



Determinants of Carbon Emission Disclosure: The Role of Gender Diversity in Moderating Financial and Environmental Factors in Energy Sector Companies

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Abstract

The issue addressed in this study is the inconsistent empirical findings of prior research regarding the roles of leverage, institutional ownership, and environmental management. Gender diversity is included as a moderating variable to explain the inconsistent research findings. The sample was selected from energy sector companies listed on the Indonesia Stock Exchange (IDX) from 2021 to 2024, this resulted in 228 firm-year observations. The results indicate that leverage and environmental management significantly affect carbon emission disclosure, whereas institutional ownership shows no significant effect. Furthermore, gender diversity is found to moderate the relationship between the independent variables and carbon emission disclosure. These findings suggest that financial conditions and corporate commitment to environmental management play an important role in enhancing the transparency of carbon emission disclosure. This study contributes to the environmental accounting literature and provides practical insights for improving sustainability reporting practices in Indonesia.

Keywords: *Carbon Emission, Leverage, Institutional Ownership, Gender Diversity Environmental Management.*

Abstrak

Isu yang dibahas dalam penelitian ini adalah temuan empiris yang tidak konsisten dari penelitian sebelumnya mengenai peran leverage, kepemilikan institusional, dan manajemen lingkungan. Keragaman gender dimasukkan sebagai variabel moderasi untuk menjelaskan temuan penelitian yang tidak konsisten tersebut. Sampel dipilih dari perusahaan sektor energi yang terdaftar di Bursa Efek Indonesia (IDX) pada tahun 2021 hingga 2024, yang menghasilkan 228 observasi perusahaan-tahun. Hasil penelitian menunjukkan bahwa leverage dan manajemen lingkungan secara signifikan memengaruhi pengungkapan emisi karbon, sedangkan kepemilikan institusional tidak menunjukkan pengaruh yang signifikan. Lebih lanjut, keragaman gender ditemukan memoderasi hubungan antara variabel independen dan pengungkapan emisi karbon. Temuan ini menunjukkan bahwa kondisi keuangan dan komitmen perusahaan terhadap manajemen lingkungan memainkan peran penting dalam meningkatkan transparansi pengungkapan emisi karbon. Penelitian ini berkontribusi pada literatur akuntansi lingkungan dan memberikan wawasan praktis untuk meningkatkan praktik pelaporan keberlanjutan di Indonesia.

Kata Kunci: *Emisi Karbon, Leverage, Kepemilikan Institusional, Keberagaman Gender, Manajemen Lingkungan.*

1. INTRODUCTION

Climate change has become a strategic issue in global sustainable development and a major concern for the international scientific community over the past few decades. The *Intergovernmental Panel on Climate Change* (Intergovernmental Panel on Climate Change (IPCC), 2023) the report confirmed a 1.1°C increase in global temperatures. This increase has occurred since the pre-industrial era. The rise is mainly due to greenhouse gas emissions. These emissions are mostly carbon dioxide (CO₂). The CO₂ comes from industrial, energy, and transportation activities. The IPCC also stated that without substantial emission reductions, the risks of ecosystem damage, reduced economic productivity, and impaired human health will increase significantly.

Globally, the energy sector is the largest contributor to carbon emissions. More than 36% of CO₂ emissions come from the production and consumption of fossil fuels (International Energy Agency, 2023). This situation is also reflected in Indonesia. Indonesia ranks eighth among countries contributing the most carbon emissions from fossil fuels (Pierre Friedlingstein et al., 2022). The Indonesian government affirmed its commitment through the ratification of the Kyoto Protocol in Law Number 17 of 2004 and through the enactment of Presidential Regulation Number 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions. However, these regulations do not explicitly require companies to disclose detailed carbon emissions, so emissions reporting remains a voluntary disclosure Ladista et al., (2023).

Voluntary reporting conditions lead to varying levels of corporate transparency, particularly in the energy sector, which has the potential to generate high levels of CO₂ emissions. In the context of sustainability accounting and reporting, carbon emission disclosure (CED) is an important instrument for stakeholders to assess the extent to which a company is committed to mitigating environmental impacts. The CED does not only serve as an environmental communication tool, but also as a mechanism for increasing corporate legitimacy in the eyes of the public (Deegan, 2002). This is in line with legitimacy theory, which states that companies will strive to adapt their activities and reporting to be accepted by society (Deegan, 2002). From the perspective of stakeholder theory, environmental disclosure is part of a company's obligation to meet stakeholder demands Bui et al., (2011). Meanwhile, agency theory suggests that disclosure can reduce information asymmetry between management and capital owners.

Several previous studies have examined various factors influencing carbon emission disclosure (CED), such as leverage, institutional ownership, and environmental management. However, empirical findings have been inconsistent. Tarigan et al., (2022) and Ruhayat et al. (2025) found that leverage negatively impacts CED. Conversely, Simon et al. (2025) reported a positive effect, while others found no significant effect (Syahdanti & Marietza, 2024; Kotleria, 2020). Several studies conclude that institutional investor involvement can strengthen corporate carbon emission reporting practices (Purnamasari & Suhermin, 2017; Suherman and Kurniawati, 2023; Putri et al., 2022). However, other studies show no empirical evidence supporting this relationship (Putri Andini Eleshya 2023; Rinda Nugraha, 2025). The environmental management variable also yields inconsistent findings. Research by Rohmah et al. (2022) and Suherman and Kurniawati (2023) indicates that environmental management

practices contribute to increased carbon emission disclosure. Conversely, a study by Desvita and Rahma (2025) provides inconsistent empirical evidence. These varied results indicate empirical inconsistencies that open up room for further research. This situation reinforces the urgency of re-examining, particularly in the energy sector, which is most closely linked to carbon emissions.

