

THE INFLUENCE OF FIRM SIZE, ENVIRONMENTAL PERFORMANCE, BOARD INDEPENDENCE, AND BOARD GENDER DIVERSITY ON CARBON EMISSION DISCLOSURE IN ENERGY COMPANIES LISTED ON THE INDONESIA STOCK EXCHANGE (2023–2024)

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Abstract

This study aims to determine the influence of firm size, environmental performance, board independence, and board gender diversity on carbon emission disclosure among energy companies listed on the Indonesia Stock Exchange during the 2023–2024 period. The study utilized a sample of 61 companies selected through purposive sampling. Data analysis was conducted using multiple linear regression. The results indicate that firm size and environmental performance have a positive effect, whereas board independence and board gender diversity have no effect.

Keywords: *Carbon Emission Disclosure, Firm Size, Environmental Performance, Board Independence, Board Gender Diversity*

INTRODUCTION

Climate change has emerged as a major environmental issue garnering serious global attention over the past few decades from governments, corporations, and investors alike. It triggers transformations in physical natural conditions, directly impacting hydrological systems and accelerating global warming (Kurniawan, Widagdo, & Ika, 2024). The primary driver of increased global warming is the rising volume of greenhouse gas (GHG) emissions in the atmosphere. Among the various types of GHGs, CO₂ emissions make the largest contribution, accounting for over 70% of the total (Sachan, Pradhan, Mohindra, & Menegaki, 2025). Nationally, data from the Global Carbon Budget indicates that Indonesia's carbon emissions have continued to rise, reaching 812.22 million tons in 2024—placing the country among the top ten GHG emitters globally (Hidayat, Ismail, Taqi, & Yulianto, 2022). According to data from the International Energy Agency (IEA), the volume of global carbon emissions resulting from energy combustion and industrial activities tends to increase annually. The energy sector is the largest contributor to GHG emissions worldwide, accounting for 75.7% of the total, based on data from the World Resources Institute (2024). In an effort to reduce and control emissions, Indonesia has established various reduction targets. Data from the Climate Transparency Report (2021) indicates that Indonesia has set a national emission reduction target of 29% to 41% by 2030, as stipulated in Presidential Regulation of the Republic of Indonesia Number 98 of 2021 (Putri & Ariefiara, 2023). In addition to medium-term targets, Indonesia has established a long-term goal of achieving Net Zero Emissions (NZE) by 2060. The government also mandates that companies prepare sustainability reports, as stipulated in Financial Services Authority Regulation (POJK) Number 51/POJK.03/2017, Article 10, Paragraph (1)—a requirement subsequently updated by the issuance of SEOJK (Financial Services Authority Circular Letter) No. 16/SEOJK.04/2021. However, to date, there is no regulatory framework specifically governing carbon emission limits or disclosure standards (Abdullah, Musriani, Syariati, & Hanafie, 2020). Carbon Emission Disclosure (CED) practices in Indonesia remain low, inconsistent, and uneven; they are also potentially biased due to the discretion companies have in determining reporting scope (Wahyuningrum, Agustina, Ihlashul'amal, Jati, Sularsih, Anwar, & Sriningsih, 2025). Energy sector companies are expected to disclose comprehensive carbon emission information. Yet, a study by Fahira and Yuliandhari (2025) indicates that only about 40% of large-scale coal and energy companies in Indonesia clearly report their carbon emission data. The level of CED is influenced by various factors, including

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internal characteristics and corporate governance. Firm size is one determinant that generally shows a positive relationship with CED (Riantono & Sunarto, 2022). Another significant factor is environmental performance. Companies with strong environmental performance reflected, for instance, by holding International Organization for Standardization (ISO) 14001 certification tend to be more motivated to disclose environmental information. From a corporate governance perspective, board independence plays a crucial role in enhancing the effectiveness of the oversight function, thereby raising executive awareness regarding social and environmental obligations (Githaiga, 2025). Another governance aspect examined in this study is board gender diversity assessed based on the number of women on the board which is believed to foster improvements in the quality of Corporate Environmental Disclosure (CED) (Wahyuningrum et al., 2025). Given this context, this study aims to analyze the impact of firm size, environmental performance, board independence, and board gender diversity on CED among energy companies listed on the Indonesia Stock Exchange during the 2023–2024 period. Previous research on CED has yielded inconsistent results, necessitating further study within the Indonesian energy sector.

