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The Impact of Participation in Carbon Trading and Carbon Management Strategies on Emissions Reduction Performance and Financial Performance at Energy Companies in Indonesia

Ari Purwanti[1], Junet Kaswoto[2], Dahlia Tri Anggraini[3], Dini Hadiati Putri Kinasih[4], Selfy Andreany[5], Eko Sudarmanto[6]
[1] Universitas Gunadarma
[2] Fakultas Ekonomi dan Bisnis, Universitas Muhammadiyah Tangerang
[3,4] Universitas Muhammadiyah Jakarta
[5] BAPPEDA Kab. Tangerang
[6] Universitas Muhammadiyah Tangerang

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ABSTRACT

This study examines the effects of participation in carbon trading and carbon management strategies on emissions reduction performance and financial performance in energy companies in Indonesia. A quantitative research design was employed using primary data collected from 55 respondents through structured questionnaires measured on a five-point Likert scale. The respondents consisted of managers, supervisors, sustainability officers, finance managers, and executives with knowledge of environmental and carbon management practices. Data were analyzed using Structural Equation Modeling–Partial Least Squares with SmartPLS 3. The results indicate that participation in carbon trading has a positive and significant effect on emissions reduction performance and financial performance. Carbon management strategy also positively and significantly affects emissions reduction performance and financial performance. Furthermore, emissions reduction performance has a positive and significant effect on financial performance. The model explains 65.1% of the variance in emissions reduction performance and 70.3% of the variance in financial performance. These findings demonstrate that internal carbon management capabilities have a stronger influence on emissions reduction than participation in carbon trading alone. They also confirm that improved environmental performance can generate economic benefits through operational efficiency, reduced regulatory risk, enhanced reputation, and stronger stakeholder confidence. The study highlights the importance of integrating carbon trading participation with comprehensive carbon management strategies to support the transition of Indonesia's energy sector toward low-carbon and financially sustainable operations.

Corresponding Author:

Name: Ari Purwanti
Institution: Universitas Gunadarma
Email: aripurwanti@staff.gunadarma.ac.id

1. INTRODUCTION

Climate change has become one of the most pressing global challenges affecting environmental sustainability, economic development, and corporate governance. The continued increase in greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), has accelerated global warming and intensified environmental risks, including extreme weather events, biodiversity loss, ecosystem degradation, and economic disruption. The energy sector remains the largest contributor to global carbon emissions, accounting for nearly three-quarters of total GHG emissions, making it a primary focus of international climate mitigation policies [1], [2]. Consequently, governments, regulators, investors, and international organizations increasingly encourage corporations to incorporate climate-related strategies into their business operations while simultaneously maintaining long-term financial resilience. Market-based mechanisms such as carbon trading have emerged as one of the most prominent policy instruments for achieving emission reduction targets because they create economic incentives for firms to reduce emissions through technological innovation and operational efficiency rather than relying solely on traditional command-and-control regulations [3], [4].

Beyond participation in carbon markets, corporations have increasingly recognized that effective carbon management constitutes a strategic organizational capability rather than merely a regulatory compliance activity. Carbon management encompasses systematic processes of measuring, monitoring, reporting, reducing, and continuously improving carbon emissions throughout organizational operations [5], [6]. These practices enable firms to optimize resource utilization, improve production efficiency, strengthen environmental transparency, and reduce climate-related risks. From the perspective of the Natural Resource-Based View (NRBV), environmental capabilities such as carbon management represent valuable, rare, and difficult-to-imitate strategic resources capable of generating sustainable competitive advantage. Simultaneously, Stakeholder Theory suggests that increasing pressure from regulators, investors, customers, and society encourages companies to demonstrate stronger environmental responsibility through both internal management practices and external participation in carbon markets [7], [8]. Consequently, environmental initiatives are increasingly viewed as strategic investments capable of improving both environmental and financial performance rather than merely increasing operational costs.

Despite the growing importance of carbon-related strategies, previous empirical findings remain inconclusive regarding their effectiveness in enhancing corporate performance. Several studies report that carbon trading participation significantly improves environmental performance by encouraging technological innovation and cleaner production, whereas others argue that carbon markets produce limited benefits when carbon prices remain relatively low or when firms participate only to satisfy regulatory requirements [9], [10]. Likewise, while carbon management has consistently demonstrated positive associations with operational efficiency and environmental performance, evidence regarding its contribution to financial performance remains mixed because substantial investments in environmental management may delay financial returns. These inconsistent findings indicate that the relationship between carbon-related strategies and organizational outcomes remains insufficiently understood and warrants further investigation [11], [12].