Previous studies indicate that carbon emission disclosure is influenced by various firm characteristics, including leverage, institutional ownership, and environmental management. However, existing empirical evidence remains mixed and inconclusive. Such inconsistencies are observed not only in leverage-related studies but also in research on institutional ownership and environmental management. Institutional ownership is often viewed as a monitoring mechanism that may enhance corporate environmental transparency. Nevertheless, several studies report that institutional ownership does not consistently have a significant effect on carbon emission disclosure, suggesting that institutional investors may not always prioritize sustainability issues. Similar patterns are also found in environmental management variables, where some studies show a positive relationship with carbon emission disclosure, while others provide inconclusive results. These mixed findings indicate the presence of empirical inconsistencies across all examined variables and highlight the need for further investigation, particularly in the energy sector, which contributes substantially to carbon emissions.

In addition to key variables, governance factors such as gender diversity on boards of directors are also increasingly discussed in the sustainability literature. Women in corporate leadership are believed to be more sensitive to ethical and environmental issues and promote greater corporate accountability Adams, (2009). Various studies also show that gender diversity improves oversight quality, thereby strengthening the relationship between governance variables and environmental disclosure Omenihu et al., (2025). However, research incorporating gender diversity as a moderating variable in the relationship between leverage, institutional ownership, environmental management, and CED is still very limited, particularly in energy sector companies in Indonesia.

Gender diversity on boards of directors represents an important governance mechanism that enhances oversight quality, ethical orientation, and attention to sustainability issues. Accordingly, gender diversity not only has a direct influence but also shapes how firm characteristics are translated into carbon emission disclosure. In the context of environmental management, gender-diverse boards are more likely to emphasize accountability and transparency, thereby strengthening the extent to which environmental policies and management systems are reflected in carbon emission disclosure. Gender diversity may also moderate the relationships between leverage, institutional ownership, and carbon disclosure, as more diverse boards tend to promote cautious decision-making and greater responsiveness to stakeholder expectations. Therefore, positioning gender diversity as a moderating variable is theoretically justified in explaining variations in carbon emission disclosure.

The main strength of this study lies in the use of board gender diversity as a moderating variable to explain variations in carbon emission disclosure (CED). Rather than examining gender diversity merely as an independent factor, this study demonstrates that board gender composition plays a crucial role in shaping how financial pressure, ownership structure, and environmental management practices are translated into environmental transparency. By adopting a moderating perspective, the study provides deeper insight into why similar firm

characteristics may result in different levels of carbon emission disclosure.

This study contributes to the environmental accounting and corporate governance literature in several important ways. First, it extends prior research by integrating gender diversity into a moderating framework, thereby addressing inconsistencies in earlier empirical findings on the determinants of CED. Second, the findings highlight the governance effectiveness in environmental disclosure that depends not only on structural factors such as leverage and institutional ownership but also on board's characteristics. Third, by focusing on energy sector firms in an emerging economy, the study offers context-specific evidence that remains limited in the existing literature.

From a practical perspective, the results provide meaningful implications for both regulators and corporate decision-makers. For regulators, the findings support the development of governance policies that encourage greater gender diversity on corporate boards as part of broader sustainability and disclosure regulations. For firms in the energy sector, increasing female representation at the board level can function as an effective governance mechanism to strengthen the alignment between environmental management practices and carbon emission disclosure. This, in turn, enhances the transparency, credibility, and legitimacy of corporate environmental reporting in the eyes of stakeholders.

2. LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Stakeholder Theory

Freeman (2015) states that a company's sustainability depends heavily on its ability to meet the expectations of all stakeholders, not just shareholders but also the community, government, and customers. In this context, carbon emissions disclosure serves as a means of communication between companies and stakeholders to demonstrate social responsibility and a commitment to sustainable development.

A number of empirical findings support this view. Research by Hörisch, Freeman, and Schaltegger (2014) suggested that disclosing sustainability issues, including carbon emissions, is a strategy used by companies to meet stakeholders' information needs while strengthening their institutional legitimacies. Mangoting et al. (2019) and Yuniarto et al. (2024) found that stakeholder pressure and expectations play a significant role in encouraging companies to present more comprehensive carbon emissions information as a form of accountability and transparency. Thus, carbon emissions disclosure serves not only as a reporting obligation but also as a strategic tool for maintaining social legitimacy, strengthening stakeholder relationships, and ensuring business sustainability. Therefore, stakeholder theory provides a strong theoretical foundation for understanding energy companies' motivations for more comprehensive emissions reporting.

Legitimacy Theory

Legitimacy theory explains that every company strives to ensure that all its business activities are accepted by society and do not conflict with prevailing social norms Deegan, (2002). When companies disclose environmental information, including carbon emissions, this becomes a strategy to gain social recognition and maintain the company's reputation. Therefore, environmental transparency is often used as a means of building public trust and strengthening legitimacy among stakeholders.

