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Leverage, Firm Size, and Environmental Performance as Determinants of Carbon Emission Disclosure: An Educational Perspective of Energy and Industrial Sector Firms Listed on the Indonesia Stock Exchange

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ABSTRACT

This study examined the influence of leverage, firm size, and environmental performance on carbon emission disclosure among energy and industrial sector firms listed on the Indonesia Stock Exchange during the 2021–2024 period. The analysis reveals that leverage and firm size do not have a significant impact on disclosure, indicating that debt levels and organizational scale are not central determinants of environmental transparency. Conversely, environmental performance—measure through the PROPER rating—exerts a positive and significant influence, suggesting that firms with stronger environmental achievements demonstrate greater commitment to disclosing carbon-related information. Framed within an educational perspective, these findings highlight the critical role of environmental accountability in shaping organizational learning, stakeholder awareness, and the dissemination of sustainability values. The results contribute to both academic and practical knowledge by emphasizing that environmental responsibility, rather than financial or structural attributes, is a more effective driver of carbon disclosure. This reinforces the importance of integrating sustainability and disclosure practices into corporate training, higher education curricula, and professional development initiatives to cultivate long-term awareness and accountability.

Keywords: *Carbon emission disclosure; leverage; firm size; environmental performance; PROPER; sustainability reporting; educational perspective.*

INTRODUCTION

Global climate change is becoming increasingly severe, primarily due to the rise in greenhouse gas emissions, such as carbon dioxide (CO_2), resulting from human activities. The Earth's temperature has risen by 1.1°C since the late 19th century, leading to more frequent and intense extreme weather events such as floods and droughts (IPCC, 2018). In this context, carbon emission disclosure by companies serves as a form of transparency to gain legitimacy from stakeholders and to mitigate operational risks caused by environmental impacts (Gunawan & Aryati, 2024).

According to climate monitoring data from the European Union, the year 2024 marked the first year with an average temperature clearly exceeding 1.5°C compared to

pre-industrial levels. Several global records have been broken, including those related to greenhouse gas levels, air temperatures, and sea surface temperatures, all of which have contributed to extreme events such as floods, heatwaves, and wildfires. Furthermore, based on data from the Copernicus Climate Change Service of the European Union, the Earth's temperature has continued to rise over the past year.

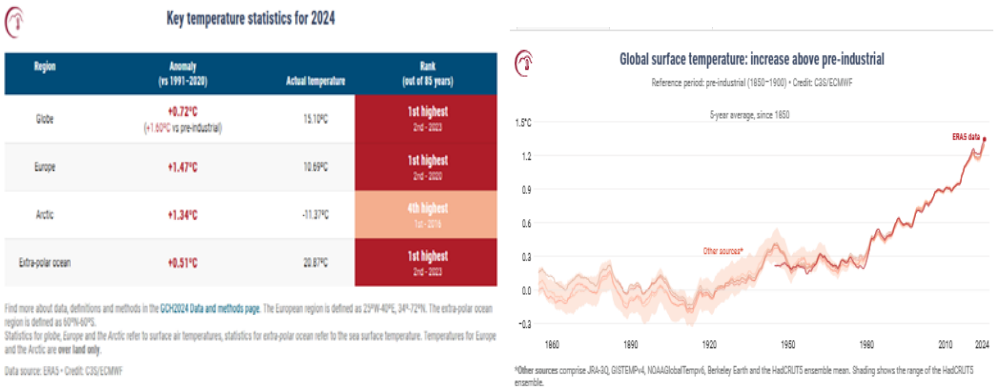

Figure I.1 Global Temperature Increase in the Past Year
Source: Copernicus.eu

In 2019, greenhouse gas (GHG) emissions from the energy sector showed annual improvement. Emission reductions in that year reached 54.8 million tons. This downward trend continued, with emission reductions reaching 64.4 million tons in 2020 and 70 million tons in 2021. In 2022 and 2023, the amount of emissions successfully reduced increased to 91.5 million tons and 127.6 million tons, respectively. Then, in 2024, GHG emission reductions in the energy sector reached 147.67 million metric tons of CO_2, surpassing the predetermined target. Despite this significant reduction, there remains a considerable gap between aspiration and realization of emission reduction, indicating challenges that must be addressed in emission mitigation efforts (Katadata Green, 2019 in Pusparisa, 2021). Climate Watch reported that Indonesia ranks sixth globally among the largest greenhouse gas emitters, contributing 3.11% of global emissions. The energy sector is the highest contributor, accounting for 45.73% of total GHG emissions.