Another important limitation of the existing literature concerns the fragmented examination of carbon trading and carbon management. Most previous studies investigate these variables independently, emphasizing either external market mechanisms or internal environmental management practices without considering their complementary relationship.

Consequently, limited empirical evidence explains how participation in carbon trading and effective carbon management jointly influence both emissions reduction performance and financial performance within an integrated research framework [13], [14]. Furthermore, this limitation is particularly evident in developing economies where environmental governance systems, corporate sustainability practices, and carbon markets continue to evolve. As a result, the interaction between external environmental policies and internal organizational capabilities remains underexplored in sustainability accounting and environmental management research [15], [16].

Indonesia provides an important empirical setting for addressing these research gaps because it is among the world's largest greenhouse gas emitters while simultaneously experiencing rapid industrialization and increasing energy demand. The Indonesian government has committed to achieving Net Zero Emissions by 2060 or earlier through various climate policies, including the implementation of carbon economic value regulations, mandatory greenhouse gas reporting, and the operationalization of the Indonesia Carbon Exchange. Nevertheless, corporate participation in carbon trading remains relatively limited, while the implementation of carbon management practices differs substantially across organizations due to variations in technological readiness, managerial commitment, organizational capability, and financial resources [17]. These differences raise important questions regarding whether participation in carbon trading alone is sufficient to improve corporate performance or whether comprehensive carbon management capabilities are required to translate climate initiatives into measurable environmental and financial outcomes.

Against this background, the present study develops an integrated framework combining carbon trading participation and carbon management strategies to explain organizational performance among energy companies in Indonesia. Specifically, this research examines the direct effects of carbon trading participation and carbon management on emissions reduction performance and financial performance, while also investigating the contribution of emissions reduction performance to corporate financial outcomes. By integrating external market-based environmental policies with internal organizational capabilities, this study extends the sustainability accounting literature and contributes empirical evidence from an emerging carbon market. The findings are expected to provide practical implications for policymakers, regulators, and corporate managers seeking to accelerate Indonesia's transition toward a competitive low-carbon economy while maintaining corporate financial sustainability.

2. LITERATURE REVIEW

2.1 Natural Resource-Based View (NRBV)

The Natural Resource-Based View (NRBV), developed by Hart (1995), extends the Resource-Based View by positioning environmental capabilities as strategic resources that can generate sustainable competitive advantage. Through pollution prevention, carbon monitoring, energy efficiency, low-carbon technologies, carbon accounting, renewable energy adoption, and organizational learning, firms can reduce emissions, improve resource efficiency, minimize environmental risks, and strengthen stakeholder confidence [18], [19]. NRBV also explains carbon trading participation because firms with stronger carbon management capabilities are better able to meet emission targets, generate surplus allowances, and transform environmental

performance into economic value. Therefore, NRBV provides a relevant theoretical foundation for explaining the effects of carbon trading participation and carbon management strategies on emissions reduction and financial performance.

2.2 *Stakeholder Theory*

Stakeholder Theory, introduced by Freeman (1984), argues that organizational success depends on the ability to address the interests of multiple stakeholders, including regulators, investors, customers, employees, financial institutions, communities, and environmental organizations. Growing demands for climate accountability, ESG performance, transparent reporting, and environmentally responsible business practices encourage firms to participate in carbon trading and implement comprehensive carbon management strategies [7], [8]. These initiatives demonstrate regulatory compliance, managerial commitment, measurable emissions reduction, and organizational accountability. By meeting stakeholder expectations, firms can strengthen legitimacy and reputation, reduce regulatory uncertainty, enhance investor confidence, and improve financial performance [7], [20]. Therefore, Stakeholder Theory complements NRBV by explaining the external pressures that motivate companies to adopt carbon-related strategies.

2.3 *Participation in Carbon Trading*

Carbon trading is a market-based mechanism that assigns economic value to greenhouse gas emissions by allowing firms operating below their emission limits to sell surplus allowances, while firms exceeding their quotas must purchase additional allowances or reduce emissions. This mechanism provides greater flexibility and cost efficiency than command-and-control regulation by encouraging technological innovation, cleaner production, renewable energy adoption, and operational improvements [5], [6]. Participation also requires reliable emissions inventories, continuous monitoring, carbon accounting, and effective environmental governance. Accordingly, carbon trading can improve emissions performance, reduce compliance costs, strengthen corporate reputation, enhance competitiveness, and create revenue through carbon credit sales [21], [22]. In this study, carbon trading participation refers to the extent to which energy companies engage in carbon markets, comply with relevant regulations, incorporate carbon pricing into business decisions, and use trading mechanisms as part of their environmental strategy.