Disclosure of carbon emissions is one strategy that energy companies can use to build and maintain legitimacy. By providing information on emissions, mitigation strategies, and energy transition commitments, companies seek to demonstrate accountability while reducing reputational risk. Shows that organizations tend to increase disclosure when they perceive legitimacy pressure from their environment. Similarly, research by Anjilni and Asih (2023) reveals that environmental disclosure practices are generally influenced by evolving social dynamics, particularly because such disclosure is still voluntary. As sustainability issues become increasingly prominent in public discourse, organizations feel the need to demonstrate commitment through more systematic disclosure of environmental information. Thus, disclosure of carbon emissions and other environmental information serves not only as a reporting tool but also as a mechanism for organizations to demonstrate the alignment of their actions with societal values and expectations.

Thus, legitimacy theory provides a relevant justification for explaining why energy sector companies are increasing their carbon emissions disclosures. This disclosure is not merely a reporting obligation, but part of the company's strategy. to maintain social acceptance and ensure operational sustainability amidst increasing public concern about environmental impacts.

Carbon Emission Disclosure

Carbon emission disclosure is the presentation of a company's information regarding its carbon emissions and mitigation strategies. CED is typically associated with standards such as GRI 305, which provides disclosure guidelines for direct and indirect emissions, as well as emission control and reduction efforts. CED has become a crucial aspect of sustainability practices as stakeholders increasingly demand transparency regarding the environmental impact of business activities.

Carbon Emission Disclosure is necessary for businesses to demonstrate their efforts to reduce the environmental damage caused by these gases. To raise awareness and hold businesses accountable, more and more companies are disclosing their carbon footprints Andrian & Kevin, (2021). A monitoring group is needed to pressure businesses to be transparent about their carbon emissions Pramuditya & Budiasih, (2020).

Hypothesis Development

Leverage, which reflects the proportion of debt in a company's capital structure, can influence managerial decisions regarding information disclosure. Conceptually, firms with lower leverage have greater financial flexibility, allowing them to allocate resources to non-financial activities, such as carbon emissions disclosure. In contrast, highly leveraged companies tend to prioritize debt obligations, limiting their capacity to engage in voluntary reporting of environmental information. Therefore, a negative relationship between leverage and the extent of carbon emissions disclosure is expected.

Empirical evidence supports this conceptual link. Companies with lower leverage generally provide more comprehensive carbon emissions disclosure, while firms with higher debt levels tend to restrict the scope of such reporting Jannah and Muid (2014). Firms with significant debt obligations often concentrate resources on debt repayment, making management more cautious in allocating funds to discretionary activities. Previous studies also highlight this phenomenon. Choi et al (2013) indicate that financial constraints can limit

voluntary disclosure, and according to stakeholder theory, concerns from creditors and other stakeholders regarding the firm's going concern may further compel management to prioritize debt servicing over full carbon emissions disclosure Irwhantoko and Basuki (2016).

H1: Leverage has a significant negative effect on carbon emission disclosure.

Institutional ownership serves a strategic function in motivating firms to improve transparency in their reporting, including carbon emissions disclosure. Conceptually, institutional investors possess strong oversight capabilities, which can pressure management to implement more disciplined and accountable environmental reporting practices. Firms with higher levels of institutional ownership are therefore more likely to prioritize accurate and transparent disclosure. In contrast, companies with lower institutional ownership often concentrate more on internal management priorities, which may reduce their commitment to voluntary reporting, including carbon emissions. Consistent with stakeholder theory, all parties with an interest in the company have a right to comprehensive information regarding its operations, including environmental impacts, creating both ethical and economic responsibilities for management to provide transparent disclosure.

Evidence from previous studies supports this conceptual relationship. Putri et al., (2023) found that companies with higher institutional ownership tend to produce more disciplined and accountable environmental reports. Firms with lower institutional ownership are generally less committed to voluntary disclosures, including carbon emission reporting. Mangoting et al., (2019) highlighted that stakeholder expectations encourage management to deliver comprehensive and transparent environmental information. Collectively, these findings indicate that institutional ownership has a positive influence on both the extent and quality of carbon emissions disclosure.

H2: Institutional Ownership has a significant positive effect on carbon emission disclosure.

Firms with strong environmental management practices, such as the ISO 14001 Environmental Management System (EMS), are likely to improve both the breadth and accuracy of their carbon emissions disclosure. Conceptually, ISO 14001 provides a structured approach to managing environmental impacts, ensuring that business operations align with sustainable practices. The standard promotes systematic monitoring and reporting of environmental performance, enabling more reliable and comprehensive disclosure of carbon emissions. From the perspective of legitimacy theory, adopting ISO 14001 signals that a company is acting in accordance with societal expectations regarding environmental responsibility, reinforcing its commitment to transparent and sustainable operations.

Previous research supports this conceptual relationship. Setiawan and Iswati (2019). found that companies with ISO 14001 certification tend to report carbon emissions more extensively and accurately than those without formal environmental management systems. Similarly, Maqfirah et al., (2020), Indah Sukmawati and Deliza Henny (2024), show that the implementation of ISO 14001 EMS has a positive impact on carbon emissions disclosure, suggesting that both public and stakeholder pressures motivate firms to adopt structured environmental management standards. Collectively, these studies suggest that the adoption of

ISO 14001 EMS significantly enhances the scope and quality of carbon emissions reporting.