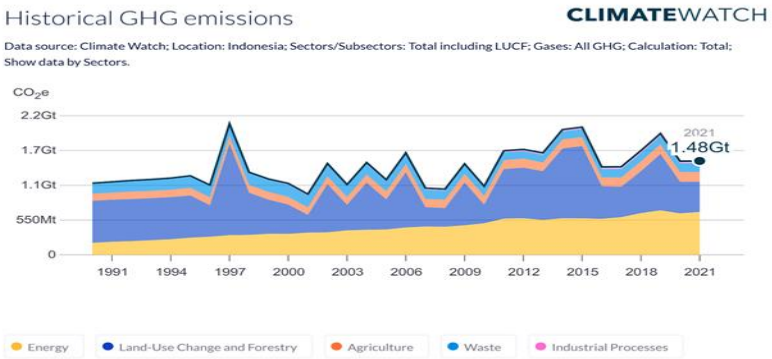

Figure I.2 Increase in Carbon Emissions by Sector
Source: Historical GHG Emissions – Climate Watch (2025)

From the figure above, it can be explained that the energy sector ranks highest, contributing 679 Mt out of a total of 1.48 Gt CO_2e. In second place is the land use and forestry governance sector, contributing 476.85 Mt. The agriculture sector ranks third with 154.15 Mt, followed by the waste sector in fourth place at 140.31 Mt, and lastly the industrial processes sector, contributing 34.34 Mt.

The energy and industrial sectors are the main contributors to carbon dioxide (CO_2) emissions and other greenhouse gases. Activities such as fossil fuel combustion in the energy sector and industrial production processes produce significant emissions. According to a report by the Ministry of Environment and Forestry (2019), the energy sector accounted for 56% of Indonesia's total GHG emissions (Muliawati, 2023). The Indonesian government has issued several regulations to reduce carbon emissions, including Presidential Regulation No. 98 of 2021 on the Implementation of Carbon Economic Value. This indicates that these sectors are under strict scrutiny and are expected to disclose carbon emissions transparently.

According to the IPCC (2018), the opportunity to meet the 1.5°C target will only last until 2030. To achieve the minimum temperature increase goal, global GHG emissions must peak by 2030 and then decline sharply to reach net-zero emissions by 2050. Addressing this issue requires fast, efficient, and comprehensive mitigation measures, involving stakeholders worldwide. Based on projections ("CAT 2035 Climate Target Updates Tracker", 2026), Indonesia's GHG emissions from the energy, transportation, shipping, and industrial sectors (excluding LULUCF) are estimated to reach 1,573–1,751 $MtCO_2e$ by 2030. This figure accounts for 3.75–4% of total global GHG emissions, which are projected to reach 40 $GtCO_2e$. Of Indonesia's total projected emissions in 2030, the electricity generation sector is estimated to contribute approximately 400 million tons CO_2e.

Methane is a GHG with a global warming potential 30 times greater than carbon dioxide over a 100-year period (IPCC, 2018). Ember Climate stated that methane emissions from coal mines in Indonesia are up to eight times higher (Suryowati, 2024). As part of its climate commitment, Indonesia ratified the Kyoto Protocol through Law No. 17 of 2004 and issued Presidential Regulation No. 61 of 2011 on the National Action Plan for GHG Emissions Reduction (RAN-GRK). Article 4 of this regulation states that RAN-GRK serves as a guideline for the public and businesses in implementing emissions reduction actions. Thus, companies are now evaluated not only by their profitability, but also by their social and environmental achievements, which can be assessed through the implementation of carbon accounting (Andriadi & Werastuti, 2020).

PT Bukit Asam Tbk (PTBA), one of Indonesia's largest coal mining companies, has been involved in several environmental pollution cases. A notable case occurred in 2021 with the pollution of the Kiahaan River in Tanjung Enim, South Sumatra. Mining activities by PTBA in the area were suspected of causing air and water pollution, affecting the community. In response, the Ministry of Environment and Forestry (KLHK) launched an investigation and found that PTBA's operations had impacted the river's water quality. As a result, administrative sanctions were imposed,

requiring PTBA to improve its waste management system and restore the affected environment. The sanctions were lifted on December 14, 2021, after PTBA was deemed to have met the required conditions (Prasetro, 2024).

The environmental impact of this pollution was significant, both to the river ecosystem and surrounding communities. Water quality degradation threatened aquatic life and reduced access to clean water, increasing health risks. In addition to the Kiahaan River case, PTBA was also found guilty in January 2024 by the Lahat District Court for environmental damage in Merapit Village, East Merapi District, covering over 13 hectares. PTBA was ordered to restore the land and fined Rp10 million per day for non-compliance (Prasetro, 2024). Although sanctions in the Kiahaan River case were lifted, monitoring of PTBA's activities continues under the supervision of the South Sumatra Provincial Environmental Agency. This monitoring ensures compliance with environmental standards, including water, air, and hazardous waste (B3) management. However, many companies have yet to disclose their carbon emissions transparently, including PT Vale Indonesia Tbk (INCO), PT Aneka Tambang Tbk (ANTAM), PT Adaro Energy Indonesia Tbk (ADRO), and PT Pajitex.
Carbon emissions are a consequence of human activities that negatively affect the environment and society (Ramadhani & Astuti, 2023 in Marlina, 2024). Disclosure is carried out by businesses to quantify and reduce the carbon they emit (Nisa, 2022), typically reported in annual or sustainability reports. However, in Indonesia, such disclosures are voluntary, meaning not all businesses include them in their reports (Bahriansyah & Ginting, 2022). A checklist of items, based on the Carbon Disclosure Project (CDP) developed by Choi et al. (2013), is often used to track these emissions.