2.4 *Carbon Management Strategy*

Carbon management strategy refers to an integrated organizational approach for measuring, monitoring, controlling, reporting, and continuously reducing greenhouse gas emissions across business operations. It incorporates carbon accounting, emissions reduction planning, energy efficiency, low-carbon technology investment, renewable energy use, supply

chain management, employee engagement, climate risk management, and transparent disclosure into corporate governance and strategic decision-making [13], [14]. Effective carbon management enables firms to identify operational inefficiencies, reduce energy consumption and production costs, optimize resource utilization, mitigate regulatory risks, and strengthen organizational resilience. It can also improve environmental and financial performance through lower emissions, enhanced reputation, stronger investor confidence, and improved ESG outcomes [16], [23]. In this study, carbon management strategy is defined as the internal organizational capability that translates climate commitments into measurable operational and performance improvements.

2.5 Emissions Reduction Performance

Emissions reduction performance refers to an organization's measurable effectiveness in lowering greenhouse gas emissions through operational improvements, technological innovation, energy efficiency, renewable energy adoption, and sustainable resource management. Organizations with strong emissions reduction performance typically establish clear reduction targets, continuously monitor emissions, adopt cleaner technologies, and integrate sustainability into operational decision-making [24], [25]. Beyond supporting environmental sustainability, improved emissions reduction can reduce energy consumption, increase operational efficiency, lower compliance costs, strengthen corporate reputation, and improve access to sustainable financing. Therefore, emissions reduction performance functions as both an environmental and strategic business indicator [14], [26]. In this study, it is defined as the measurable success of energy companies in reducing greenhouse gas emissions through the systematic implementation of carbon-related initiatives.

2.6 Financial Performance

Financial performance reflects an organization's ability to generate sustainable economic value through efficient resource utilization and is commonly assessed through profitability, operational efficiency, revenue growth, return on investment, cost efficiency, and long-term financial sustainability [27], [28]. In environmental management, financial performance also captures value created through sustainability initiatives, including lower energy and production costs, innovation, stronger reputation, increased customer loyalty, greater investor confidence, and reduced regulatory risk. Carbon trading participation may enhance financial outcomes through carbon credit revenues, lower compliance costs, and improved competitiveness, while carbon management strategies can reduce waste, optimize resources, and strengthen organizational resilience [21], [29]. Accordingly, this study defines financial performance as the perceived improvement in profitability,

operational efficiency, competitive advantage, and long-term economic sustainability resulting from carbon-related strategic initiatives.

2.7 *Conceptual Framework*

This study integrates the Natural Resource-Based View (NRBV) and Stakeholder Theory to explain how carbon trading participation and carbon management strategies influence organizational performance. NRBV positions environmental capabilities as strategic resources that can generate competitive advantage through operational efficiency, emissions control, and sustainability, while Stakeholder Theory explains how firms respond to environmental expectations from regulators, investors, customers, and society to strengthen legitimacy and financial outcomes. Within this framework, carbon trading participation represents an external market-based mechanism that provides economic incentives for emissions reduction, whereas carbon management strategy represents an internal organizational capability for planning, measuring, monitoring, controlling, and continuously improving carbon-related activities. Accordingly, carbon trading participation and carbon management strategy are positioned as exogenous variables, emissions reduction performance as an environmental outcome and mediating mechanism, and financial performance as the ultimate organizational outcome.

Carbon trading participation is expected to improve emissions reduction performance by encouraging firms to adopt cleaner technologies, increase energy efficiency, and continuously improve environmental operations. It may also enhance financial performance through lower compliance costs, carbon credit revenues, improved operational efficiency, and stronger corporate reputation. Similarly, comprehensive carbon management strategies are expected to improve emissions reduction performance through systematic emissions monitoring, reduction programs, energy optimization, and environmental governance, while also strengthening financial performance by reducing environmental risks, increasing stakeholder confidence, and enhancing long-term competitiveness. Furthermore, successful emissions reduction is expected to contribute to superior financial performance by lowering operating and regulatory costs, improving corporate reputation, and increasing investor confidence.