H3: Environmental management has a significant positive effect on carbon emission disclosure.

Gender diversity of directors may moderate this relationship by influencing managerial decision-making and strategic orientation. Female directors are generally perceived as more attentive to accountability and strong corporate governance, promoting transparent reporting Gonenc, (2022). Boards with greater gender diversity are expected to reinforce the company's inclination to disclose carbon emissions, even under conditions of high leverage, thereby strengthening the link between leverage and carbon emission disclosure.

Empirical evidence on the relationship between leverage and carbon emission disclosure (CED) remains inconclusive. Several studies report a negative association, indicating that firms with higher debt levels tend to limit voluntary environmental disclosures due to financial constraints and reporting costs. Jannah & Muid, (2014) find that companies with substantial leverage often reduce discretionary reporting to prioritize liquidity and debt obligations. Similarly, Rahmadhani, (2019) shows that financially constrained firms are less likely to provide extensive carbon-related information. Conversely, other studies report a positive relationship, as firms relying more on external financing disclose more carbon information to enhance transparency and maintain stakeholder trust Deegan, (2002). These findings suggest that the effect of leverage on carbon disclosure varies depending on external scrutiny and stakeholder expectations.

Empirical evidence on the relationship between leverage and carbon emission disclosure (CED) remains inconsistent. Several studies indicate that leverage does not significantly affect carbon disclosure. For instance, Mudi et al., (2022) find no significant influence of leverage on CED in Indonesian manufacturing firms. Suryani et al., (2019) how that leverage is not a significant determinant of greenhouse gas disclosure, including carbon. The coexistence of negative, positive, and insignificant findings highlights a clear inconsistency in prior research, justifying the use of a moderating variable to better understand this relationship.

In this context, gender diversity on the board has been suggested as an important moderating factor. Empirical evidence supports this role, showing that board gender composition can influence how firms respond to financial pressures. Jannah and Muid (2014) report that companies with high leverage often limit voluntary disclosure due to associated costs. Conversely, Kamaludin et al., (2022) find that firms with female representation on boards are more likely to maintain transparent reporting practices, including environmental disclosures, even when facing financial constraints. These findings suggest that gender-diverse boards can strengthen the positive effect of leverage on carbon emission disclosure by broadening perspectives and increasing sensitivity to environmental responsibility.

H4: Gender diversity on the board of directors strengthens the positive influence of leverage on carbon emission disclosure.

Empirical evidence on the relationship between institutional ownership and carbon emission disclosure (CED) remains inconclusive and fragmented. While several studies emphasize that institutional investors serve as effective monitoring agents and, due to their long-term investment orientation, tend to promote greater environmental transparency, the findings are not uniform. Ghofur, (2025) show that firms with higher institutional ownership

disclose carbon emissions more extensively, suggesting that institutional investors can exert meaningful pressure on environmental reporting practices. However, other studies report insignificant results. Krisnawanto & Solikhah (2019) and Akhirah & Kiswanto (2016) find that institutional ownership does not significantly influence carbon emission disclosure. These inconsistent findings imply that the effectiveness of institutional ownership varies depending on the strength of monitoring mechanisms and the quality of internal corporate governance.

Such inconsistencies highlight the need to consider additional governance factors that shape how external monitoring pressure translates into disclosure decisions. In this respect, board gender diversity may function as an important moderating mechanism. Adams, (2009) argues that the presence of female directors enhances board oversight and improves governance effectiveness. Supporting this perspective, Budanti et al., (2025) find that firms with higher institutional ownership experience stronger pressure to expand carbon emission reporting, while Dwinajayanti et al., (2024). demonstrate that boards with a greater proportion of women are more inclined to adopt sustainable and accountable reporting practices. Collectively, these findings suggest that gender-diverse boards may strengthen the influence of institutional ownership, thereby enhancing the quality and scope of carbon emission disclosure.

H5: Gender diversity on the board of directors strengthens the positive influence of institutional ownership on carbon emission disclosure.

Empirical findings regarding the impact of implementing an *Environmental Management System* (EMS), such as ISO 14001, on carbon emission disclosure (CED) remain mixed. Some studies suggest a positive effect; for example, Putu et al., (2021) found that companies with EMS exhibit more transparent carbon emissions reporting, indicating that structured environmental management enhances disclosure comprehensiveness. Conversely, other research, including Iratiwi & Sulfitri, (2023) reported no significant effect of EMS on carbon emission disclosure, implying that merely having an EMS does not automatically ensure improved reporting transparency. These divergent results suggest that EMS alone may not fully explain variations in corporate carbon reporting.

Given these inconsistencies, it is crucial to consider governance factors that may moderate the relationship between EMS implementation and carbon emission disclosure. Board gender diversity has been proposed as such a moderating factor because it can strengthen oversight, enhance compliance, and increase corporate commitment to sustainability. Adams, (2009) argues that female directors contribute to higher-quality board supervision and governance. Supporting this, Rohmah et al., (2022) found that EMS adoption promotes more transparent carbon reporting, while Wahyuningrum et al., (2025). showed that boards with higher female representation tend to prioritize sustainability and compliance, resulting in more meticulous and accountable reporting. Additional evidence indicates that female representation on boards is positively associated with Environmental, Social, and Governance (ESG) performance, particularly in areas related to environmental disclosure Samsudin et al., (2025).