Leverage reflects a firm's debt-to-equity ratio and indicates financial pressure. Companies with high leverage are less likely to voluntarily disclose carbon emissions, as it could be seen as financially detrimental (Sekarini & Setiadi, 2021). High leverage can also lower carbon emissions, as the increased operational costs from carbon output require greater efficiency (Florencia & Handoko, 2021). Abdullah et al. (2020) found a positive impact of leverage on carbon emissions, although this was refuted by Ratmono et al. (2021), in line with studies by Mulya & Rohman (2020), Sekarini & Setiadi (2021), and Florencia & Handoko (2021) that found no significant relationship between leverage and carbon disclosure.

Firm size refers to a company's scale based on total assets, sales, or market capitalization. Larger firms are often subject to greater regulatory scrutiny and may engage more in environmentally conscious practices (Septriyawati et al., 2019). Research shows firm size is related to financial capacity and operational complexity, but not necessarily to emission levels. Studies by Septriyawati et al. (2019), Witri Astiti & Wirama (2020), and Gunawan & Aryati (2024) indicate no significant relationship between firm size and carbon emissions. Larger firms also tend to interact more collaboratively with communities, enhancing legitimacy and brand image through environmentally friendly actions.

Environmental performance measures a company's interaction with the environment — such as water usage, impact of operations, product risks, and

regulatory compliance (Nisa, 2022). The Ministry of Environment uses PROPER (Company Performance Rating Program in Environmental Management) to evaluate firms. The PROPER program ranks companies from best to worst as gold, green, blue, red, and black. This system not only evaluates compliance but helps firms gain public and stakeholder support, reinforcing legitimacy (Rinaldi et al., 2024). According to Sekarini & Setiadi (2021), higher PROPER ratings correlate with better environmental sustainability. Studies by Sadira Ashia Priliana & Ermaya (2023) and Rahmawaty & Harahap (2024) confirm that better environmental performance positively influences carbon emissions reduction. However, other studies (Sekarini & Setiadi, 2021) argue environmental performance does not significantly impact disclosure.

This study adopts legitimacy theory, as companies disclose emissions to gain public approval. High leverage attracts creditor pressure, large firms attract public attention, and strong environmental performance boosts reputation. These factors encourage carbon disclosure as a means of maintaining legitimacy. According to legitimacy theory, businesses must operate in line with social norms and standards to maintain legitimacy (Titisari, 2020). Suchman & Mark C. (1995) add that legitimacy is linked to a company's ability to align with societal beliefs and values. Voluntary disclosure of environmental and social issues is grounded in this theory (Anggraeni, 2015; Silaban et al., 2023). With increasing public awareness and stakeholder pressure, energy and industrial firms are expected to enhance carbon emission transparency to build credibility and trust.

Based on the background explanation above, several key problem identifications can be outlined. Firstly, many companies in Indonesia have not yet fully disclosed their carbon emissions, as such disclosure remains voluntary in nature. Secondly, companies with high leverage tend to have different incentives regarding carbon emission disclosure, as such reporting may increase their financial burden. Thirdly, although large companies generally possess more resources to disclose information transparently, they also face greater pressure from stakeholders to report their environmental performance. Fourthly, many companies still pay little attention to the social and environmental impacts of their operations, thereby contributing to environmental degradation. Lastly, the energy and industrial sectors contribute significantly to carbon emissions and environmental damage, which highlights the need for companies in these sectors to enhance their commitment to fulfilling social and environmental responsibilities.

Studies on carbon emission disclosure remain limited. This study identifies a gap in the variables and objects used in prior research. This study focuses on the Energy and Industrial sectors listed on the Indonesia Stock Exchange (IDX) from 2021 to 2024. The variables of environmental performance and firm size are considered novel contributions. Based on the background above, the author is interested in conducting research entitled: "The Influence of Leverage, Firm Size, and Environmental Performance on Carbon Emission Disclosure (Case Study of Energy and Industrial Sector Companies Listed on the Indonesia Stock Exchange 2021–2024)."

