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Carbon Accounting: Evidence from Carbon Emission Measurement, Recognition, Recording, and Disclosure of Indonesian Energy Companies

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ABSTRACT

The global climate crisis compels energy firms to enhance their environmental transparency through formalized carbon management systems. This study investigates the effects of carbon emission measurement, recognition, recording, and disclosure on corporate carbon accounting implementation. This quantitative verificative study utilizes secondary panel data from listed energy corporations on the Indonesia Stock Exchange (IDX). Data were collected from 96 firm-year observations during 2021–2023 and analyzed via logistic regression. Descriptive statistics show that 86.46% of firms measure emissions, 41.70% recognize emissions, 47.90% record carbon data, and 51% implement carbon accounting. Logistic regression indicates that carbon emission recognition ($b = 2.415$, $p < 0.001$), recording ($b = 1.843$, $p = 0.002$), and disclosure ($b = 3.106$, $p = 0.014$) significantly influence implementation. Conversely, carbon emission measurement has no significant effect ($b = 0.812$, $p = 0.192$), showing technical calculations remain isolated from formal accounting. Practically, regulators must standardize carbon accounting guidelines, and managers should explicitly integrate emission data into formal reporting to enhance corporate transparency.

Keywords: Carbon Accounting; Carbon Emission Measurement; Carbon Emission Recognition; Carbon Emission Recording; Carbon Emission Disclosure; Energy Sector

JEL Classification: M41; Q54; Q56

INTRODUCTION

Climate change has become a critical global issue affecting economic activities, environmental sustainability, and corporate governance practices. Increasing greenhouse gas emissions, particularly carbon dioxide generated from industrial operations and energy consumption, serve as primary contributors to global warming. The energy industry receives substantial scrutiny because its operational activities depend heavily on fossil fuels, which produce high levels of carbon emissions. Consequently, companies operating in this sector face intensified pressure from governments, investors, and society to enhance environmental responsibility and provide transparent sustainability information. As part of its commitment to global initiatives like the Paris Agreement, Indonesia has introduced strategic policies, including Presidential Regulation No. 98 of 2021 on Carbon Economic Value, forcing corporations to strengthen environmental governance and transition from narrative-based environmental commitments to structured reporting practices.

Within corporate environmental management, carbon accounting has emerged as a fundamental framework encompassing the explicit processes of measuring, recognizing, recording, and disclosing greenhouse gas emissions. Legally and operationally, effective carbon accounting requires robust internal reporting systems capable of converting technical emission metrics into formal financial and non-financial data. However, the implementation of comprehensive carbon accounting practices remains deeply uneven and fragmented, particularly in emerging economies like Indonesia. Many energy firms still report climate-related impacts selectively or in purely descriptive formats without integrating quantitative emission measurements into formal accounting treatments. This structural discrepancy creates a pressing necessity to evaluate how distinct corporate actions, starting from technical measurement up to public disclosure, actively shape the actual implementation of integrated carbon accounting systems.

A significant research gap persists in the existing environmental accounting literature. While prior studies heavily focus on the determinants of general sustainability reporting, empirical research evaluating the full internal spectrum of carbon accounting, specifically isolating measurement, recognition, and recording alongside disclosure, remains highly scarce (Onat et al., 2025; Qian & Schaltegger, 2017). Furthermore, empirical findings regarding the implications of environmental transparency remain inconclusive. Some researchers argue that active carbon management practices reflect substantive corporate accountability and stimulate internal data infrastructure development, while others contend that environmental reporting is often executed symbolically as a greenwashing tactic to maintain corporate legitimacy (Delmas & Burbano, 2011). Most prior empirical investigations have been conducted within developed nations under mature regulatory frameworks, leaving a critical knowledge gap regarding how carbon management components interact within the developing regulatory landscape of Indonesia's energy sector.

To address these limitations, the objective of this study is to investigate the empirical influence of carbon emission measurement, recognition, recording, and disclosure on the overall implementation of corporate carbon accounting. This research applies a quantitative verificative approach using secondary panel data from 96 firm-year observations of energy sector companies listed on the Indonesia Stock Exchange (IDX) during the 2021–2023 period, evaluated through logistic regression analysis. The novelty of this study lies in its comprehensive research framework that unpacks carbon management into four distinct operational accounting constructs, moving beyond the singular focus on voluntary disclosure found in traditional literature. By analyzing these

four dimensions simultaneously, this study uncovers which specific stage of the accounting process serves as the primary driver or barrier to institutionalizing carbon management. This study contributes theoretically by enriching environmental accounting literature and legitimacy theory within the context of emerging economies under regulatory transition. Practically, the insights generated offer critical entry points for Indonesian regulators to standardize compliance frameworks and assist corporate executives in establishing integrated carbon reporting systems to satisfy evolving stakeholder expectations.

LITERATURE REVIEW

Theoretical Framework

Environmental disclosure can therefore be interpreted as a strategic response by companies to legitimize their operations and reduce potential criticism from stakeholders and society (Brammer & Pavelin, 2008). Carbon emission disclosure, in particular, has become an important tool for companies to show their commitment to climate change mitigation and sustainable development (Toukabri & Youssef, 2023). However, to maintain credibility, companies must ensure that disclosed carbon information is supported by reliable internal measurement systems. This requirement encourages organizations to develop corporate carbon accounting systems capable of measuring, monitoring, and reporting greenhouse gas emissions accurately (Ascui & Lovell, 2011). Consequently, legitimacy theory suggests that companies disclose carbon emissions not only to satisfy societal expectations but also to strengthen internal environmental management practices, including carbon accounting.