Therefore, gender diversity on boards is expected to moderate the EMS–CED relationship, such that companies implementing EMS with gender-diverse boards are likely to achieve more comprehensive and accountable carbon emission reporting. This combination enhances oversight, compliance, and commitment to sustainable practices, providing a clear

theoretical and empirical justification for including *gender diversity* as a moderating variable in studies examining EMS and carbon emission disclosure.

H6: Gender diversity of directors strengthens the positive influence of environmental management on carbon emission disclosure.

3. RESEARCH METHODS

Sample

The sample was selected from listed energy companies on the Indonesia Stock Exchange (IDX) in 2021–2024. Data are collected from the official BEI website (<https://www.idx.co.id>) and company websites. Using a purposive sampling method, 57 companies were available for the test of hypotheses with a total of 228 observations over four years as described in Table 1.

Table 1. Sample Selection

Criteria	Total
Energy sector companies in 2021-2024.	66
No sustainability reports available during sample period	(9)
Number of companies available for further analysis	57

Measurement of Variables

This section explains the operational definitions and measurement of research variables, which are based on theoretical foundations and previous research to ensure objective and consistent measurement. The dependent variable in this study is carbon emission disclosure, while the independent variables include leverage, institutional ownership, and environmental management, with gender diversity of directors as a moderating variable and firm size and profitability as control variables. A summary of the operational definitions, indicators, and measurement scales for each variable is presented in the variable operational table in the following section.

Table 2. Definitions and Indicators of Variables

Variable	Definition	Indicator
Carbon Emission Disclosure (CED)	Carbon emission disclosure is a practice company reports emission carbon and related strategies to stakeholders as a form of accountability for issue change climate. (Choi et al., 2013)	This study uses the Global Reporting Initiative (GRI 305, 2016) index to measure carbon emission disclosure. The index consists of 7 items, and the disclosure score is calculated based on the proportion of disclosed items to the total items. Number of <u>items disclosed</u> Total items (7)

Leverage (LEV)	Company dependency level on funding external (debt) compared to capital Alone. (Weston et al., 1980)	$\frac{\text{Total Debt}}{\text{Total Equity}}$
Institutional Ownership (INSTI)	Institutional ownership of company shares (banks, pension funds, insurance, institutions finance other). (Jensen and Meckling 1976)	$\frac{\text{Number of Institutional shares}}{\text{Number of Shares Outstanding}} \times 100\%$
Environmental Management (ENVI)	Environmental management is part of corporate strategy Which is oriented on management skills resource natural sustainably For achieving excellence Term long. (Stuart, 1995).	Dummy = If it has ISO 14001 certification then it is scored 1, and if it is not disclosed then it is scored 0
Gender Diversity (GD)	Gender diversity refers to the existence of women in a board of directors that brings different perspectives to the decision-making process, increasing the effectiveness of monitoring and control management. (Adams and Ferreira 2009).	$\frac{\text{GD Female Directors}}{\text{Total Board of Director}}$
Firm Size (SIZE)	Big small company which describes the source Power and abilities to make a disclosure. (Studies et al., 2025)	Ln (Total Assets)
Profitability (ROA)	The company's ability to produce profit from operational activities. (Vidyana & Buchory, 2024)	$\frac{\text{Net Income}}{\text{Total Assets}}$

Research Model

This research model analyzes the influence of leverage, institutional ownership, and environmental management on carbon emission disclosure in energy sector companies listed on the Indonesia Stock Exchange (IDX) for the 2021–2024 period, with gender diversity on the board of directors as a moderating variable and firm size and profitability as control variables. The analysis begins with descriptive statistics to describe the data characteristics. Next, a panel data model selection test was conducted using the Chow test, the Hausman test, and the Lagrange Multiplier (LM) test, which indicated that the Random Effects Model (REM) was the most appropriate estimation model.

After the REM model was selected, relevant classical assumption tests were conducted,

namely the residual normality test and the multicollinearity test. The results of the normality test indicate that the residuals are not fully normally distributed. However, based on the views of Model Economics et al., (2013), and Peter & M, (1987), in panel data regression, especially REM, violations of the normality assumption are not a serious problem, especially when the number of observations is relatively large. Therefore, to address potential residual non-normality, this study uses robust standard errors, so that coefficient estimates remain consistent and reliable.

Further analysis was conducted using a panel data regression using the Random Effects Model (REM robust). Hypothesis testing included simultaneous tests (F-test), coefficient of determination (R^2) tests, and partial tests (t-test) to examine the influence of each independent variable, moderating variable, and control variable on carbon emission disclosure. The regression equation model is formulated as follows:

$$CED_{it} = \alpha + \beta_1 LEV_{it} + \beta_2 INST_{it} + \beta_3 ENVI_{it} + \beta_4 GD_{it} + \beta_5 (LEV_{it} * GD_{it}) + \beta_6 (INST_{it} * GD_{it}) + \beta_7 (ENVI_{it} * GD_{it}) + \beta_8 SIZE_{it} + \beta_9 ROA_{it} + e$$

Where, CED_{it} = Carbon Emission Disclosure of firm 1 at year t; LEV = Leverage; INST = Institutional Ownership; ENVI = Environmental Management; GD = Gender Diversity.