This study is subject to several limitations to avoid broadening the scope of the research problem. The research is limited to examining the influence of leverage, company size, and environmental performance on carbon emission disclosure in energy and industrial sector companies listed on the Indonesia Stock Exchange during the 2021–2024 period. The study uses the parameters from the Carbon Disclosure Project (CDP) and data from the Ministry of Environment and Forestry (KLHK) as references for measuring carbon emission disclosure and environmental performance.

METHOD

This research combines a quantitative approach with a descriptive approach. Quantitative analysis refers to statistical research that utilizes statistical tools to analyze data, thereby producing data and findings in numerical form (Hafni Sahir, 2021). The analysis technique used in this study is multiple linear regression analysis. The purpose of the multiple linear regression analysis in this research is to examine whether leverage, firm size, and environmental performance have an influence on carbon emission disclosure in the energy and industrial sectors of companies listed on the Indonesia Stock Exchange during the period 2021–2024.

The variable of concern in this study is carbon emissions. The dependent variable, also known as the variable that is influenced by the independent variable, is the result of the effect of the independent variable (Hafni Sahir, 2021). Carbon emission disclosure is assessed through carbon accounting practices to address environmental issues (Andriadi & Werastuti, 2020). Carbon emission disclosure is measured using an 18-item checklist developed by Choi et al. (2013). Each item disclosed by the company is awarded a score of 1. These scores are then comprehensively analyzed, compared to the total number of items in the index, and the result is evaluated as a percentage out of 100% to determine the level of compliance (Mulya & Rohman, 2020).

A sample is a part of the population selected for study (Hafni Sahir, 2021). This research uses a purposive sampling method, which involves selecting samples based on specific criteria and the relevance of characteristics (Hafni Sahir, 2021).

Based on the report above, 35 companies did not publish annual financial reports, and 54 companies did not publish sustainability reports consecutively during 2021–2024. Additionally, 46 companies were not included in the PROPER ranking consecutively during 2021–2024. Below are the names of companies in the energy and industrial sectors that were used as research samples:

Table 1. Research Samples

No.	Company Code	E1	E2	E3	E4	E5	E6	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	Total	CED (%)
1	AALI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
2	ADRO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
3	ANTM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
4	BIPI	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
5	BORN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
6	BSSR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
7	BYAN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
8	GEMS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
9	HRUM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%
10	ITMG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18	100%

To determine the most suitable regression model, the following tests are applied: Chow Test: Determines whether FEM or CEM is more appropriate. If p-value < 0.05, FEM is chosen; otherwise, CEM. Hausman Test: Decides between FEM and REM. If p-value < 0.05, use FEM; if > 0.05, use REM. Lagrange Multiplier Test (LM): Compares REM and CEM. If p-value < 0.05, REM is used. If the Chow and Hausman tests select FEM, LM is not needed.

Panel Regression Equation

The regression model used is:

$Y = a + \beta X_1 + \beta X_2 + \beta X_3 + \varepsilon$

Where:

Y = Carbon Emission Disclosure
a = Constant
β = Regression Coefficients
X_1 = Leverage
X_2 = Company Size
X_3 = Environmental Performance
ε = Error Term

3.6.7 Hypothesis Testing

The t-test (partial test) is used to test the significance of the relationship between each independent variable and the dependent variable.

If p-value < 0.05, the variable has a significant influence.

If p-value > 0.05, the variable does not significantly influence the dependent variable.

FINDINGS AND DISCUSSION

Descriptive Statistical Analysis

Descriptive statistical analysis is a statistical test that presents data in the form of a table containing the minimum, maximum, mean, and standard deviation values. Descriptive statistics were conducted on the research variables: Carbon Emission Disclosure (Y), Leverage (X1), Firm Size (X2), and Environmental Performance (X3). The results are as follows:

Table 2.1 Descriptive Statistics Results

	Y	X1	X2	X3
Mean	0.574131	0.453881	22602.67	3285.714
Median	0.556000	0.341000	22560.00	3000.000
Maximum	0.833000	3.518000	28870.00	5000.000
Minimum	0.167000	0.017000	13186.00	2000.000
Std. Dev.	0.139390	0.524734	5224.774	1000.860
Skewness	-0.384067	4.087149	-0.181939	0.347877
Kurtosis	3.201104	22.30263	1.588199	2.088001
Jarque-Bera	2.206653	1537.937	7.439562	4.605353
Probability	0.331766	0.000000	0.024239	0.099991
Sum	48.22700	38.12600	1898624.	276000.0
Sum Sq. Dev.	1.612654	22.85367	2.27E+09	83142857
Observations	84	84	84	84

Source: EViews 12 Output, Processed Data (2025)

1. Carbon Emission Disclosure (Y)

The variable Carbon Emission Disclosure shows a minimum value of 0.167000, recorded by PT Asahimas Flat Glass Tbk during the period 2021–2024. The maximum value of 0.833000 was achieved by PT Medco Energy International Tbk in 2022–2024, indicating the company is transparent and proactive in disclosing carbon emission information.