H1: Participation in carbon trading positively affects emissions reduction performance.

H2: Participation in carbon trading positively affects financial performance.

H3: Carbon management strategy positively affects emissions reduction performance.

H4: Carbon management strategy positively affects financial performance.

H5: Emissions reduction performance positively affects financial performance.

3. METHODS

3.1 Research Design

This study employed a quantitative explanatory approach to examine the relationships among carbon trading participation, carbon management strategy, emissions reduction performance, and financial performance in Indonesian energy companies. Data were collected through a cross-sectional survey using structured questionnaires, enabling the objective measurement of latent constructs and statistical testing of direct relationships among the variables. The proposed model was analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with SmartPLS 3 because this method supports predictive analysis, accommodates relatively small samples, does not require strict multivariate normality, and enables simultaneous assessment of the measurement and structural models.

3.2 Population and Sample

The population comprised energy companies operating in Indonesia that had implemented environmental sustainability initiatives, greenhouse gas management practices, or carbon-related programs, including firms engaged in electricity generation, oil and gas, coal mining, renewable energy, and other carbon-intensive energy industries. Respondents were selected using purposive sampling based on four criteria: the company operated in Indonesia's energy sector, had implemented environmental or sustainability programs, and the respondent possessed relevant knowledge of environmental management, sustainability, carbon emissions, or corporate strategy while holding a managerial, supervisory, sustainability, environmental, finance, or executive position. Based on these criteria, 55 valid responses were included in the final analysis, which was considered adequate for exploratory and predictive SEM-PLS analysis.

3.3 Data Collection Technique

Primary data were collected through a structured questionnaire developed from previously validated measurement scales in the sustainability management, environmental accounting, carbon management, and corporate performance literature. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), and respondents were asked to assess each statement based on their company's current practices and organizational conditions. Before distribution, the questionnaire underwent content evaluation to ensure clarity, relevance, and consistency with the research constructs, after which it was administered to eligible respondents through electronic and direct survey methods.

3.4 Operational Definition of Variables

This study comprises two exogenous variables—Participation in Carbon Trading (PCT) and Carbon Management Strategy (CMS)—one mediating endogenous variable, Emissions Reduction Performance (ERP), and one final endogenous variable, Financial Performance (FP). PCT measures the extent to which companies engage in carbon credit transactions, comply with carbon market regulations, integrate carbon pricing into business decisions, demonstrate commitment to carbon market participation, and use carbon trading as an emissions reduction strategy. CMS reflects organizational practices for measuring, planning, monitoring, reporting, and continuously reducing emissions through energy efficiency, low-carbon technology, and employee involvement. ERP captures the achievement of emissions reduction targets, lower carbon emissions, improved energy efficiency, greater use of clean technologies, and continuous environmental improvement,

while FP measures perceived improvements in profitability, cost efficiency, revenue growth, competitive advantage, and long-term financial sustainability. All constructs were measured reflectively using multiple indicators adapted from prior sustainability accounting, environmental management, carbon accounting, and corporate performance studies, with minor wording adjustments to ensure relevance to Indonesia's energy sector.

3.5 Data Analysis Technique

Data were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with SmartPLS 3 because this method is prediction-oriented, suitable for relatively small samples, capable of simultaneously examining complex causal relationships, and robust to non-normal data. The analysis involved evaluating the measurement and structural models. The measurement model was assessed using outer loadings of at least 0.70, although indicators between 0.60 and 0.70 could be retained when construct reliability remained adequate, Cronbach's alpha and composite reliability values of at least 0.70, an Average Variance Extracted (AVE) value of at least 0.50, and discriminant validity based on the Fornell–Larcker criterion, cross-loadings, and an HTMT ratio below 0.90. After reliability and validity were established, the structural model was evaluated using the coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), Standardized Root Mean Square Residual (SRMR), path coefficients, and bootstrapping with 5,000 subsamples. Hypotheses were considered statistically significant when the t-value exceeded 1.96 and the p-value was below 0.05 at the 95% confidence level.

4. RESULTS AND DISCUSSION

4.1 Respondent Profile

A total of 55 valid questionnaires were collected from respondents representing energy companies operating in Indonesia. The respondents consisted of managers, sustainability officers, environmental specialists, finance managers, operational managers, and senior executives who possessed sufficient knowledge regarding carbon management practices and corporate sustainability strategies.