4. RESULTS AND DISCUSSION

Descriptive Statistics

As a first step in data analysis, descriptive statistics were examined for all research variables. This analysis included calculating the mean, minimum, maximum, and standard deviation, aimed at understanding the characteristics, distribution, and variation of the data. The summary results of the descriptive statistics are presented systematically on Table 3 and provides an initial overview before further inferential analysis is carried out.

Table 3. Descriptive Statistics

Description	Mean	Median	Minimum	Maksimum	Std. Dev
CED	10.4420	18.7773	0	20.5691	9.9934
LEV	4.4483	4.7405	0.6931	5.4293	0.9451
INST	4.1152	4.4127	0.6931	5.0498	0.8975
ENVI	0.3648	0.6931	0	0.6931	0.3468
GD	1.0021	0.6931	0.6931	2.3025	0.5201
LEV*GD	4.4772	3.5618	0.4804	11.8709	2.5284
INST*GD	4.1600	3.1885	0.4804	11.5374	2.4553
ENVI*GD	0.3986	0.4804	0	1.5960	0.4694
SIZE	4.4685	4.7492	0.6931	5.4293	0.9133
ROA	4.4675	4.7492	0.6931	5.4293	0.9124

The descriptive statistics show that carbon emission disclosure (CED) has a mean of 10.44, indicating that, on average, companies disclose a moderate level of carbon emissions

information. and a median of 18.7773, with a range of 0–20.56 and a standard deviation of 9.99, indicating variations in the level of carbon emission disclosure between companies. The mean value of leverage is 4.44, This indicates that, on average, companies maintain a moderate level of debt in their capital structure. Such a level of leverage reflects a balance between utilizing debt for growth and managing financial risk. a median of 4.7405, with a range of 0.69 - 5.42 and standard deviation 0.94, which shows the difference in the level of debt usage. Institutional ownership shows a mean of 4.11, This indicates that, on average, institutional investors hold a moderate portion of company shares in the sample. Such a level reflects a balanced influence of institutional shareholders on company policies, potentially affecting decisions related to governance and disclosure practices. median 4.4127, with a range of values 0.69 - 5.04 and a standard deviation of 0.89, reflecting relatively uniform institutional ownership.

Environmental management has a mean of 0.36, This indicates that, on average, companies in the sample have implemented environmental management practices at a relatively low level. Such a result suggests that there is still significant room for improvement in adopting structured environmental management systems and promoting sustainability practices. A median of 0.6931, with a range of 0 - 0.69 and a standard deviation of 0.34, indicating that the level of corporate environmental management is still relatively low. Meanwhile, gender diversity direction has a mean of 1.00, This indicates that, on average, companies in the sample have minimal gender diversity in their board of directors. Such a result suggests that the representation of women in decision-making positions is limited, highlighting the need for greater inclusion to strengthen governance and sustainability practices. a median of 0.6931, with a range of 0.69 - 2.30 and a standard deviation of 0.52, indicating that gender representation in the board of directors is still limited.

In the interaction variable, the results of descriptive statistics show that the interaction between gender diversity direction and leverage (LEV_GD) has an average value of 4.47 and a median of 3.5618, with a minimum value of 4.478 and a maximum of 11.87, and a standard deviation of 2.52, indicating differences in the role of gender diversity in companies with different debt levels. The interaction between gender diversity direction and institutional ownership (INST_GD) has a mean value of 4.16 and a median of 3.1885, with a minimum value of 0.48 and a maximum of 11.53, and a standard deviation of 2.45, indicating that the moderating effect varies depending on the ownership structure. Meanwhile, the interaction between gender diversity direction and environmental management (ENVI_GD) shows a mean value of 0.39 and a median of 0.4804, with a minimum value of 0 and a maximum of 1.59, and a standard deviation of 0.46, indicating that the moderating role in this relationship is relatively smaller. Overall, these value variations reflect differences in characteristics between companies and support the need for further analysis to understand the relationship between variables in more depth.

Panel Data Regression Model Test

Based on the Chow test results in Table 4, a probability value of 0.0000 (<0.05) indicates that the Fixed Effect Model (FEM) is more appropriate than the Common Effect Model (CEM). This result indicates differences in specific characteristics between companies that influence the dependent variable, so the model that assumes uniformity between observation units

(CEM) is unable to adequately explain data variation. The Hausman test shows a probability value of 0.4428 (>0.05), indicating that the difference in estimates between the Fixed Effect and Random Effect models is statistically insignificant. Therefore, the assumption that individual firm effects are uncorrelated with the independent variables is acceptable, and the Random Effect Model (REM) is considered more efficient and consistent than the Fixed Effect.

Table 4. Model Selection

Testing	Result (Prob)	Model
Chow Test	0.0000	Fixed Effect Model
Hausman Test	0.4428	Random Effect Model
Lagrange Multiplier Test	0.0000	Random Effect Model

The Lagrange Multiplier (LM) test results show a probability value of 0.0000 (<0.05). These results confirm that the Random Effects model is more appropriate than the Common Effects model due to the significant individual effect variance in the panel data. Therefore, based on this series of model tests, the Random Effects Model (REM) is the most appropriate model to use in this study because it is able to capture variations between companies more effectively and efficiently.