The mean value is 0.574131 with a standard deviation of 0.139390, which implies that the average is higher than the deviation. In other words, the data distribution is relatively narrow, suggesting that only a few companies have carbon emission disclosure values far from the mean.

2. Leverage (X1)

The variable Leverage has a minimum value of 0.017000, recorded by PT Sumi Indo Kabel Tbk, while the maximum value was recorded by PT Medco Energy International Tbk in 2023.

The mean is 0.453881 and the standard deviation is 0.524734, which shows that the deviation is larger than the average. This indicates a wide data distribution, meaning that leverage levels vary greatly among the sample companies.

3. Firm Size (X2)

The Firm Size variable has a minimum value of 13,186.00, recorded by PT Petrosea Tbk in 2021, and a maximum value of 28,870.00 by PT Surya Toto Indonesia Tbk, suggesting this company is more capable of managing and allocating resources for carbon disclosure activities.

The mean is 22,602.67, and the standard deviation is 5,224.774, indicating the average is larger than the deviation. This shows a relatively narrow data spread, meaning only a few companies differ significantly in firm size from the average.

4. Environmental Performance (X3)

The Environmental Performance variable has a minimum score of 2, recorded by several companies over 2021–2024, including:

- PT RMK Energy Tbk
- PT Apexindo Pratama Duta Tbk
- PT Arwana Citramulia Tbk
- PT Kabelindo Murni Tbk
- PT Lion Metal Works Tbk
- PT Tira Austenite Tbk
- The maximum score of 5 was achieved by:
- PT Mitrabara Adiperdana Tbk (2024)
- PT Bukit Asam Tbk (2021–2024)
- PT Medco Energi International Tbk (2021–2024)
- PT United Tractors Tbk (2023–2024)
- PT Adaro Energy Tbk (2021, 2023, 2024)

This indicates that these companies are the most active in carbon emission disclosure among the sample. The mean is 3,285.714 with a standard deviation of 1,000.860, where the average is higher than the deviation, suggesting a relatively tight information spread and a good consistency of environmental performance among the companies.

Panel Data Regression Model Selection

Panel data regression is used to analyze data that has two dimensions: cross-section (companies) and time series (years). Panel regression analysis includes three main model types:

1) Common Effect Model (CEM)

2) Fixed Effect Model (FEM)
3) Random Effect Model (REM)

To determine the most appropriate model, several diagnostic tests must be conducted, including the Chow test, Hausman test, and Lagrange Multiplier (LM) test. The results are as follows:

Chow Test

Table 2.2 Chow Test Results

Redundant Fixed Effects Tests
Equation: MODEL_FEM
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	3.472030	(20,60)	0.0001
Cross-section Chi-square	64.585714	20	0.0000

Source: EViews 12 Output, Processed Data (2025)

Based on the results of the Chow test, the probability value of the cross-section chi-square is 0.0001, which is less than 0.05. Therefore, the null hypothesis (H_0) is rejected, indicating that the Fixed Effect Model (FEM) is more appropriate than the Common Effect Model (CEM).
The next step is to compare FEM with REM using the Hausman test.

Hausman Test

Table 2.3 Hausman Test Results

Correlated Random Effects - Hausman Test
Equation: MODEL_REM
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	7.393405	3	0.0604

Source: EViews 12 Output, Processed Data

The Hausman test shows a probability value of 0.0604, which is greater than 0.05, indicating that there is no significant difference between FEM and REM. Therefore, the Random Effect Model (REM) is considered more suitable for this research.

Lagrange Multiplier (LM) Test

Table 2. 4 Lagrange Multiplier Test Results

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	11.11004 (0.0009)	4.976850 (0.0257)	16.08689 (0.0001)

Source: EViews 12 Output, Processed Data (2025)

Based on the Breusch-Pagan Lagrange Multiplier (LM) test, the following p-values were obtained:mCross-section: 0.0009, Time: 0.0257 Both (combined): 0.0001. All p-values are less than the 5% significance level, indicating the presence of individual effects in the model. In other words, the most appropriate panel regression model for this research is the Random Effect Model (REM).

Classical Assumption Test

The classical assumption test in this study aims to ensure that the regression model is free from bias, allowing the analysis results to be valid and reliable. However, normality and autocorrelation tests were not performed, as the data used is panel data — a combination of cross-section and time-series data. The classical assumption tests conducted in this study are detailed as follows:

1. Multicollinearity Test

Table 2.5 Multicollinearity Test Results

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	0.010296	54.46812	NA
LEVERAGE_X1	0.000754	1.906852	1.085191
UKURAN_PERUSAH...	8.77E-06	24.96002	1.251742
KINERJA_LINGKUN...	0.000254	15.83765	1.330088

Source: EViews 12 Output, Processed Data (2025)

Based on the multicollinearity test results, all independent variables in the regression model have Centered Variance Inflation Factor (VIF) values below the threshold of 10. The lowest VIF value is 1.085 for the Leverage variable, and the highest is 1.330 for the Environmental Performance variable.