Carbon accounting is closely related to the broader concept of environmental management accounting, which focuses on identifying, measuring, and managing environmental costs and impacts within organizations (Burrit et al., 2023). Carbon accounting systems enable companies to quantify greenhouse gas emissions generated by their activities and to evaluate strategies for reducing carbon footprints (Onat et al., 2025). By providing reliable information on emission sources and environmental performance, carbon accounting supports both internal decision-making and external environmental reporting (Burrit et al., 2023). Organizations that implement carbon accounting systems are better able to track emission reduction initiatives and assess the effectiveness of their climate strategies (Ascui & Lovell, 2011). These systems also enhance the credibility of environmental disclosures by ensuring that reported emission data are based on systematic measurement and monitoring processes (Andrew & Cortese, 2011). In this context, carbon emission disclosure and corporate carbon accounting are strongly interconnected. Companies that disclose carbon emission information must rely on internal carbon accounting systems to generate accurate and verifiable environmental data.

Carbon Emission Disclosure

Carbon emission disclosure refers to the practice of reporting information related to greenhouse gas emissions generated by corporate activities. This disclosure may include quantitative information regarding emission levels as well as qualitative information about carbon management strategies, emission reduction targets, and climate-related risks (Jiang et al., 2022). Carbon emission disclosure is increasingly recognized as an important element of corporate environmental accountability and sustainability reporting because it allows stakeholders to evaluate corporate environmental performance and climate change strategies (Stanny & Ely, 2008). Previous studies suggest that carbon disclosure is an important mechanism for communicating corporate environmental performance to stakeholders. Companies

disclose carbon information to demonstrate their commitment to environmental sustainability and to respond to pressure from regulators, investors, and society (Luo et al., 2023).

Corporate Carbon Accounting

Corporate carbon accounting refers to the process of identifying, measuring, recording, and reporting greenhouse gas emissions generated by corporate activities. Carbon accounting is a key component of environmental management systems because it allows organizations to quantify their environmental impacts and develop strategies to reduce emissions (Ascui & Lovell, 2011). The concept of carbon accounting has emerged in response to the growing need for reliable information regarding corporate greenhouse gas emissions as climate change becomes a major global concern (Burrit et al., 2023). According to previous research, carbon accounting plays a critical role in supporting climate governance and corporate environmental strategies because it provides the information required to design effective carbon management policies (Ascui & Lovell, 2011). Organizations that implement carbon accounting systems are better able to manage environmental risks and improve their carbon mitigation performance (Burrit et al., 2023).

Research shows that different methodological choices in measuring emissions can significantly influence the reported emission levels, which may affect the reliability and comparability of carbon accounting information (Lee et al., 2024). Furthermore, some studies indicate that corporate greenhouse gas reporting may suffer from inconsistencies and data quality problems due to weak internal measurement systems or incomplete reporting frameworks (Kolk et al., 2008). In some cases, emission data reported by companies may not accurately reflect their actual environmental performance because companies may use different measurement boundaries or estimation methods (Andrew & Cortese, 2011). These challenges highlight the importance of developing robust corporate carbon accounting systems to ensure the credibility and reliability of environmental information disclosed by companies (Burrit et al., 2023).

Hypotheses Development

The Effect of Carbon Emission Measurement on the Implementation of Carbon Accounting

Carbon emission measurement has an important role in the implementation of carbon accounting because it supplies the essential information needed by companies to identify, record, and disclose carbon-related data in financial statements and sustainability reports. Accurate measurement enables organizations to quantify greenhouse gas emissions generated from operational activities and evaluate their environmental impacts (Ascui & Lovell, 2011). Carbon emission measurement is often considered the initial step in implementing carbon accounting systems, as it provides essential information for identifying emission sources and assessing environmental performance (Burrit et al., 2023). Without reliable emission measurement, companies cannot properly record carbon-related costs, liabilities, or assets within their accounting systems

Various standardized methods have been established to facilitate the measurement of carbon emissions. The Greenhouse Gas (GHG) Protocol, for example, classifies emissions into Scope 1, Scope 2, and Scope 3, which helps organizations systematically measure direct and indirect emissions generated throughout their value chains (Gillenwater, 2023). Other tools, such as Life Cycle Assessment (LCA) and carbon footprint calculators, also assist organizations in evaluating environmental impacts across the entire life cycle of products and operations (Guenther et al., 2016). Accurate

measurement of carbon emissions supports the application of exit price accounting, where carbon liabilities and assets are valued based on market prices of carbon credits (Ratnatunga & Balachandran, 2009). This valuation approach requires reliable emission data to determine the financial implications of carbon emissions within corporate accounting systems (Burrit et al., 2023). Previous studies indicate that companies implementing structured emission measurement methods are more prepared to adopt carbon accounting practices. Firms that apply internationally recognized standards such as ISO 14064 and the GHG Protocol tend to demonstrate higher levels of transparency and accountability in environmental reporting (Gillenwater, 2023).

Empirical studies also support the positive relationship between carbon emission measurement and carbon accounting implementation. Companies that adopt structured emission measurement practices are more capable of integrating environmental data into their accounting systems and sustainability reports (Burrit et al., 2023). Similarly, organizations applying science-based emission measurement approaches are more likely to implement carbon accounting within their financial reporting frameworks (Ratnatunga & Balachandran, 2009). However, some studies argue that emission measurement alone may not guarantee the implementation of carbon accounting. Regulatory pressure, internal organizational readiness, and government incentives may also influence the adoption of carbon accounting practices (Gillenwater, 2023). Based on these arguments, the following hypothesis is proposed:

H1: Carbon emission measurement positively influences the implementation of carbon accounting.