Results

Regression results are presented on Table 5. The simultaneous test results show a Wald Chi² value of 16.89 with a probability of 0.0505, which means that all independent variables and interaction variables jointly influence CED. However, the R-Square value of 0.0319 indicates that the model is only able to explain 3.19% of the variation in CED, so that carbon emission disclosure is also greatly influenced by other external factors, as explained in the legitimacy theory that social and regulatory pressures also shape corporate disclosure behavior.

Tabel 5. Regression Results

Variables	Prediction	Coefficient	<i>P-value</i>
LEV	-	-5.9775	0.006
INST	-	-1.1049	0.519
ENVI	+	10.7282	0.015
GD	-	-27.5365	0.043
LEV_GD	+	4.8318	0.036
INST_GD	+	1.9702	0.177
ENVI_GD	-	-10.6377	0.013
SIZE	+	1.3170	0.204
ROA	+	1.0557	0.133
F Test		16.89	0.0505
Adj R ²		0.0139	

The partial t-test results indicate that not all independent variables and interaction terms significantly influence carbon emission disclosure. Leverage and environmental management

have significant effects on CED but institutional ownership did not. Furthermore, gender diversity of the board of directors has a significant effect on the relationship between leverage and CED and the relationship between environmental management and CED. These findings form the basis for further discussion of each research hypothesis.

Discussion

Leverage and Carbon Emission Disclosure

The results of the partial test show that leverage has a statistically significant and negative impact on carbon emission disclosure (CED), as indicated by a coefficient of -5.97 and a significance level of $0.006 (<0.05)$, which supports the acceptance of H1. This outcome is in line with earlier research Jannah and Muid (2014), Tarigan et al., (2022), and Ruhayat Endang, Holiawati (2025), suggesting that firms with greater debt burdens are less inclined to provide extensive carbon emission disclosures. From the standpoint of legitimacy theory, companies facing substantial financial constraints tend to concentrate on preserving credibility with creditors and investors, rather than allocating resources to voluntary environmental reporting that may generate additional costs. Consequently, carbon emission disclosure is often minimized as part of a strategy to safeguard financial performance and organizational image.

Furthermore, the inverse relationship between leverage and carbon emission disclosure indicates that management in highly leveraged firms prioritizes short-term financial commitments over long-term sustainability transparency. Limited financial flexibility encourages firms to emphasize operational efficiency and risk avoidance, causing environmental disclosure to be viewed as a secondary concern. This finding also aligns with stakeholder theory, which posits that organizations under strong financial pressure are more responsive to the interests of dominant stakeholders, particularly creditors, than to wider social and environmental groups. As a result, environmental reporting receives less managerial attention, despite its potential benefits for strengthening long-term legitimacy and corporate reputation.

Institutional Ownership and Carbon Emission Disclosure

The results reveal that institutional ownership does not have a statistically significant influence on carbon emission disclosure (CED), as indicated by a probability value of $0.519 (>0.05)$; therefore, H2 is rejected. This result is consistent with prior studies Putri Andini Eleshya (2023), Rinda Nugraha (2025). which suggest that the involvement of institutional investors has not been sufficient to motivate companies to expand their carbon disclosure practices. From the perspective of legitimacy theory, this finding indicates that the pressure from institutional shareholders regarding environmental accountability remains relatively limited, so firms do not perceive institutional ownership as a key factor in determining their carbon emission disclosure policies.

Moreover, the absence of a significant effect may reflect that many institutional investors still emphasize short-term financial performance rather than long-term sustainability concerns. When environmental transparency is not directly linked to financial returns, institutional shareholders may have little incentive to actively monitor or demand detailed carbon disclosures. As a result, institutional ownership has not functioned as an effective governance mechanism in promoting environmental transparency. Consequently, companies tend to

disclose carbon-related information only to comply with basic requirements, rather than as part of a strategic effort to enhance corporate legitimacy and stakeholder confidence.

Environmental Management and Carbon Emission Disclosure

The findings indicate that environmental management has a positive and statistically significant effect on carbon emission disclosure (CED), as reflected by a coefficient of 10.72 and a probability value of 0.015 (<0.05); therefore, H3 is accepted. This result is consistent with prior studies Rohmah dan Nazir (2022) and Suherman and Kurniawati (2023), which suggest that firms with well-established environmental management systems are more likely to provide broader disclosures related to carbon emissions. From the perspective of legitimacy theory, such disclosures function as a communication tool to demonstrate a company's commitment to environmental responsibility and to obtain social approval for its operational activities that may affect the environment.

Furthermore, the positive relationship implies that companies with strong environmental management are more confident and transparent in reporting their environmental performance, as they perceive disclosure not as a risk but as a strategic advantage. Effective environmental management reduces uncertainty and enhances organizational credibility, encouraging firms to voluntarily share more detailed carbon-related information. This practice not only strengthens corporate legitimacy but also helps build trust with stakeholders and supports long-term sustainability objectives.

Gender Diversity as A Moderating Variable

The empirical findings demonstrate that gender diversity on the board of directors significantly and positively moderates the relationship between leverage and carbon emission disclosure (CED), as shown by a coefficient of 4.83 and a probability value of 0.036 (<0.05); therefore, H4 is supported. This result suggests that the involvement of female directors is able to reduce the adverse impact of leverage on the level of carbon emission disclosure. In this context, gender-diverse boards appear more capable of balancing financial constraints with the firm's responsibility to maintain social legitimacy through transparent environmental reporting.

