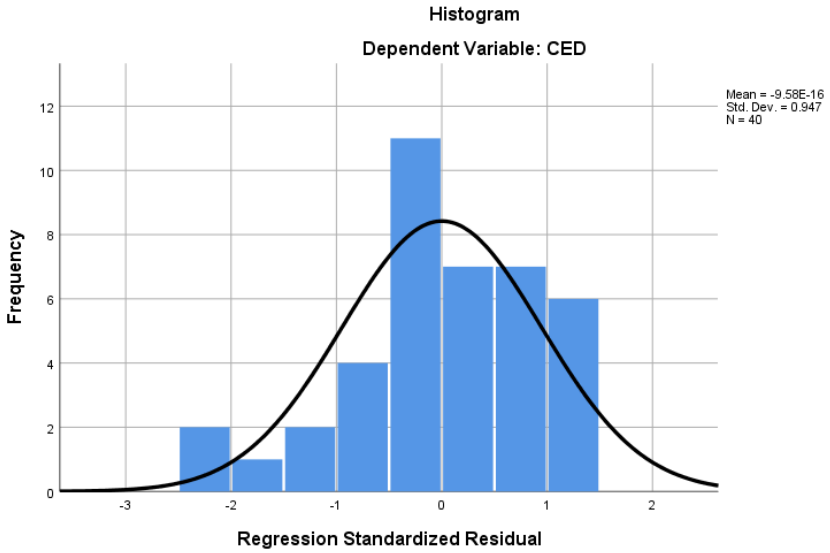


Figure 3. Histogram of Regression Standardized Residual
Source: Research data processed by the researchers, 2026.

The simultaneous significance of the regression model was evaluated using the F-test. The original analysis reports a calculated F value of 16.527 with a significance level of 0.000, while the critical F value based on four independent variables and the reported degrees of freedom was 2.634. Since the calculated F value exceeds the critical value and the significance level is below 0.05, environmental performance, energy intensity, environmental costs, and firm size jointly have a statistically significant relationship with carbon emission disclosure. This finding supports the multidimensional character of carbon transparency, where disclosure is shaped by combined operational and organizational factors rather than being attributable to a single corporate feature (Di Vaio et al., 2024; Izzo et al., 2026).

Table 7. F-Test Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.987	4	.247	16.527	.000[b]
	Residual	.523	35	.015		
	Total	1.510	39			

a. Dependent Variable: CED

b. Predictors: (Constant), Ukuran Perusahaan, Kinerja Lingkungan, Energy Intensity, Biaya Lingkungan

Source: Research data processed by the researchers, 2026.

Table 8. Critical F-Value Reference

Parameter	Value
Number of independent variables (k)	4
Number of observations (n)	40
Degrees of freedom used	4; 36
Critical F-value	2.634
Calculated F-value	16.527
Significance	0.000

The individual contribution of each predictor was then evaluated using the t-test at the 0.05 significance level. Environmental performance produced a significance value of 0.221 and a calculated t value of 1.245, which is below the reported critical t value of 2.030. This result indicates that environmental performance does not have a statistically significant effect on carbon emission disclosure, even though its regression coefficient is positive. The finding reinforces the distinction between formal environmental performance and disclosure intensity, an inconsistency also observed in earlier studies of Indonesian carbon reporting (Nurjanah & Mulyandini, 2024; Puteri & Inawati, 2023).

Energy intensity produced a significance value of 0.000 with a calculated t value of -7.628, indicating a statistically significant negative relationship with carbon emission disclosure. The negative coefficient of -1.084 shows that higher energy consumption relative to revenue is associated with lower disclosure levels when the other variables are held constant. This result is analytically important because energy intensity represents an operational characteristic rather than a conventional governance or financial variable, extending carbon-accounting research toward the relationship between energy-use efficiency and disclosure behavior. Research on carbon performance and environmental transparency similarly indicates that firms with greater environmental exposure may not necessarily provide proportionately greater disclosure (Albert, 2025; Xia, 2026).

Environmental costs show a positive and statistically significant relationship with carbon emission disclosure, with a significance value of 0.001 and a calculated t value of 3.821. The coefficient of 0.009 indicates that a greater proportion of environmental expenditure relative to net income after tax is associated with broader carbon disclosure, holding the other predictors constant. This pattern suggests that firms making greater environmental financial commitments may have stronger incentives to communicate those commitments through sustainability reporting and related environmental disclosures. Empirical studies linking environmental expenditure with carbon transparency and corporate sustainability reporting support this interpretation (Majidah et al., 2025; Valencia & Arsjah, 2025).