Thus, it can be concluded that there are no symptoms of multicollinearity among the independent variables in the model. Therefore, the regression model is considered to meet the requirements for further analysis.

2. Heteroskedasticity Test

Heteroskedasticity testing is performed to determine whether the regression model has constant variance. If the probability (p-value) for each variable exceeds 0.05, the null hypothesis is accepted, indicating that no heteroskedasticity is present.

Table 2.6 Heteroskedasticity Test Results

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	1.142387	Prob. F(9,74)	0.3447
Obs*R-squared	10.24714	Prob. Chi-Square(9)	0.3309
Scaled explained SS	12.23211	Prob. Chi-Square(9)	0.2005

Source: EViews 12 Output, Processed Data (2025)

Based on the White Test, all variables show probability values greater than the 5% significance level, indicating that the model does not exhibit heteroskedasticity. Thus, the regression residuals have constant variance, supporting the validity of the model.

Coefficient of Determination (R^2) Test

Table 2.7 Coefficient of Determination (R^2) Results

R-squared	0.133408	Mean dependent var	0.315195
Adjusted R-squared	0.100911	S.D. dependent var	0.107313
S.E. of regression	0.101755	Sum squared resid	0.828322
F-statistic	4.105209	Durbin-Watson stat	1.696958
Prob(F-statistic)	0.009199		

Source: EViews 12 Output, Processed Data (2025)

The results show an Adjusted R-squared value of 0.100911, or approximately 10.09%, with a regression standard error of 0.101755, which is lower than the standard deviation of the dependent variable (0.107313).

This indicates that the independent variables — Leverage, Firm Size, and Environmental Performance — collectively explain 10.09% of the variation in the dependent variable, namely carbon emission disclosure among energy and industrial sector companies listed on the Indonesia Stock Exchange (IDX) during 2021–2024.

The remaining 89.91% is influenced by other variables not included in the model, implying that external factors also play a significant role in determining carbon emission disclosure.

Panel Data Regression Results

The panel data regression analysis in this study uses the Random Effect Model (REM). The regression results are presented below:

Table 2.8
Panel Data Regression Model Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.384654	0.123373	3.117806	0.0025
X1	0.023471	0.027760	0.845515	0.4003
X2	-6.79E-07	3.62E-06	-0.187462	0.8518
X3	5.91E-05	2.01E-05	2.943468	0.0042

Effects Specification		
	S.D.	Rho
Cross-section random	0.075416	0.3669
Idiosyncratic random	0.099071	0.6331

Weighted Statistics			
R-squared	0.133408	Mean dependent var	0.315195
Adjusted R-squared	0.100911	S.D. dependent var	0.107313
S.E. of regression	0.101755	Sum squared resid	0.828322
F-statistic	4.105209	Durbin-Watson stat	1.696958
Prob(F-statistic)	0.009199		

Unweighted Statistics			
R-squared	0.187509	Mean dependent var	0.574131
Sum squared resid	1.310266	Durbin-Watson stat	1.072780

Source: EViews 12 Output, Processed Data (2025)

Based on the results in the table above, the linear regression equation for the panel data model is as follows:

Where:

CED = Carbon Emission Disclosure

X_1 = Leverage

X_2 = Firm Size

X_3 = Environmental Performance

The regression equation can be interpreted as follows:

Constant (0.384654): When all independent variables are held constant, the predicted carbon emission disclosure value is 0.384654.

Leverage Coefficient (X_1 = 0.023471): An increase of one unit in the leverage variable leads to an increase in carbon emission disclosure by 0.023471, assuming other variables are constant.

Firm Size Coefficient (X_2 = -6.79E-07): An increase of one unit in firm size results in a decrease in carbon emission disclosure by 6.79×10^{-7}, holding other variables constant.

Environmental Performance Coefficient (X_3 = 5.91E-05): An increase of one unit in environmental performance increases carbon emission disclosure by 5.91×10^{-5}, ceteris paribus.

Hypothesis Testing (t-test)

Table 2. 9
t-Test Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.384654	0.123373	3.117806	0.0025
X1	0.023471	0.027760	0.845515	0.4003
X2	-6.79E-07	3.62E-06	-0.187462	0.8518
X3	5.91E-05	2.01E-05	2.943468	0.0042

Source: EViews 12 Output, Processed Data (2025)

Based on the hypothesis testing results presented above, the following interpretations can be made:

CED = 0.384654 + 0.023471X1 - 6.79E-07X2 + 5.91E-05X3 + ε

Leverage (X_1):

p-value = 0.4003 (greater than 0.05), Coefficient = 0.023471. Since the p-value exceeds the 5% significance level, leverage does not have a significant effect on carbon emission disclosure. Conclusion: Hypothesis H1 ("Leverage affects carbon emission disclosure") is rejected.