LITERATURE REVIEW

2.1 Legitimacy Theory

Legitimacy theory emphasizes the existence of a relationship between a company and society based on the concept of a social contract. First proposed by Dowling and Pfeffer (1975), the theory describes a situation where the value system held by the community surrounding a company's operations aligns with the values and activities pursued by the company itself (Abdullah, Musriani, Syariati & Hanafie, 2020).

2.2 Carbon Emission Disclosure

Carbon Emission Disclosure (CED) is a form of environmental reporting that encompasses GHG emission intensity and energy usage, corporate governance, and strategies designed to address the impacts of climate change (Nasih, Puspitasari, Harymawan, Putra & Djajadikerta, 2024).

2.3 Firm Size

Firm size refers to the scale of a company, which can be classified using various indicators such as stock market value, total assets, operational capacity, and others. Generally, firm size is categorized into three groups: large, medium, and small enterprises (Utami, Saraswati, & Purwati, 2022).

2.4 Environmental Performance

Environmental performance reflects the extent of a company's effectiveness in managing environmental aspects arising from its operational activities, services, and products, as well as its overall environmental impact. Assessments of environmental performance are conducted using an Environmental Management System (EMS) focused on the management and control of environmental aspects (Jannah & Narsa, 2021).

2.5 Board Independence

Board independence refers to the proportion of independent directors within a company (Lina & Devyanti, 2024). The presence of independent directors is believed to encourage management to expand Carbon Emission Disclosure (CED) in order to mitigate information asymmetry.

2.6 Board Gender Diversity

Board gender diversity represents the presence of women within the composition of the board of directors (Hidayah, Purnomowati, & Cummings, 2024). Gender diversity within this structure can influence decision-making mechanisms and the direction of corporate policy. The presence of women on the board of directors is more effective and more oriented toward corporate social issues compared to their male counterparts (Githaiga, 2025).

2.7 The Influence of Firm Size on Carbon Emission Disclosure

According to Kholmi, Karsono, and Syam (2020), companies with larger total assets also possess a larger firm size. Large companies tend to exhibit more intensive operational levels, thereby generating higher carbon emissions (Hidayat et al., 2022). Consequently, large companies face greater social and administrative pressure to disclose environmental information compared to small companies. Research by Utami et al. (2022) indicates that firm size has a positive effect on CED; the larger the company, the more visible its contribution to the surrounding environment, leading to higher and more extensive CED reporting.

H1: Firm Size has a positive effect on Carbon Emission Disclosure.

2.8 The Influence of Environmental Performance on Carbon Emission Disclosure

High environmental performance positively influences the disclosure of GHG and carbon emissions (Harits & Mutasowifin, 2024). This is supported by findings from Wahyuningrum and Baroroh et al. (2025), stating that

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companies with excellent environmental performance generally address the threat of climate change and maintain long-term commitments across all operations, thereby integrating climate change considerations into their business strategies. Research by Yauri and Widianingsih (2023) shows that environmental performance has a positive effect on CED; companies with strong environmental performance are highly motivated to disclose carbon emission information.

H2: Environmental Performance has a positive effect on Carbon Emission Disclosure.