The Effect of Carbon Emission Recognition on the Implementation of Carbon Accounting

Carbon emission recognition refers to the process of identifying and formally acknowledging greenhouse gas emissions within corporate reporting systems. This process includes recognizing emission-related assets, liabilities, and expenses within financial or sustainability reports (Burrit et al., 2023). Proper recognition of carbon emissions enhances corporate transparency and accountability by ensuring that environmental impacts are systematically integrated into financial reporting systems (Ascui & Lovell, 2011). When emissions are recognized in accounting systems, companies can better assess environmental risks and comply with environmental regulations. Recognition of carbon emissions is particularly important in carbon trading schemes such as cap-and-trade systems, where emission allowances must be recorded as assets or liabilities within corporate financial statements (Burrit et al., 2023). Accurate recognition ensures that companies properly account for emission permits and carbon credits within their accounting frameworks.

International standards such as the GHG Protocol and ISO 14064 provide guidelines for consistent carbon emission recognition and reporting across organizations (Ascui & Lovell, 2011). These standards improve the comparability and reliability of environmental data reported by companies. Previous studies indicate that companies recognizing carbon emissions within their financial reporting systems tend to adopt more comprehensive carbon accounting practices. Transparent recognition of carbon emissions enhances investor confidence and strengthens corporate environmental accountability (Ratnatunga & Balachandran, 2009). Nevertheless, several studies argue that carbon emission recognition may remain symbolic if it is not supported by strong regulatory enforcement or incentives. In many developing countries, carbon emission recognition is still voluntary and not fully integrated into corporate accounting systems

(Burrit et al., 2023). Based on the theoretical arguments and empirical findings, the following hypothesis is proposed:

H2: Carbon emission recognition positively influences the implementation of carbon accounting.

The Effect of Carbon Emission Recording on the Implementation of Carbon Accounting

Recording carbon emissions is an essential component of carbon accounting implementation. Carbon emission recording involves documenting emission data, carbon-related liabilities, and carbon assets within corporate accounting systems (Guenther et al., 2016).

Proper recording of emission-related transactions ensures that companies can accurately monitor their environmental impacts and comply with environmental regulations. Carbon-related obligations arising from emission reduction requirements or carbon credit purchases must be recorded systematically within corporate financial statements (Ratnatunga & Balachandran, 2009). Carbon credits, for example, are often recognized as intangible assets that can be traded in carbon markets or used to offset future emission obligations (Delmas & Burbano, 2011). Accurate recording of these assets helps companies maintain financial transparency and comply with sustainability reporting standards.

Empirical studies also suggest that firms actively recording carbon emissions within their accounting systems tend to achieve higher environmental, social, and governance (ESG) performance scores and greater access to green financing opportunities (Luo et al., 2023). However, differences in reporting standards across companies and countries may create inconsistencies in carbon recording practices. The absence of harmonized reporting standards can limit the effectiveness of carbon accounting implementation (Ratnatunga & Balachandran, 2009). Based on these arguments, the following hypothesis is proposed:

H3: Carbon emission recording positively influences the implementation of carbon accounting.

The Effect of Carbon Emission Disclosure on the Implementation of Carbon Accounting

Carbon emission disclosure refers to the reporting of carbon-related information in corporate financial statements and sustainability reports. Disclosure practices provide stakeholders with insights into how companies manage environmental risks and carbon emissions (Luo et al., 2023). Transparent disclosure of carbon emissions improves corporate accountability and enhances the credibility of environmental reporting (Clarkson et al., 2008). Disclosure also encourages companies to strengthen internal carbon accounting systems in order to provide reliable environmental data.

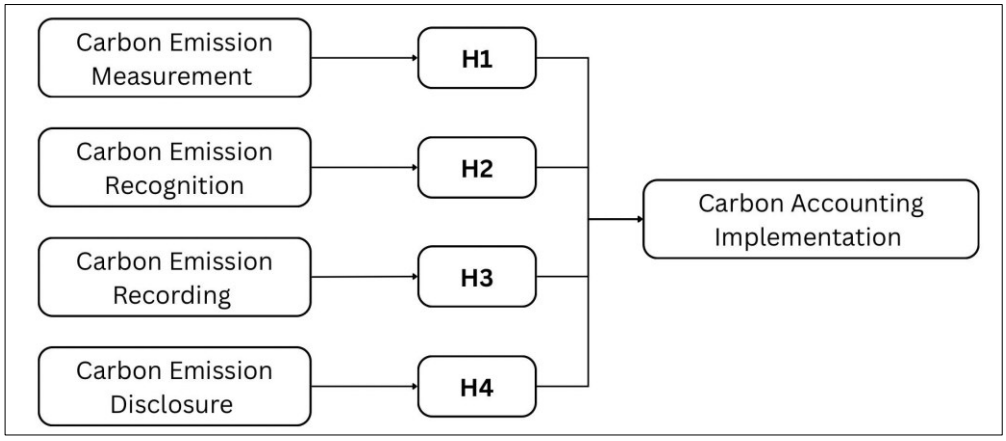
Regulatory frameworks such as sustainability reporting guidelines and international disclosure standards have increased pressure on companies to disclose environmental information, including carbon emissions (Brammer & Pavelin, 2008). Previous studies demonstrate that firms with higher levels of carbon emission disclosure tend to implement more advanced environmental management and carbon accounting systems (Qian & Schaltegger, 2017). Nevertheless, some researchers argue that carbon disclosure may sometimes be symbolic or motivated by reputational concerns rather than substantive environmental performance improvements (Luo et al., 2022). In these

situations, disclosure does not always result in the comprehensive implementation of carbon accounting practices. Based on theoretical explanations and empirical evidence, the following hypothesis is formulated:

H4: Carbon emission disclosure positively influences the implementation of carbon accounting.

Conceptual Framework
Based on the theoretical framework, previous studies, and the hypotheses that have been formulated, the study framework model is depicted in Figure 1.