Firm size also has a positive and statistically significant effect on carbon emission disclosure, with a significance value of 0.001 and a calculated t value of 3.658. Its coefficient of 0.018 indicates that larger firms, as measured by the natural logarithm of total assets, tend to disclose more carbon-

related information after controlling for the other variables. Larger organizations generally face broader stakeholder scrutiny and possess greater reporting resources, which can strengthen both their capacity and incentive to produce more extensive environmental information. Comparable evidence identifies firm size as an important determinant of carbon reporting and as a factor that may amplify the economic relevance of disclosure (Bedi, 2024; Ardelia & Paramita, 2026; Puteri & Handayani, 2026).

Table 9. t-Test Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.142	.137		1.042	.305
	Kinerja Lingkungan	.013	.011	.128	1.245	.221
	Energy Intensity	-1.084	.142	-.875	-7.628	.000
	Biaya Lingkungan	.009	.002	.444	3.821	.001
	Ukuran Perusahaan	.018	.005	.368	3.658	.001

a. Dependent Variable: CED

Source: Research data processed by the researchers, 2026.

Table 10. Critical t-Value Reference

Parameter	Value
Significance level (α)	0.05
α/2	0.025
Number of observations (n)	40
Number of independent variables (k)	4
Degrees of freedom	35
Critical t-value	2.030

The coefficient of determination provides a final assessment of the explanatory capacity of the estimated model. The reported R-square value is 0.654, indicating that 65.4% of the variation in carbon emission disclosure is explained by environmental performance, energy intensity, environmental costs, and firm size within the sampled firms. The remaining variation is not explained by the four predictors included in the specification, which is consistent with the broader literature identifying governance, ownership, media exposure, carbon performance, and other institutional factors as additional determinants of disclosure (Putri & Arieftiara, 2023; Fidiano & Dewi, 2026). The magnitude of the reported R-square supports the empirical relevance of the model while still recognizing carbon disclosure as a multidimensional corporate reporting phenomenon.

Table 11. Coefficient of Determination

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809[a]	.654	.614	.12219

a. Predictors: (Constant), Ukuran Perusahaan, Kinerja Lingkungan, Energy Intensity, Biaya Lingkungan

Recorded result: **R Square = 0.654 (65.4%)**
Source: Research data processed by the researchers, 2026.

The inferential results establish a clear differentiation among the four determinants examined in the model. Environmental performance does not independently explain carbon emission disclosure, while energy intensity has a significant negative association and both environmental costs and firm size have significant positive associations. The simultaneous F-test and the R-square value further indicate that these variables collectively provide substantial explanatory information regarding differences in carbon transparency among Indonesian energy-sector companies. Such evidence supports a view of carbon disclosure as a reporting outcome shaped by operational efficiency, environmental financial commitment, and organizational capacity rather than formal environmental performance alone (Houten & Wedari, 2023; Zhu et al., 2024).

Integrated Interpretation and Implications of Carbon Disclosure Determinants

The empirical results indicate that carbon emission disclosure among Indonesian energy-sector companies is influenced more strongly by operational energy dependence, environmental expenditure, and organizational scale than by formal environmental performance. Energy intensity produced the strongest statistical association in absolute terms, followed by environmental costs and firm size, while environmental performance did not reach statistical significance. This pattern indicates that corporate environmental transparency is not merely an extension of environmental ratings but is also related to the operational and financial characteristics underlying corporate activities. Prior studies similarly characterize carbon disclosure as a multidimensional reporting outcome shaped by environmental, financial, and organizational attributes rather than by a single performance indicator (Nilasakti et al., 2024; Widianingsih, 2025).

The insignificant effect of environmental performance suggests a separation between environmental achievement and the breadth of carbon-related information communicated to stakeholders. A firm may achieve a comparatively favorable PROPER rating while maintaining a reporting strategy that does not extensively disclose carbon information, because the two measures capture different dimensions of environmental accountability. Evidence from Indonesian energy-sector firms has also shown that environmental performance does not consistently translate into stronger carbon emission disclosure across different samples and analytical specifications (Nurjanah & Mulyandini, 2024; Lumbantungkup & Alam, 2026). This finding cautions against using environmental ratings as a direct substitute for transparency when assessing the quality of corporate climate accountability.