Firm Size (X_2):

p-value = 0.8518 (greater than 0.05), Coefficient = -6.79E-07

⇒ The p-value indicates no statistically significant effect of firm size on carbon emission disclosure. Conclusion: Hypothesis H2 ("Firm size affects carbon emission disclosure") is rejected.

Environmental Performance (X_3):

p-value = 0.0042 (less than 0.05), Coefficient = 5.91E-05

The result indicates that environmental performance has a positive and significant effect on carbon emission disclosure. Conclusion: Hypothesis H3 ("Environmental performance affects carbon emission disclosure") is accepted.

Disscussion

The Influence of Leverage on Carbon Emission Disclosure

Companies with high leverage tend to act more cautiously in managing funds, as they must meet significant debt and interest payment obligations. In such circumstances, they typically prioritize maintaining financial stability over voluntarily disclosing information—such as carbon emissions reports—which may incur additional costs. As a result, leverage does not serve as a primary driver for carbon emission disclosure. Moreover, because carbon emission disclosure is not yet mandatory in Indonesia, highly leveraged firms are generally reluctant to disclose such information (Florencia & Handoko, 2021).

Therefore, Hypothesis 1 (H1) is rejected. A high level of leverage may lead companies to reduce their carbon emission disclosure. This is due to the need for

careful financial management, as disclosure activities can increase operational costs (Florencia & Handoko, 2021).

Companies are more likely to prioritize operational activities—such as debt payments to suppliers—over allocating funds to disclosure practices. Thus, both high and low levels of leverage may have no influence on the extent of carbon emission disclosure. This finding is consistent with previous research by Septriyawati et al. (2019) and Florencia & Handoko (2021), which found no significant effect of leverage on carbon emission disclosure. Generally, companies are cautious in disclosing expense-related information. Given that carbon emission reporting is still voluntary, firms must carefully assess whether disclosing such information is an effective strategy to gain legitimacy—or whether alternative approaches might be more suitable.

Fluctuations in leverage levels are therefore not yet capable of increasing or decreasing the breadth of carbon emission disclosure (Herinda et al., 2021). This finding aligns with studies by Mulya & Rohman (2020) and Choi et al. (2013), which state that leverage has a negative relationship with carbon emission disclosure. Creditors often pressure firms to focus fund allocation on financial obligations such as interest payments and debt repayment, rather than on voluntary disclosures (Choi et al., 2013). Consequently, the higher the leverage, the lower the level of carbon emission disclosure (Mulya & Rohman, 2020).

The Influence of Firm Size on Carbon Emission Disclosure

Large-scale companies generally possess more substantial resources. These resources can support the provision of adequate information and encourage higher-quality voluntary environmental disclosures as part of their efforts to gain legitimacy from stakeholders.

However, firm size has no significant effect on carbon emission disclosure. This is because in Indonesia, carbon emission reporting remains voluntary. As such, company size is not the main determinant of whether a firm will disclose its emissions. Although large companies usually operate on a broader scale and may generate more emissions, they tend to focus more on activities that directly enhance their image and legitimacy—such as corporate social responsibility (CSR) programs—rather than on voluntary emission reporting. Since disclosure is not legally required, even large companies may not be inclined to report, despite having sufficient resources (Gunawan & Aryati, 2024).

Hence, Hypothesis 2 (H2) is rejected. This may be due to the perception among companies that voluntary disclosure does not yet provide sufficient benefits (Florencia & Handoko, 2021). Furthermore, Presidential Regulation No. 61 of 2011 does not explicitly require only large firms to disclose carbon emissions. Therefore, participation in carbon reduction efforts is expected from all companies, regardless of size. These findings are supported by earlier studies (Florencia & Handoko, 2021; Melja et al., 2022; Wiratno & Muaziz, 2020; Gunawan & Aryati, 2024), which also show that firm size has no significant effect on disclosure practices. Thus, more stringent regulations

are needed to encourage large firms to report their carbon emissions, especially considering their typically greater environmental impact. In addition, comprehensive education and mandatory disclosure policies are critical to ensuring environmental sustainability for future generations.