2.9 The Influence of Board Independence on Carbon Emission Disclosure

A dominant proportion of independent commissioners is believed to foster stricter oversight regarding corporate survival, business continuity, and expansion (Solikhah Wahyuningrum, Yulianto, Sarwono, & Widiatami, 2021). Companies with high board independence are likely to be transparent about operations that impact the ecosystem. This is supported by the findings of Gulo, Sari, Hapsari, and Tihar (2025), which explain that a larger proportion of independent commissioners strengthens oversight and transparency while encouraging sustainability reporting. Research by Saraswati, Puspita, and Sagitaputri (2021) shows similar results, indicating that board independence has a positive effect on Carbon Emission Disclosure (CED) because independent commissioners can strengthen oversight of management and foster management transparency.

H3: Board independence has a positive effect on Carbon Emission Disclosure.

2.10 The Influence of Board Gender Diversity on Carbon Emission Disclosure

Companies with gender diversity on their boards tend to possess a broader mix of skills and experience, which serves as a crucial determinant in optimizing board effectiveness (Astuti & Setiany, 2021). Research findings by Githaiga (2025) indicate that board gender diversity has a positive influence on Carbon Emission Disclosure (CED), as female directors generally possess greater environmental awareness than their male counterparts. Studies by Wahyuningrum and Baroroh et al. (2025) confirm similar results, showing that greater female representation on the board contributes positively to CED due to women's heightened concern and attention regarding sustainability and environmental issues.

H4: Board Gender Diversity has a positive influence on Carbon Emission Disclosure.

METHOD

This study focuses on energy sector companies listed on the Indonesia Stock Exchange, covering the observation period of 2023–2024. A non-probability sampling method—specifically purposive sampling—was employed for sample selection. The criteria for sample selection were as follows:

1. Energy companies listed on the Indonesia Stock Exchange during the 2023–2024 period.
2. Companies that consistently published annual reports and sustainability reports throughout the 2023–2024 period.
3. Companies that presented information regarding carbon emissions in their annual and sustainability reports (specifically, at least one policy related to carbon emissions or the disclosure of at least one carbon emission item).

Based on these criteria, 61 companies met the requirements; given the two-year study period, the total dataset comprises 122 observations (61 companies × 2 years). This is a secondary research study utilizing data from the annual and sustainability reports of energy companies listed on the Indonesia Stock Exchange for the years 2023–2024. Data were collected via the documentation method and subsequently processed using SPSS. Two types of variables are used in this study: dependent and independent variables. The dependent variable is Carbon Emission Disclosure (CED). The independent variables include firm size, environmental performance, board independence, and board gender diversity.

CED is measured based on the extent of information disclosed by the company in its reports. The measurement utilizes the Carbon Disclosure Project (CDP) checklist items. These items were developed by Choi et al. (2013) and consist of five main disclosure categories comprising a total of 18 items. Each item is assigned equal weight upon disclosure. A company's maximum score is 18, awarded if it discloses information regarding all 18 items listed in the table. An item receives a score of 1 if the company discloses information in accordance with the checklist, and a score of 0 if the item is not disclosed as specified. Firm size is calculated using the natural logarithm (ln). The total value of a company's assets can amount to millions or even billions of rupiah; therefore, simplification is required by converting the figure into a logarithm (Nasih et al., 2019).

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Environmental performance is assessed based on whether the company holds ISO 14001 certification (Kurniawan et al., 2024). A dummy variable is used for measurement, where companies holding ISO 14001 certification are assigned a value of 1, while those without it are assigned a value of 0. Board independence is measured based on the proportion of independent commissioners on the board of commissioners (Saraswati et al., 2021). Board gender diversity is calculated using a ratio—specifically, by dividing the number of female members of the board of directors by the total number of directors within the organizational structure (Wahyuningrum & Baroroh et al., 2025).