Energy intensity provides a contrasting result because its negative coefficient indicates that greater energy consumption relative to revenue is associated with lower carbon emission disclosure. The relationship may reflect stronger informational sensitivity among companies whose operating models depend heavily on energy use, particularly when higher energy intensity can increase exposure to environmental scrutiny and carbon-related risk. Research on carbon information asymmetry indicates that firms may possess substantially more information about their own environmental exposure than external users, creating room for selective reporting when disclosure has reputational or market implications (Cohen et al., 2023). The present evidence extends this argument by showing that energy-use intensity itself is statistically associated with disclosure behavior after environmental performance, environmental costs, and firm size are controlled.

The negative relationship between energy intensity and disclosure also strengthens the distinction between substantive environmental exposure and corporate communication. Higher environmental exposure does not necessarily produce more extensive transparency, especially when the disclosed information could reveal inefficiencies or intensify scrutiny from regulators, investors, and communities. Studies linking carbon performance, green strategies, and corporate reporting similarly show that environmental behavior and disclosure practices do not always move in the same direction (Yuliana & Wedari, 2023; Xia, 2026). This divergence is particularly relevant for the energy sector because operational dependence on fossil-fuel-based processes can magnify the informational consequences of carbon-related reporting.

Table 16 summarizes the analytical interpretation of the four determinants based strictly on the regression results reported in the study. The synthesis distinguishes the statistical direction of each relationship from its substantive meaning, allowing the results to be interpreted without introducing variables or evidence beyond the original model. The contrast between the insignificant PROPER-based measure and the significant effects of energy intensity, environmental costs, and firm size

illustrates that carbon disclosure is more closely associated with operational exposure, environmental spending, and organizational capacity within the observed sample. This interpretation is consistent with recent carbon-accounting research that emphasizes the interaction between corporate resources, sustainability strategy, and disclosure incentives (Di Vaio et al., 2024; Izzo et al., 2026).

Table 12. Analytical Synthesis of Carbon Emission Disclosure Determinants

Determinant	Empirical Direction	Statistical Status	Analytical Meaning
Environmental Performance	Positive	Not significant	PROPER performance does not independently determine the breadth of carbon disclosure
Energy Intensity	Negative	Significant	Greater energy dependence relative to revenue is associated with lower carbon disclosure
Environmental Costs	Positive	Significant	Higher environmental expenditure is associated with broader carbon disclosure
Firm Size	Positive	Significant	Larger organizational scale is associated with broader carbon disclosure

Source: Synthesized from the regression results of this study, 2026.

The positive effect of environmental costs indicates that environmental expenditure functions not only as a financial commitment but also as a potential stimulus for corporate communication. Firms allocating greater resources to environmental management have stronger incentives to explain how those resources are used, particularly when investors and other stakeholders evaluate whether environmental spending is accompanied by observable sustainability actions. Recent Indonesian research has similarly linked environmental costs with carbon transparency and broader sustainability reporting, although the strength of this relationship varies by sector and measurement approach (Majidah et al., 2025; Valencia & Arsjah, 2025). The result supports the interpretation that environmental expenditure can increase the informational relevance of carbon disclosure when firms seek to demonstrate accountability for environmental resource allocation.

Firm size also exhibits a positive association with carbon emission disclosure, reflecting the role of organizational capacity and public exposure in shaping reporting behavior. Larger firms generally manage more extensive assets, operations, stakeholder relationships, and reporting infrastructures, which can increase both the ability and the pressure to provide climate-related information. Studies examining firm size in carbon-disclosure models have repeatedly identified organizational scale as an important determinant, although the strength of its effect remains sensitive to institutional and industry conditions (Bedi, 2024; Cahyaningsih & Rahmadiah, 2024; Ardelia & Paramita, 2026). The present result suggests that larger Indonesian energy companies face stronger incentives to maintain information visibility through more extensive carbon reporting.