Figure 1. Research Framework



RESEARCH METHOD

Research Design
This study employs a descriptive and verificative research approach to analyze the implementation of carbon accounting in energy sector companies. Descriptive research is used to describe and analyze data as they are without making generalized conclusions, while verificative research aims to test hypotheses regarding the relationship between research variables (Sugiyono, 2018). The research focuses on the measurement, recognition, recording, and disclosure of carbon emissions and their influence on the implementation of corporate carbon accounting practices. The object of this study consists of energy sector companies listed on the IDX that are involved in carbon-related activities and publish both annual reports and sustainability reports. The observation period covers 2021–2023. The study specifically examines how companies measure, recognize, record, and disclose carbon emissions in their corporate reports and how these practices contribute to the implementation of carbon accounting.

This research uses secondary data obtained from corporate annual reports and sustainability reports published on the official website of the IDX, as well as on the official websites of the respective companies. Additional information regarding carbon reporting standards and environmental regulations was collected from official institutional publications. Secondary data refer to data that have already been collected by other parties for different research purposes (Sekaran & Bougie, 2016).

Population and Sample
The population of this study consists of all energy sector companies listed on the IDX. The sample was selected using purposive sampling, which allows researchers to select companies that meet specific criteria relevant to the research objectives (Sugiyono, 2018). The population defined for this research comprises all energy sector companies

listed on the IDX during the period of 2021 to 2023. A purposive sampling technique was carried out based on predefined criteria to select the final analytical sample. The sample selection criteria include companies that belong to the energy sector, remain consistently listed on the IDX throughout 2021–2023, and publish complete annual reports as well as sustainability reports containing explicit carbon or environmental performance indicators. Table 1 presents the step-by-step purposive sample selection process.

Table 1. Purposive Sample Selection Criteria

No.	Criteria Description	Excluded	Remaining
1.	Energy sector companies listed on the IDX during 2021–2023	-	43
2.	Companies suspended or delisted during the observation period	(4)	39
3.	Companies that did not publish complete annual and sustainability reports	(7)	32
Total	Final Sample Size (Companies)	-	32
Total	Total Observations (32 companies x 3 years)	-	96

Operational Definition and Measurement of Variables

To ensure research transparency and enable future replication, each tested variable is explicitly defined and operationalized based on standardized reporting indicators. The dependent variable, Carbon Accounting Implementation, is measured using a dummy variable approach where a value of 1 is assigned if a firm comprehensively integrates measurement, recognition, recording, and reporting within its books, and 0 otherwise.

For the independent variables, Carbon Emission Measurement, Recognition, and Recording are evaluated based on content analysis of corporate reporting evidence, each scored as a dummy variable (1 if practiced, 0 if absent). Carbon Emission Disclosure is measured using an index based on 18 specific disclosure items adapted from global climate reporting standards. To ensure research transparency, each tested variable is defined and operationalized based on standardized reporting indicators as shown in Table 2.

Table 2. Variable Operationalization Matrix

Variable Name	Concept / Definition	Indicators	Measurement Scale
Carbon Accounting Implementation (Y)	Integration of systematic carbon monitoring into accounting structures.	Simultaneous execution of measurement, recognition, recording, and reporting.	Dummy variable: 1 if all processes are integrated; 0 otherwise.
Carbon Emission Measurement (X1)	Quantification of actual GHG operational outputs.	Identification of emissions based on Scope 1, Scope 2, or Scope 3 metrics.	Dummy variable: 1 if technical tracking exists; 0 if absent.
Carbon Emission Recognition (X2)	Formal acknowledgement of carbon impact in corporate reports.	Formal assignment of emissions in TonCO_2eq and scope mapping.	Dummy variable: 1 if formally recognized; 0 if absent.
Carbon Emission Recording (X3)	Data integration into structural corporate accounting records.	Journaling of environmental liabilities, costs, or capital assets.	Dummy variable: 1 if recorded in financial/sustainability books; 0 if absent.

Carbon Emission Disclosure (X4)	Public communication of carbon metrics and governance.	18 checklist items across 5 thematic carbon-reporting dimensions.	Disclosure Index (Total score obtained divided by the maximum score of 18).

Data Analysis Method

Data were collected using library research and documentation methods. Library research was conducted by reviewing books, academic journals, and previous studies related to carbon accounting and environmental reporting. Documentation analysis was performed by examining corporate reports to identify information related to carbon emission measurement, recognition, recording, and disclosure (Nuryaman & Christina, 2014). The data analysis method used in this study consists of descriptive statistical analysis and logistic regression analysis. Descriptive analysis is used to describe carbon accounting practices implemented by companies, including the level of carbon emission disclosure and reporting patterns. Logistic regression analysis is used because the dependent variable is binary and aims to examine the probability that a company implements carbon accounting practices based on the independent variables (Lintukangas et al., 2023). Statistical analysis was conducted using IBM SPSS Statistics. The secondary data collected from the firm-year panel observations are processed and analyzed using statistical software tools. Because the dependent variable is structured as a binary nominal construct, a logistic regression analysis method is selected as the primary econometric tool. The predictive model does not require ordinary least squares normality assumptions, making it highly suitable for binary outcome evaluations. The mathematical structure of the logistic regression equation is formulated as follows:

Within this structural equation, P represents the probability of successful corporate carbon accounting implementation, while β0 represents the constant coefficient. The regression coefficients β1, β2, β3, and β4 correspond to the independent variables of Carbon Emission Measurement (X1), Carbon Emission Recognition (X2), Carbon Emission Recording (X3), and Carbon Emission Disclosure (X4), respectively. The parameter ε denotes the remaining structural error term of the model. Statistical testing is conducted at a 5% significance level to evaluate the individual hypotheses.