Moreover, the moderating role of gender diversity may be attributed to the tendency of female board members to emphasize ethical values, long-term sustainability, and stakeholder engagement. Their presence can foster more comprehensive discussions and encourage management to consider environmental accountability even under conditions of high financial pressure. As a result, gender diversity within the board strengthens corporate governance and supports carbon disclosure as a strategic instrument to enhance legitimacy and stakeholder trust, thereby weakening the negative influence of leverage on environmental transparency.

The results indicate that gender diversity on the board of directors does not significantly moderate the relationship between institutional ownership and carbon emission disclosure (CED), as shown by a probability value of 0.177 (>0.05); therefore, H5 is rejected. This finding suggests that the presence of female directors neither strengthens nor weakens the influence of institutional ownership on carbon emission disclosure. It implies that the legitimacy pressure exerted by institutional investors on environmental transparency remains limited, even when the board structure is more gender-diverse.

Furthermore, the absence of a moderating effect may reflect that institutional investors still prioritize financial performance over environmental accountability, and this orientation is not substantially altered by board gender composition. Although gender-diverse boards may encourage broader perspectives, their influence may not be strong enough to change the strategic priorities of dominant shareholders. As a result, institutional ownership continues to play a minimal role in driving carbon disclosure practices, regardless of gender diversity within the board.

The results indicate that gender diversity on the board of directors significantly and negatively moderates the relationship between environmental management and carbon emission disclosure (CED), as reflected by a coefficient of -10.63 and a probability value of 0.013 (<0.05); therefore, H6 is rejected. This finding suggests that greater gender diversity within the board actually weakens the positive effect of environmental management on the level of carbon emission disclosure. From a legitimacy perspective, this outcome reflects differences in strategic viewpoints among board members regarding how far environmental information should be disclosed, even when the firm already operates with an effective environmental management system.

Furthermore, this negative moderating effect may indicate that gender-diverse boards engage in more cautious and risk-averse decision-making, particularly when environmental disclosure is perceived as potentially exposing the firm to external scrutiny or regulatory pressure. While environmental management systems signal internal commitment, the board may choose to limit disclosure to avoid reputational or compliance risks. As a result, the presence of gender diversity can unintentionally reduce the extent to which strong environmental management translates into broader carbon disclosure, highlighting the complex role of board composition in shaping sustainability reporting strategies.

5. CONCLUSIONS AND SUGGESTIONS

Carbon emission disclosure in energy sector companies plays a crucial role, given the nature of this sector's operational activities, which contribute significantly to greenhouse gas emissions. Transparency of carbon emissions information is one form of corporate accountability in responding to stakeholder demands and maintaining social legitimacy. Therefore, this study aims to examine the determinants and moderating factors that influence carbon emission disclosure among energy sector companies, in order to better understand how corporate characteristics and governance structures shape environmental transparency.

Based on the results of panel data regression analysis using the Random Effect Model (REM), this study shows that leverage, institutional ownership, environmental management, gender diversity direction, and interaction variables simultaneously influence carbon emission disclosure, although the model's ability to explain variations in CED is still relatively limited with an R-Square value of 3.19% . Partially, leverage has a significant negative effect on CED, indicating that energy sector companies with high debt levels tend to limit carbon emission disclosure. Institutional ownership does not have a significant effect on CED, indicating that pressure from institutional investors on carbon emission disclosure practices is still relatively weak. Conversely, environmental management has a significant positive effect on CED, indicating that companies with better environmental management tend to increase carbon emission disclosure as an effort to gain social legitimacy.

Furthermore, gender diversity direction has a significant negative effect on CED. However, as a moderating variable, gender diversity direction moderates the relationship between leverage and CED, but does not moderate the relationship between institutional ownership and CED, and weakens the relationship between environmental management and CED. These findings confirm that carbon emission disclosure practices in energy sector companies are the result of an interaction between financial conditions, environmental policies, and corporate governance dynamics in an effort to maintain legitimacy among stakeholders.

Based on the results and limitations of this study, future research is recommended to expand the research objective by not only focusing on energy sector companies, but also encompassing other sectors with high carbon emission levels to obtain a more comprehensive picture of carbon emission disclosure practices in Indonesia. Furthermore, future research can extend the observation period to more accurately capture the dynamics and developments in carbon emission disclosure along with increasing attention to sustainability issues and greenhouse gas emission reduction policies. Future research is also recommended to develop the research model by examining other theoretically and empirically relevant variables in explaining carbon emission disclosure, thereby enriching the analysis and increasing the research's explanatory power. In addition, the use of more diverse carbon emission disclosure measurement standards, such as a combination of the GRI 305 index with other international standards can be considered so that the research results are more comparative and globally relevant.

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Table 1 Global Reporting Initiative (GRI 305) index

2021 GRI Index	
Emissions	
305-1	Direct (Scope 1) GHG Emissions
305-2	Energy Indirect (Scope 2) GHG Emissions
305-3	Other Indirect (Scope 3) GHG Emissions
305-4	GHG Emissions Intensity
305-5	Reduction of GHG Emissions
305-6	Emissions of Ozone-Depleting Substances (ODS)
305-7	Nitrogen Oxides (NOx), Sulfur Oxides (SOx), and Other Significant Air Emissions