RESULTS AND DISCUSSION

4.1 Statistic Descriptive Analysis

Table 4.1 Statistic Descriptive

Variabel	N	Minimum	Maximum	Mean	Std. Deviation
CED	122	-.3	.73	0.2924	0.19667
FS	122	5.36	19.16	14.4646	2.03767
EP	122	-.5	1.00	0.4166	0.33948
BI	122	.03	.75	0.2241	0.11243
BGD	122	-.25	.67	0.0676	0.15795

Based on the data presented in Table 4.1 above, each research variable exhibits variations in minimum, maximum, mean, and standard deviation values. The firm size variable has a mean value of 14.4646, a maximum value of 19.22, a minimum value of 5.42, and a standard deviation of 2.03767. This indicates that the average firm size during the 2023–2024 period was 14.4646, with a maximum value of 19.22 and a minimum value of 5.42. The environmental performance variable has a mean value of 0.4166, a maximum value of 1.00, a minimum value of -0.5, and a standard deviation of 0.33948. This indicates that the average environmental performance during the 2023–2024 period was 0.4166, with a maximum value of 1.00 and a minimum value of -0.5. The board independence variable has a mean value of 0.2241, a maximum value of 0.75, a minimum value of 0.00, and a standard deviation of 0.11243. This indicates that the average board independence during the 2023–2024 period was 0.2241, with a maximum value of 0.75 and a minimum value of 0.00. The board gender diversity variable has a mean value of 0.0676, a maximum value of 0.67, a minimum value of -0.25, and a standard deviation of 0.15795. This indicates that the average board gender diversity during the 2023–2024 period was 0.0676, with a maximum value of 0.67 and a minimum value of -0.25. The CED variable has a mean value of 0.2924, a maximum value of 0.73, a minimum value of -0.3, and a standard deviation of 0.19667. This indicates that the average CED value for the 2023–2024 period was 0.2924, with the highest disclosure value reaching 0.73 and the lowest reaching -0.3.

4.2 Classical Assumption Test

Classical assumption tests are conducted to assess the validity of the regression model and determine whether it meets the fundamental regression assumptions. Based on the calculations and decision criteria for the autocorrelation test, the Cochrane-Orcutt test is employed as an alternative method within the classical assumption and hypothesis testing framework, as it involves transforming the regression model.

4.3 Normality Test

The normality test is used to determine whether the standardized residuals in the regression model follow a normal distribution. The Kolmogorov-Smirnov test is utilized for this purpose. Data are considered to be normally distributed if the test's significance value exceeds 0.05. Based on the Kolmogorov-Smirnov normality test Table 4.2, the obtained Asymp. Sig. (2-tailed) value is 0.200. This indicates that the data used in this study are normally distributed.

Table 4.2 Normality Test

<i>One-Sample Kolmogorov -Smirnov Test</i>		
		LAG_RES
<i>Normal Parameters a,b</i>	<i>Mean</i>	.0003
	<i>Std. Deviation</i>	.19668
<i>Most Extreme Differences</i>	<i>Absolute</i>	.062
	<i>Positive</i>	.062
	<i>Negative</i>	-.042
<i>Test Statistic</i>		.062
<i>Asymp. Sig. (2-tailed)</i>		.200 ^{c,d}

4.4 Multicollinearity Test

The multicollinearity test aims to determine whether there is a significant relationship or correlation between independent variables in a regression model.

Table 4.3 Multicollinearity Test

<i>Coefficients^a</i>			
Model		Collinearity Statistics	
		Tolerance	VIF
1	<i>(Constant)</i>		
	LAG_FS	.715	1.399
	LAG_EP	.787	1.271
	LAG_BI	.881	1.135
	LAG_BGD	.977	1.024

Based on the information presented in the table, the Collinearity Statistics column shows that the Tolerance values for the variables of firm size, environmental performance, board independence, and board gender diversity are all greater than 0.10. These results indicate that each independent variable meets the criteria for the multicollinearity test.

4.5 Heteroskedasticity Test

The heteroskedasticity test aims to determine whether there is inequality in the variance of residual values across observations in a regression model.