RESULTS

Descriptive Analysis of Carbon Accounting Practices

This study analyzes the implementation of carbon accounting practices among energy sector companies listed on the IDX during the period 2021–2023. The data analysis focuses on four main dimensions of carbon accounting: carbon emission measurement, carbon emission recognition, carbon emission recording, and carbon emission disclosure, which together influence the implementation of corporate carbon accounting. To ensure data clarity and statistical consistency throughout the analysis, all reported percentages are calculated based on the total 96 firm-year observations as the primary denominator.

Carbon Emission Measurement

The empirical tracking of corporate operational actions shows that carbon emission measurement represents a widely adopted baseline stage within the sampled sector. Based on the pooled data, 86.46% of the 96 firm-year observations actively conduct technical carbon emission measurement, though the operational boundaries vary across the monitoring periods. In terms of emission categorization, the descriptive data reveal that 71.10% of the 96 firm-year observations measure Scope 1 and Scope 2 emissions

simultaneously within their corporate sustainability frameworks. In contrast, a comprehensive measurement that includes Scope 3 emissions is executed in only 21.69% of the total 96 firm-year observations, indicating that the technical tracking of indirect supply chain activities, transportation, and lifecycle impacts remains limited among Indonesian energy corporations.

The relatively low measurement of Scope 3 emissions indicates that many companies still face challenges in collecting data from external stakeholders and supply chain partners. This limitation is commonly observed in developing economies where environmental reporting systems are still evolving.

Table 3. Carbon Emission Measurement Practices

Measurement Indicator	Percentage
Companies measuring emissions	86.46%
Scope 1 and Scope 2 measurement	71.10%
Scope 3 measurement	21.69%
Companies not measuring emissions	13.54%

As shown in Table 3, the empirical tracking of corporate operational actions shows that carbon emission measurement represents a widely adopted baseline stage within the sampled sector. Based on the pooled data, 86.46% of the 96 firm-year observations actively conduct technical carbon emission measurement, though the operational boundaries vary across the monitoring periods. In terms of emission categorization, the descriptive data reveal that 71.10% of the 96 firm-year observations measure Scope 1 and Scope 2 emissions simultaneously within their corporate sustainability frameworks. In contrast, a comprehensive measurement that includes Scope 3 emissions is executed in only 21.69% of the total 96 firm-year observations, indicating that the tracking of indirect supply chain activities, transportation, and lifecycle impacts remains limited among Indonesian energy corporations (Hahn & Kühnen, 2013).

Carbon Emission Recognition

Carbon emission recognition refers to the acknowledgment of carbon emissions in corporate reporting systems. Recognition is considered complete when companies report total annual emissions in TonCO_2eq, identify emission sources according to emission scopes, apply internationally recognized measurement standards, and establish emission management strategies. According to Table 4, the findings show that 41.70% of companies fully recognize carbon emissions, while 58.30% of companies do not fully recognize them. Companies that recognize emissions typically include detailed quantitative data, identify major emission sources, and provide information regarding emission reduction initiatives such as energy efficiency programs or renewable energy adoption.

Table 4. Carbon Emission Recognition

Category	Percentage
Companies recognizing emissions	41.70%
Companies are not recognizing emissions	58.30%

The relatively low level of carbon emission recognition indicates that environmental accounting practices are still developing among Indonesian energy companies. Recognition of environmental impacts in corporate reporting is often influenced by stakeholder pressure and regulatory requirements (Bedi & Singh, 2024). Companies that provide detailed emission information generally aim to enhance transparency and demonstrate accountability regarding environmental performance.

Carbon Emission Recording

Carbon emission recording refers to how carbon-related information is integrated into financial statements or sustainability reports. This practice reflects the extent to which environmental issues are incorporated into corporate accounting systems. The results indicate that 47.90% of companies record carbon-related information, while 52.10% do not explicitly record carbon emissions within their accounting reports. Among companies that record emissions, the accounting treatment varies.

Table 5. Carbon Emission Accounting Treatment

Accounting Category	Percentage
Environmental liabilities	34.78%
Environmental costs	41.30%
Environmental assets	23.92%

Table 5 provides a detailed breakdown of the specific carbon emission accounting treatments documented across the sampled periods. Based on the data presented in Table 5, the denominator used for calculating the percentages of environmental liabilities, environmental costs, and environmental assets is consistently fixed at the 96 firm-year observations. The empirical results demonstrate that environmental costs represent the most frequently implemented accounting category, appearing in 41.30% of the total 96 firm-year observations, primarily driven by reported expenses associated with sustainability programs, emission reduction initiatives, or environmental management activities.

Furthermore, Table 5 shows that environmental liabilities are recognized in 34.78% of the 96 firm-year observations, which are typically related to reclamation obligations or environmental restoration provisions within energy operations. In contrast, the recognition of environmental assets related to investments in environmentally friendly technologies or infrastructure is the least adopted treatment, occurring in only 23.92% of the total observations. Additionally, the content analysis reveals that no corporate reporting framework explicitly documents carbon trading activities in their financial statements, indicating that carbon market mechanisms are not yet integrated into corporate accounting systems within the Indonesian energy sector. Environmental accounting literature emphasizes that integrating environmental costs into financial reporting helps companies improve transparency and environmental performance (Burrit et al., 2023).

Carbon Emission Disclosure

Carbon emission disclosure refers to the extent to which companies communicate carbon-related information to stakeholders. In this study, disclosure was measured using an 18-item Carbon Emission Disclosure (CED) checklist. As presented in Table 6, The results show considerable variation among companies. The minimum disclosure score is 11, while the maximum score reaches 83, with an average score of 52.04. These findings indicate that overall disclosure levels are moderate but not yet comprehensive.