Table 1. Respondent Characteristics

Characteristics	Category	Frequency	Percentage (%)
Gender	Male	37	67.3
	Female	18	32.7
Age	<30 Years	9	16.4
	30–39 Years	19	34.5
	40–49 Years	17	30.9
	≥50 Years	10	18.2
Education	Bachelor's Degree	31	56.4
	Master's Degree	21	38.2
	Doctorate	3	5.4
Position	Manager	23	41.8
	Supervisor	11	20.0
	Sustainability Officer	8	14.5
	Finance Manager	6	10.9
	Executive	7	12.8
Working Experience	1–5 Years	10	18.2
	6–10 Years	17	30.9
	11–15 Years	15	27.3
	>15 Years	13	23.6

The respondent profile shows that most participants were male (67.3%), while female respondents accounted for 32.7%. The largest age group was 30–39 years (34.5%), followed by 40–49 years (30.9%), respondents aged 50 years or older (18.2%), and those below 30 years (16.4%). Most respondents held a bachelor's degree (56.4%), followed by a master's degree (38.2%) and a doctorate (5.4%). In terms of position, managers represented the largest group (41.8%), followed by supervisors (20.0%), sustainability officers (14.5%), executives (12.8%), and finance managers (10.9%). Regarding work experience, 30.9% had 6–10 years of experience, 27.3% had 11–15 years, 23.6% had more than 15 years, and 18.2% had 1–5 years, indicating that most respondents possessed substantial professional experience relevant to the study.

4.2 Descriptive Statistics

Table 2. Descriptive Statistics

Variable	Mean	Standard Deviation	Min	Max
Participation in Carbon Trading	3.97	0.61	2.40	5.00
Carbon Management Strategy	4.15	0.54	2.90	5.00
Emissions Reduction Performance	4.08	0.58	2.80	5.00
Financial Performance	3.94	0.63	2.50	5.00

Table 2 presents the descriptive statistics for the study variables. Overall, all variables exhibit relatively high mean scores, ranging from 3.94 to 4.15 on a five-point Likert scale, indicating that respondents generally agreed with statements related to carbon trading participation, carbon management strategy, emissions reduction performance, and financial performance. Carbon Management Strategy recorded the highest mean (M = 4.15; SD = 0.54), suggesting that the sampled energy companies have broadly implemented systematic carbon management practices. This was followed by Emissions Reduction Performance (M = 4.08; SD = 0.58), Participation in Carbon Trading (M = 3.97; SD = 0.61), and Financial Performance (M = 3.94; SD = 0.63). The relatively low standard deviation values (0.54–0.63) indicate limited variability in responses, reflecting a relatively consistent perception among respondents. Furthermore, the observed minimum and maximum values demonstrate sufficient variation across respondents while remaining within the expected measurement range, supporting the suitability of the data for subsequent SEM-PLS analysis.

4.3 Measurement Model Evaluation (Outer Model)

4.3.1 Convergent Validity

Table 3. Outer Loadings

Variable	Indicator	Loading
Participation in Carbon Trading	PCT1	0.845
	PCT2	0.871
	PCT3	0.884
	PCT4	0.838
	PCT5	0.857
Carbon Management Strategy	CMS1	0.842
	CMS2	0.889
	CMS3	0.876
	CMS4	0.903
	CMS5	0.852
	CMS6	0.871
	CMS7	0.846
Emissions Reduction Performance	ERP1	0.872
	ERP2	0.891

	ERP3	0.914
	ERP4	0.862
	ERP5	0.885
Financial Performance	FP1	0.861
	FP2	0.887
	FP3	0.904
	FP4	0.869
	FP5	0.882

Table 3 presents the outer loading values for all measurement indicators. The results show that all indicators have loading values ranging from 0.838 to 0.914, exceeding the recommended threshold of 0.70. Specifically, the Participation in Carbon Trading construct has loadings between 0.838 and 0.884, Carbon Management Strategy between 0.842 and 0.903, Emissions Reduction Performance between 0.862 and 0.914, and Financial Performance between 0.861 and 0.904. These findings indicate that each indicator exhibits a strong correlation with its respective latent construct, confirming satisfactory indicator reliability and convergent validity. Therefore, all indicators were retained for subsequent structural model analysis, as they adequately represent their underlying constructs.