The combined significance of energy intensity, environmental costs, and firm size also illustrates that carbon disclosure is produced at the intersection of operational efficiency, resource commitment, and organizational visibility. Energy intensity captures how heavily the company depends on energy to generate revenue, environmental costs reflect the financial resources committed to environmental management, and firm size represents the scale at which corporate activities are conducted and observed. This multidimensional structure corresponds with recent evidence showing that carbon disclosure is influenced by combinations of corporate characteristics, governance arrangements, environmental performance, and strategic sustainability decisions (Putri & Arieftiara, 2023; Fidiano & Dewi, 2026; Puteri & Handayani, 2026). The model therefore contributes to a more integrated explanation of disclosure behavior by incorporating an operational energy measure alongside established organizational and environmental variables.

The R-square value of 0.654 indicates that the four predictors explain 65.4% of the observed variation in carbon emission disclosure, leaving 34.6% associated with factors outside the current specification. This remaining variation is consistent with previous research identifying media exposure, ownership structure, board characteristics, green investment, carbon performance, and other

institutional influences as relevant determinants of corporate environmental reporting (Cahyaningsih & Rahmadiah, 2024; Fidiano & Dewi, 2026; Putri & Arieftiara, 2023). The unexplained proportion should not be interpreted as contradictory to the model because sustainability disclosure is inherently influenced by multiple organizational and institutional mechanisms. Carbon-reporting studies commonly report that explanatory power is distributed across several classes of determinants rather than concentrated in a single environmental or financial factor (Desai, 2022; Wahyuningrum et al., 2024).

The results also have implications for how stakeholders interpret carbon-related information from energy-sector companies. A relatively broad disclosure profile should not automatically be treated as evidence of superior environmental performance, since PROPER ratings were not statistically associated with disclosure while operational and financial characteristics showed stronger relationships. Research examining the consequences of carbon disclosure has similarly emphasized that disclosed information must be evaluated alongside actual carbon performance and corporate sustainability characteristics when assessing firm value, market responses, or behavioral outcomes (Houten & Wedari, 2023; Putri & Wirakusuma, 2025; Ma, 2023). Investors, regulators, and other users of sustainability reports may therefore obtain a more accurate assessment of environmental accountability when disclosure is considered together with energy intensity, environmental expenditure, and organizational scale.

The empirical structure contributes to sustainability accounting by showing that energy intensity provides explanatory information beyond environmental performance, environmental costs, and firm size. Earlier Indonesian research has largely concentrated on environmental performance, governance, media exposure, corporate characteristics, and carbon performance as determinants of carbon disclosure, while direct operational energy intensity has received substantially less attention (Riantono & Sunarto, 2022; Khairunnisa & Wilasittha, 2026). Incorporating energy intensity creates a closer connection between the company's operational resource profile and its reporting behavior, strengthening the analytical link between carbon accounting and energy efficiency. The resulting evidence supports a broader conception of carbon disclosure as an accountability mechanism whose intensity can differ materially from the environmental exposure generated by corporate operations (Albert, 2025; Reichelstein, 2024).

CONCLUSION

This study examined the effects of energy intensity, environmental performance, environmental costs, and firm size on carbon emission disclosure among energy-sector companies listed on the Indonesia Stock Exchange in 2025. The findings show that environmental performance does not have a statistically significant effect on carbon emission disclosure, indicating that differences in PROPER ratings are not sufficient to explain the variation in carbon-related reporting among the sampled firms. Energy intensity has a significant negative effect on carbon emission disclosure, showing that companies with higher energy consumption relative to revenue tend to disclose less carbon-related information. Environmental costs have a significant positive effect, indicating that greater allocation of environmental expenditure is associated with broader carbon emission disclosure. Firm size also has a significant positive effect, demonstrating that larger companies tend to provide more extensive carbon-related information. Simultaneously, the four independent variables significantly explain carbon emission disclosure, with the model accounting for 65.4% of the observed variation.

The study contributes to sustainability accounting research by extending the determinants of carbon emission disclosure through the inclusion of energy intensity as an operational characteristic alongside environmental performance, environmental costs, and firm size. The results indicate that carbon transparency is more closely associated with operational energy dependence, environmental financial commitment, and organizational scale than with formal environmental performance ratings alone. From a practical standpoint, the findings imply that corporate managers should strengthen the consistency between operational energy use, environmental expenditure, and carbon-related reporting so that disclosed information more accurately reflects the environmental profile of the company. Investors and other stakeholders may also consider energy intensity and environmental expenditure when assessing the credibility and breadth of corporate carbon disclosure. For regulators and standard setters, the variation identified in carbon reporting supports the need for greater comparability and consistency in disclosure practices among energy-sector companies.

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