Table 6. Carbon Emission Disclosure Statistics

Indicator	Value
Minimum score	11
Maximum score	83
Mean score	52.04
Standard deviation	15.95

Approximately 64.58% of companies disclose more than half of the disclosure indicators, suggesting that most firms have begun to recognize the importance of transparency in environmental reporting. Many companies follow international sustainability reporting frameworks such as the Global Reporting Initiative to structure their environmental disclosures. Nevertheless, many disclosures remain descriptive rather than quantitative, indicating that companies often focus on environmental policies rather than detailed emission data.

Implementation of Corporate Carbon Accounting

The final analysis evaluates the overall implementation of carbon accounting based on the integration of four components: measurement, recognition, recording, and disclosure. As shown in Table 7, The results indicate that 51% of companies have implemented carbon accounting, while 49% have not fully integrated carbon accounting practices into their reporting systems.

Table 7. Implementation of Carbon Accounting

Category	Percentage
Companies implementing carbon accounting	51%
Companies not implementing carbon accounting	49%

Companies that implement carbon accounting typically demonstrate stronger environmental transparency. These companies measure emissions regularly, recognize emission sources, integrate environmental costs into accounting records, and disclose emission information in sustainability reports. However, the relatively balanced proportion between companies that implement and those that do not implement carbon accounting indicates that adoption remains uneven. This condition may be influenced by regulatory limitations, differences in corporate environmental strategies, and the absence of standardized carbon accounting guidelines.

Hypothesis Testing Results

To evaluate the statistical influence of the four carbon management independent variables on the binary outcome of corporate carbon accounting implementation, a logistic regression analysis was executed. Before evaluating the individual pathways, the overall model-fit information was verified. The Omnibus Tests of Model Coefficients produced a Chi-square statistic of 54.321 with a significance value of less than 0.001, indicating that the independent variables significantly improve the model's predictive power. Furthermore, the Nagelkerke R Square value is 0.584, demonstrating that 58.40% of the variance in corporate carbon accounting implementation is explained by the four independent variables in the model. The comprehensive estimation coefficients and statistical outcomes for the hypothesized paths are presented in Table 8.

Table 8. Logistic Regression Estimation Outcomes

Variable / Path		Coeffi-cient (B)	Standard Error (S.E.)	Wald Statistic	Exp(B)	Signifi-cance (Sig.)	Decision
Constant		-3.214	1.102	8.509	0.040	0.004	Accepted
H1	Carbon Emission Measurement (X1)	0.812	0.623	1.701	2.252	0.192	Rejected
H2	Carbon Emission Recognition (X2)	2.415	0.612	15.572	11.190	< 0.001	Accepted

H3	Carbon Emission Recording (X3)	1.843	0.594	9.629	6.315	0.002	Accepted
H4	Carbon Emission Disclosure (X4)	3.106	1.264	6.038	22.331	0.014	Accepted
Model-Fit Indices:							
Omnibus Test Chi-Square		54.321	-	-	-	< 0.001	-
Nagelkerke R Square		0.584	-	-	-	-	-

Table 8 presents the inferential statistical evidence utilized to evaluate hypotheses H1 through H4 based on the 96 firm-year observations. Based on the regression parameters presented in Table 8, Carbon Emission Measurement has a coefficient of 0.812 and a significance value of 0.192, which exceeds the standard alpha threshold of 0.05, resulting in the rejection of H1. Conversely, Carbon Emission Recognition exhibits a positive coefficient of 2.415 with a Wald statistic of 15.572 and a significance value of less than 0.001, meaning H2 is fully supported. Similarly, Carbon Emission Recording yields a positive coefficient of 1.843, a Wald statistic of 9.629, and a significance value of 0.002, which provides empirical validation to support H3. Finally, Carbon Emission Disclosure exerts a strong positive influence with a coefficient of 3.106, an Exp(B) value of 22.331, and a significance value of 0.014, leading to the clear acceptance of H4.

DISCUSSION

The Effect of Carbon Emission Measurement on the Implementation of Carbon Accounting

The results of the logistic regression analysis indicate that carbon emission measurement does not have a significant effect on the implementation of carbon accounting. This finding is reflected in the significance value of 0.192, which is greater than the threshold of 0.05, indicating that the first hypothesis is rejected. These results suggest that although many companies have begun to measure their carbon emissions, such activities have not been fully integrated into corporate carbon accounting practices. One possible explanation is that emission measurement is often conducted primarily as a technical environmental activity rather than as part of a structured accounting system. In many companies, emission measurement is carried out to comply with environmental monitoring requirements rather than to support financial reporting or sustainability reporting frameworks. Consequently, the measurement process does not automatically translate into formal carbon accounting implementation.

This finding is consistent with the study by Alfianda et al. (2024), which found that corporate policies and regulatory pressure play a more significant role than emission measurement alone in driving carbon accounting practices. When organizations do not have explicit policies requiring the recognition and reporting of carbon emissions in financial statements or sustainability reports, emission measurement may remain a stand-alone environmental activity rather than a component of accounting systems. Furthermore, the absence of standardized measurement frameworks may also contribute to the lack of integration between emission measurement and carbon accounting practices. Variations in emission measurement methodologies can lead to inconsistencies across firms, making it difficult to incorporate emission data into financial reporting structures. Husnatarina (2024) argues that the lack of uniform measurement standards often creates discrepancies in carbon accounting implementation among firms.

However, the results of this study contrast with theoretical perspectives emphasizing the importance of emission measurement as the first step in carbon accounting. Recent green-accounting evidence suggests that accurate carbon measurement becomes decision-relevant only when it is embedded in structured reporting systems and carbon-accounting implementation practices (Alfianda et al., 2024; Saragih, 2024). Without reliable measurement, the accounting treatment of emissions cannot be implemented effectively. International frameworks such as the GHG Protocol also emphasize the importance of emission measurement. The GHG Protocol classifies emissions into Scope 1, Scope 2, and Scope 3 categories, which provide a standardized basis for measuring and reporting corporate carbon emissions (Deswal & Deswal, 2025). Other measurement tools such as the National Carbon Accounting System (NCAS), National Carbon Accounting Toolbox (CAT), and carbon footprint calculators are also used to quantify emissions systematically.