Table 4.4 Heteroskedasticity Test

<i>Coefficients^a</i>			
Model		t	Sig.
1	<i>(Constant)</i>	4.425	.000
	LAG_FS	-3.504	.001
	LAG_EP	.661	.510
	LAG_BI	1.090	.278
	LAG_BGD	.513	.609

Based on the data presented above, the significance values (Sig.) for the variables of firm size, environmental performance, board independence, and board gender diversity exceed 0.05. Consequently, based on the decision-making criteria of the Glejser test, the regression model can be said to show no signs of heteroskedasticity.

4.6 Autocorrelation Test

Autocorrelation testing is a statistical procedure designed to determine whether a relationship exists between residual values in one period and those in the preceding period within a regression model. This assessment is conducted using the Durbin-Watson (DW) test. The Durbin-Watson test criteria state that if the DW value falls between the Durbin-Upper (DU) value and 4-DU (i.e., $DU < DW < 4-DU$), the regression model shows no indication of autocorrelation.

Initial results yielded a DW value of 0.994. Comparing this figure against critical values from the Durbin-Watson table resulted in a DU value of 1.7727 and a 4-DU value of 2.2273. These results indicate the presence of autocorrelation, preventing the analysis from proceeding to the next stage of testing. Consequently, an alternative approach the Cochrane-Orcutt test will be employed.

Table 4.5 Durbin Watson Test

Model	<i>Std. Error of The Estimate</i>	<i>Durbin-Watson</i>
1	.17161	1.852

The results show a DW value of 1.852, a DU value of 1.7727, and a 4-DU value of 2.2273. Based on the calculations and decision-making criteria above, it can be concluded that no autocorrelation is present, and the analysis may proceed to the next stage of testing.

4.7 Coefficient of Determination Test

The coefficient of determination (R^2) is used to measure the regression model's ability to explain the contribution of independent variables to the dependent variable. In research practice, Adjusted R-squared is preferred because it accounts for value fluctuations resulting from the addition of an independent variable to the model.

Table 4.6 Coefficient of Determination Test

Model	R	<i>R Square</i>	<i>Adjusted R Square</i>
1	.548	.300	.276

Based on the test results presented in the table, the Adjusted R-squared value is 0.239. This indicates that approximately 23.9% of the variation in CED can be explained by the independent variables used in the study—namely firm size, environmental performance, board independence, and board gender diversity. However, the remaining 76.1% is influenced by factors other than the variables analyzed in this study.

4.8 T Test

The t-test is a hypothesis test conducted to determine the effect of each variable—firm size, environmental performance, board independence, and board gender diversity on CED. Decision-making in this test is based on a significance value (Sig.) of less than 0.05.

Table 4.7 Partially Test

Model	<i>Unst. Coefficients</i>		t	Sig.
	B	<i>Std. Error</i>		
1 (Constant)	.309	.119	-2.604	.010
LAG_FS	.037	.009	4.108	.000
LAG_EP	.114	.052	2.192	.030
LAG_BI	.017	.148	.116	.908
LAG_BGD	.140	.100	1.398	.165

Based on the regression results above, the multiple linear regression equation can be written as follows:

$$Y = -0.309 + 0.037 (FS) + 0.114 (EP) + 0.017 (BI) + 0.140 (BGD) + \varepsilon$$

Based on the t-test analysis, firm size shows a positive regression coefficient of 0.037, with a significance value of 0.000 (< 0.05) and a t-statistic of 4.108 ($> t$ -table of 1.97993). These results indicate that firm size has a positive effect on CED; thus, the first hypothesis of this study is accepted. The environmental performance variable shows a positive regression coefficient of 0.114, with a significance value of 0.030 (< 0.05) and a t-statistic of 2.192 ($> t$ -table of 1.97993). These results indicate that environmental performance has a positive effect on CED; thus, the second hypothesis of this study is accepted.