The Influence of Environmental Performance on Carbon Emission Disclosure

Environmental performance is a company's demonstration of commitment to creating a greener environment (Krisnawanto & Solikhah, 2019). This study uses the PROPER program as an indicator to measure environmental performance characteristics. PROPER is a color-based rating system developed by the Ministry of Environment and Forestry, which classifies companies into five categories: gold, green, blue, red, and black—each representing different levels of compliance and environmental performance. The results of hypothesis testing in this study indicate that companies with high environmental responsibility tend to disclose carbon emissions more frequently. Between 2021 and 2024, several companies consistently achieved gold and green PROPER ratings. These companies include:

a. PT Adaro Energy Tbk
b. PT Bukit Asam Tbk
c. PT Medco Energy International Tbk
d. PT Mitrabara Adiperdana Tbk
e. PT United Tractors Tbk
f. PT Baramulti Suksessarana Tbk
g. PT Perusahaan Gas Negara Tbk
h. PT Surya Toto Indonesia Tbk

These companies exhibited superior environmental management compared to entities that only received blue, red, or black ratings. During the same period, six companies were rated red, indicating failure to fully comply with environmental regulations. The black category, the lowest PROPER score, reflects serious violations of environmental laws. This finding supports legitimacy theory and stakeholder theory, which assert that companies with strong environmental performance voluntarily disclose carbon emissions as a form of public accountability. Such companies typically have various strategies to address environmental issues and aim to sustain or enhance public trust. This trust is crucial for securing ongoing support from the community and stakeholders (Priliana & Ermaya, 2023).

The findings of this study are also consistent with previous research (Melja et al., 2022; Rahmawaty & Harahap, 2024; Yessiani et al., 2023), which showed that environmental performance has a positive and significant effect on carbon emission disclosure. Companies that demonstrate strong concern for environmental sustainability tend to be more active and transparent in communicating carbon emission information to the public. This is in line with legitimacy and stakeholder theories, which propose that firms seek to gain social legitimacy by showing their commitment to environmental sustainability through transparent reporting practices.

This research is positioned within the domain of corporate sustainability and environmental accountability, specifically focusing on the measurement of Corporate Environmental Disclosure (CED). While previous studies have widely adopted the Choi et al. (2013) scoring model to evaluate environmental transparency, this study extends the application by integrating it with updated visual representations and sector-specific assessments. The research contributes by: Applying the Choi disclosure index to a specific industry or region (e.g., energy sector, Indonesia), Enhancing interpretability through compact tabular and graphical formats, and Identifying disclosure patterns and gaps that inform regulatory or managerial decisions.

This study bridges the gap between standardized disclosure scoring frameworks and practical visualization techniques, offering a methodological refinement that enhances both academic understanding and stakeholder engagement in sustainability reporting.

CONCLUSION

The findings of this research present several key insights. First, leverage does not significantly influence carbon emission disclosure, suggesting that the level of corporate debt is not a decisive factor in determining whether a company chooses to disclose its carbon emissions. Second, firm size also does not exert a meaningful impact on such disclosures. Although larger companies generally possess more resources and face greater public oversight, this does not necessarily translate into increased transparency regarding environmental information. In contrast, environmental performance shows a positive and significant effect on carbon emission disclosure. Companies with higher ratings in the PROPER program are more likely to disclose carbon emission information actively, reflecting their environmental accountability and commitment to corporate social responsibility.

From a practical standpoint, companies—particularly those operating in the energy and industrial sectors—are encouraged to enhance their awareness and commitment to environmental management. Transparent disclosure of carbon emissions not only demonstrates compliance but also strengthens public trust and investor confidence. For regulators and government bodies, the findings underscore the need to reinforce regulatory frameworks, including the potential introduction of mandatory carbon emission reporting in annual or sustainability reports. Such measures are vital to promoting higher levels of accountability in sectors characterized by high emissions. Meanwhile, for investors and other external stakeholders, information on environmental performance provides a crucial basis for assessing sustainability practices and investment risks. Thus, encouraging greater transparency in environmental disclosure plays a pivotal role in fostering responsible investment decision-making.

From an educational perspective, the study highlights the role of carbon emission disclosure as not only a corporate responsibility but also a learning process that contributes to organizational knowledge and public awareness. Integrating environmental disclosure practices into corporate training, sustainability workshops,

and higher education curricula can deepen the understanding of sustainability reporting and broaden its impact beyond compliance. For students, managers, and professionals alike, this research demonstrates how environmental accountability can be internalized as part of business ethics and long-term strategy.

On a theoretical level, the study reinforces legitimacy theory, which posits that companies disclose environmental information to secure societal approval. Future research could expand this scope by incorporating variables such as media exposure, stakeholder pressure, or corporate governance practices, and by applying complementary frameworks such as stakeholder theory and signaling theory. While the use of the PROPER rating is suitable for the Indonesian context, subsequent research may also consider alternative measures—such as Environmental, Social, and Governance (ESG) scores or other sustainability indices—to enrich the analytical robustness of future studies. Embedding these findings into both academic research and educational practice can foster a more holistic understanding of carbon disclosure as a driver of sustainability and as an instrument for cultivating environmentally responsible behavior across sectors.

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