Despite the availability of these frameworks, the results of this study suggest that emission measurement alone is insufficient to drive the implementation of carbon accounting, particularly in developing countries such as Indonesia where binding carbon accounting regulations are still evolving. This finding aligns with recent green-accounting evidence that emission measurement does not by itself lead to carbon accounting adoption unless it is embedded in structured reporting systems and governance support (Maulana & Prasetio, 2025).

The Effect of Carbon Emission Recognition on the Implementation of Carbon Accounting

The empirical results demonstrate that carbon emission recognition significantly influences the implementation of carbon accounting. The statistical results show a Wald value of 11.557 with a significance level below 0.001, indicating strong support for the second hypothesis. This finding suggests that companies that formally recognize carbon emissions within their reporting systems are more likely to implement carbon accounting practices effectively. Carbon emission recognition involves identifying, measuring, and acknowledging greenhouse gas emissions as part of corporate reporting processes, either within financial statements or sustainability reports. According to Syam et al. (2024), carbon emission recognition ensures that environmental information becomes verifiable and comparable across organizations, thereby improving the credibility of environmental reporting.

The integration of carbon-related information into corporate reporting systems is fundamentally anchored in local financial accounting standards, specifically PSAK 137 and PSAK 138. PSAK 137 regarding Provisions, Contingent Liabilities, and Contingent Assets serves as the definitive reference for recognizing carbon liabilities, where energy firms generating emissions beyond government-mandated caps or facing legal environmental restoration duties must formally recognize these current obligations as environmental provisions or liabilities in their balance sheets once the mitigation costs can be reliably estimated. Concurrently, PSAK 138 regarding Intangible Assets provides the accounting foundation for capitalizing carbon assets, such as tradable emission allowances or greenhouse gas reduction certificates, by classifying these non-monetary items without physical substance as intangible assets given their controlled nature and clear future economic benefits. Moreover, Ratnatunga and Balachandran (2009) explain that carbon emission recognition is closely linked to corporate compliance with environmental regulations. Firms participating in carbon trading mechanisms such as cap-and-trade systems or REDD+ schemes are required to recognize emission allowances as assets or liabilities within their financial statements using these structural accounting guidelines.

In the Indonesian context, regulatory frameworks such as Presidential Regulation No. 98 of 2021 on Carbon Economic Value and the Ministry of Environment Regulation No. 21 of 2022 have strengthened the requirement for transparent emission reporting. These policies encourage companies to formally recognize carbon emissions, thereby facilitating the implementation of carbon accounting practices. Luo et al. (2023) also argue that emission recognition contributes to greater consistency in emission measurement and reporting. The use of international standards such as the GHG Protocol and ISO 14064 provides companies with methodological guidance for calculating emissions accurately and consistently. Furthermore, transparent recognition of carbon emissions may enhance investor confidence and reduce regulatory risk. Recent evidence also shows that ESG disclosure is associated with firm value, suggesting that clearer environmental reporting can strengthen stakeholder confidence and market evaluation (Avinda et al., 2025). Therefore, the results of this study indicate that emission recognition plays a crucial role in supporting carbon accounting implementation by ensuring that emission-related information is formally integrated into corporate reporting systems.

The Effect of Carbon Emission Recording on the Implementation of Carbon Accounting

The findings also indicate that carbon emission recording has a significant positive effect on the implementation of carbon accounting. The statistical results show a significance value of 0.002, which is below the 0.05 threshold, confirming the acceptance of the third hypothesis. Carbon emission recording refers to the systematic documentation of greenhouse gas emissions within corporate reporting systems. Recording emissions allows companies to maintain consistent environmental data that can be verified and compared across reporting periods. According to Burrit et al. (2023), proper recording of emissions ensures that environmental information becomes part of corporate accounting records, thereby improving transparency and accountability in sustainability reporting. The use of accounting standards such as PSAK 137 and PSAK 138 provides guidelines for recognizing carbon-related assets, liabilities, and expenses.

Guenther et al. (2016) also highlight that emission recording plays an important role in ensuring corporate compliance with environmental regulations. Companies participating in carbon markets must record emission allowances and carbon liabilities within their financial statements. International reporting frameworks such as the GHG Protocol and GRI 305 provide standardized methodologies for emission recording and reporting, especially when firms integrate them into formal reporting routines and green-accounting practices (Maulana & Prasetio, 2025). Nevertheless, some studies suggest that emission recording does not always translate into comprehensive carbon accounting implementation.

The Effect of Carbon Emission Disclosure on the Implementation of Carbon Accounting

The results of this study further demonstrate that carbon emission disclosure significantly influences the implementation of carbon accounting. The significance value of 0.014 confirms the acceptance of the fourth hypothesis. Carbon emission disclosure plays an important role in improving corporate transparency and accountability. Companies that disclose environmental information in sustainability reports demonstrate greater commitment to environmental responsibility and good corporate governance practices. Luo et al. (2023) argue that transparent carbon disclosure enhances corporate reputation and strengthens stakeholder trust. Recent energy-sector evidence suggests that green

accounting and sustainability reporting become more value-relevant when they are tied to governance and firm-value mechanisms (Maulana & Prasetio, 2025).

International reporting frameworks such as the Global Reporting Initiative (GRI) Standards and the GHG Protocol provide widely accepted guidelines for emission disclosure. These frameworks encourage companies to report emission data in a structured and comparable manner. Regulatory support also plays a significant role in promoting emission disclosure. In Indonesia, policies such as Presidential Regulation No. 98 of 2021 on Carbon Economic Value and Financial Services Authority Regulation No. 51/POJK.03/2017 on Sustainable Finance encourage companies to disclose environmental information transparently.