Based on the t-test analysis, board independence shows a positive regression coefficient of 0.017, with a significance value of 0.908 (> 0.05) and a t-statistic of 0.116 ($< t$ -table of 1.97993). These results indicate that board independence has no effect on CED; thus, the third hypothesis of this study is rejected. It is also shown that board gender diversity has a positive regression coefficient of 0.140, with a significance value of 0.165 (> 0.05) and a t-statistic of 1.398 ($< t$ -table of 1.97993). The results indicate that board gender diversity has no effect on CED; thus, the fourth hypothesis of this study is rejected.

4.9 The Influence of Firm Size on Carbon Emission Disclosure

Empirical test results show that CED is positively and significantly influenced by firm size. This is reflected by a significance value of 0.000 (below the 0.05 threshold) and a t-statistic of 4.108 (exceeding the t-table value of 1.979); consequently, the first hypothesis (H1) is statistically accepted. These findings indicate that an increase in firm size tends to correlate with an increase in Carbon Emission Disclosure (CED). This positive relationship reflects

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the fact that larger companies generally produce carbon emission reports to enhance their corporate credibility and reputation. The larger the company, the more visible its contribution to the surrounding environment; consequently, the scope and extent of its reported carbon emissions tend to be greater. These results align with the study by Ika, Yuliani, Okfitasari, and Widagdo (2022), which demonstrated that firm size has a significant positive influence on CED, as companies with larger assets tend to provide more extensive CED in their annual or sustainability reports.

4.10 The Influence of Environmental Performance on Carbon Emission Disclosure

The t-test results show that CED is positively and significantly influenced by environmental performance. This is evidenced by a significance value of 0.030—which is below the 0.05 threshold—and a calculated t-value of 2.192, which exceeds the t-table value of 1.979; thus, the second hypothesis (H2) is statistically accepted. The finding that environmental performance positively influences CED indicates that companies with strong environmental performance are highly motivated to disclose carbon emission information. This aligns with the study by Krisnawanto and Solikhah (2020), which noted a tendency for companies with good environmental performance to disclose environmental information (Krisnawanto & Solikhah, 2020).

4.11 The Influence of Board Independence on Carbon Emission Disclosure

The t-test results indicate that the board independence variable has a positive coefficient direction regarding CED, but the influence is not statistically significant. This is evidenced by a significance value of 0.908—exceeding the 0.05 significance level—and a calculated t-value of 0.116, which is lower than the t-table value of 1.979. Based on these findings, it can be empirically concluded that the level of Carbon Emission Disclosure (CED) is not significantly influenced by board independence; thus, the third hypothesis (H3) is rejected. The finding that board independence does not affect CED indicates that, in reality, independent board members do not influence a company's CED strategy. Since a company's board structure comprises more than just independent members, the influence of independent directors on decision-making regarding carbon emissions is considered negligible (Wahyuningrum & Agustina et al., 2025). This result aligns with the study by Riantono and Sunarto (2022), which similarly demonstrated that a high proportion of independent commissioners does not drive companies to engage in environmental disclosure.

4.12 The Influence of Board Gender Diversity on Carbon Emission Disclosure

Referring to the t-test results, the board gender diversity variable shows a significance value of 0.165—exceeding the 0.05 threshold—and a calculated t-value (t-count) of 1.398, which is lower than the t-table value.

CONCLUSION

Research findings demonstrate that firm size has a positive and significant effect on CED. This indicates that the larger the firm, the more extensive its CED practices. Environmental performance also has a positive and significant effect on CED; companies with strong environmental performance are more motivated to engage in extensive CED practices. Board independence, however, does not affect CED. The role of independent commissioners likely remains focused on general corporate oversight rather than specifically on sustainability and environmental transparency issues. Similarly, board gender diversity has no effect on CED. The representation of women on the boards of energy companies remains low; consequently, their influence both in terms of corporate decision-making and statistical impact—is insufficient to affect CED practices.

Future research should consider incorporating other variables that may influence CED, such as profitability, leverage, institutional ownership, media exposure, environmental committees, sustainability committees, or good corporate governance. Including these variables is expected to provide a more comprehensive understanding of the factors influencing corporate CED practices.

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