Clarkson et al. (2008) suggest that companies that actively disclose carbon emissions tend to develop more mature environmental accounting systems and experience stronger investor confidence. However, several studies highlight potential limitations of emission disclosure practices. Recent Indonesian energy-sector evidence likewise indicates that carbon emissions disclosure is still uneven and depends on firm-level environmental performance and organizational readiness (Saputri et al., 2023). Guenther et al. (2016) further argue that without strict regulatory enforcement, emission disclosure may remain symbolic rather than substantive. Despite these concerns, the results of this study confirm that higher levels of carbon emission disclosure are associated with stronger implementation of carbon accounting systems. This finding is consistent with recent Indonesian energy-sector evidence showing that carbon emissions disclosure is linked to company size and environmental performance, which supports stronger carbon accounting implementation (Saputri et al., 2023).

Implications

Theoretical Implications

This study contributes to environmental accounting literature by providing empirical evidence on the relationship between carbon management and carbon accounting implementation within Indonesian energy companies. The findings demonstrate that formal accounting treatments, namely recognition, recording, and disclosure, are more critical for successful system integration than technical measurement activities alone. This supports environmental accounting theory by establishing that climate-related data only become institutionally meaningful when systematically processed through corporate books. Furthermore, the insignificant effect of measurement extends the literature by highlighting how technical quantification remains decoupled from formal reporting in developing economies where carbon regulations are still evolving. Finally, the positive impacts of recognition, recording, and disclosure reinforce legitimacy and stakeholder theories, proving that energy firms institutionalize these accounting procedures to reduce information asymmetry, satisfy external pressures, and demonstrate accountability toward stakeholders.

Practical Implications

Practically, these findings suggest that managers of Indonesian energy companies must move beyond technical emission tracking and focus on formally integrating carbon data into financial and sustainability reports through standardized accounting procedures. Corporate governance should establish clear internal guidelines for capitalizing carbon assets and provisioning climate liabilities to enhance report reliability. For regulators and policymakers, the results emphasize the urgent need to mandate clear, unified carbon accounting standards to transition technical compliance into verifiable environmental reporting across the energy sector. Ultimately, improving these structural accounting and

disclosure practices enables companies to mitigate regulatory risks, secure green financing opportunities, and foster long-term stakeholder trust.

CONCLUSION

This study examines the influence of carbon emission measurement, recognition, recording, and disclosure on the implementation of carbon accounting specifically within Indonesian energy companies. The empirical findings indicate that carbon emission recognition, recording, and disclosure have a significant positive effect on the implementation of carbon accounting, while carbon emission measurement does not significantly influence carbon accounting implementation within these observed Indonesian energy firms. The results suggest that the integration of carbon emissions into formal accounting processes plays a crucial role in supporting corporate carbon accounting practices across the Indonesian energy sector. Recognition and recording processes enable Indonesian energy companies to systematically incorporate emission information into their financial reporting systems, while disclosure enhances transparency and accountability to their corporate stakeholders.

However, the insignificant effect of emission measurement indicates that technical measurement activities alone are insufficient to promote comprehensive carbon accounting implementation within Indonesian energy companies. Without mandatory local regulatory requirements, standardized accounting frameworks, and strong corporate governance mechanisms, emission measurement may remain a purely engineering-based activity that is disconnected from the actual corporate reporting practices of Indonesian energy firms. Overall, the findings highlight the critical importance of domestic regulatory support, corporate environmental policies, and standardized reporting frameworks in promoting the effective implementation of carbon accounting among Indonesian energy companies. By strengthening these institutional aspects, Indonesian energy companies can significantly improve environmental transparency, enhance stakeholder trust, and contribute to the nation's broader sustainability and climate mitigation goals.

LIMITATION

Despite providing valuable insights into environmental reporting, this study has several inherent limitations related to its specific research design that should be acknowledged. First, the empirical evaluation is constrained by a relatively short observation period covering only the years 2021 to 2023. This tight timeframe may not fully capture the long-term structural transitions of corporate environmental practices or the evolutionary impacts of newly introduced climate regulations in Indonesia. Second, this research maintains a sector-specific focus by observing only energy sector companies listed on the IDX. Because different industries operate under varying levels of environmental regulations and stakeholder pressures, the findings may lack generalizability when applied to non-energy or low-emission corporate sectors.

Third, the methodology relies exclusively on secondary data extracted from public annual reports and corporate sustainability reports. This reliance on public documentation means the analysis might not fully capture internal, unpublicized managerial processes, as some energy firms may execute internal carbon management activities without formally presenting them in public reports. Fourth, the econometric model is subject to potential omitted variable bias, as it examines a limited number of accounting variables while excluding other critical institutional determinants such as board governance structures, explicit corporate environmental strategies, and specific government incentive parameters that could heavily influence system adoption.

Finally, from a statistical standpoint, this study utilizes pooled logistic regression analysis to evaluate the 96 firm-year observations. The use of pooled cross-sectional techniques across multiple time periods fails to isolate time-invariant, firm-specific unobserved heterogeneity, which may introduce statistical limitations regarding residual independence. Future investigations should address these limitations by expanding the longitudinal observation window, introducing mixed-method primary data collections, incorporating corporate governance variables, and applying advanced panel data modeling techniques across diverse industrial sectors.

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DECLARATION OF CONFLICTING INTERESTS
The authors declare that there are no potential conflicts of interest regarding the research, authorship, and publication of this article. The research was conducted independently without any financial, commercial, or personal relationships that could influence the objectivity and integrity of the study.

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