4.3.2 Construct Reliability

Table 4. Reliability and Convergent Validity

Variable	Cronbach's Alpha	Composite Reliability	AVE
Participation in Carbon Trading	0.911	0.934	0.739
Carbon Management Strategy	0.948	0.956	0.756
Emissions Reduction Performance	0.927	0.945	0.775
Financial Performance	0.925	0.944	0.771

Table 4 demonstrates that all constructs satisfy the recommended reliability and convergent validity criteria. Cronbach's alpha values range from 0.911 to 0.948, while composite reliability values range from 0.934 to 0.956, exceeding the minimum threshold of 0.70 and indicating strong internal consistency. In addition, the Average Variance Extracted values range from 0.739 to 0.775, which are well above the recommended threshold of 0.50. These results confirm that Participation in Carbon Trading, Carbon Management Strategy, Emissions Reduction Performance, and Financial Performance are measured reliably and explain a substantial proportion of the variance in their respective indicators. Therefore, the measurement model demonstrates satisfactory internal consistency reliability and convergent validity.

4.3.3 Discriminant Validity

Table 5. Fornell–Larcker Criterion

Variable	PCT	CMS	ERP	FP
Participation in Carbon Trading	0.860			
Carbon Management Strategy	0.604	0.869		
Emissions Reduction Performance	0.638	0.728	0.880	
Financial Performance	0.593	0.675	0.746	0.878

Table 5 confirms adequate discriminant validity based on the Fornell–Larcker criterion, as the square root of the Average Variance Extracted for each construct, represented by the diagonal values, exceeds its correlations with the other constructs. Specifically, the diagonal values for Participation in Carbon Trading (0.860),

Carbon Management Strategy (0.869), Emissions Reduction Performance (0.880), and Financial Performance (0.878) are higher than all corresponding inter-construct correlations. Although the relationship between Emissions Reduction Performance and Financial Performance is relatively strong (r = 0.746), it remains below the square root of the AVE for both constructs. Therefore, each construct is empirically distinct and measures a concept different from the other variables in the model.

4.4 Structural Model Evaluation (Inner Model)

4.4.1 Coefficient of Determination (R^2)

The coefficient of determination results indicate that the structural model has substantial explanatory power. Participation in Carbon Trading and Carbon Management Strategy jointly explain 65.1% of the variance in Emissions Reduction Performance (R^2 = 0.651), indicating a moderate-to-strong level of explanation, while the predictors of Financial Performance explain 70.3% of its variance (R^2 = 0.703), reflecting strong explanatory power. The remaining 34.9% of the variance in Emissions Reduction Performance and 29.7% of the variance in Financial Performance are attributable to factors outside the proposed model.

4.4.2 Effect Size (f^2)

Table 6. Effect Size

Relationship	f^2	Effect
PCT → ERP	0.192	Medium
CMS → ERP	0.347	Large
PCT → FP	0.126	Small
CMS → FP	0.234	Medium
ERP → FP	0.381	Large

Table 6 shows that the effect sizes of the relationships in the structural model vary from small to large. Participation in Carbon Trading has a medium effect on Emissions Reduction Performance (f^2 = 0.192) but only a small effect on Financial Performance (f^2 = 0.126), indicating that its contribution is stronger for environmental outcomes than for direct financial gains. Carbon Management Strategy has a large effect on Emissions Reduction Performance (f^2 = 0.347) and a medium effect on Financial Performance (f^2 = 0.234), demonstrating the strategic importance of internal carbon management capabilities. Meanwhile, Emissions Reduction Performance has the largest effect on Financial Performance (f^2 = 0.381), suggesting that successful emissions reduction is a major mechanism through which carbon-related initiatives generate financial benefits.

4.4.3 Predictive Relevance

The predictive relevance results indicate that the proposed structural model has satisfactory predictive capability. The Q^2 value for Emissions Reduction Performance is 0.442, while Financial Performance records a Q^2 value of 0.506, with both values exceeding the recommended threshold of zero. These findings demonstrate that the model possesses adequate predictive relevance, indicating that Participation in Carbon Trading and Carbon Management Strategy are capable of predicting Emissions Reduction Performance, which in turn contributes to predicting Financial Performance. Overall, the results confirm that the model has strong predictive accuracy and is suitable for explaining the environmental and financial outcomes of energy companies in Indonesia.

4.4.4 Model Fit

Table 7. Model Fit

Index	Value	Threshold	Result
SRMR	0.061	<0.08	Good Fit

NFI	0.921	>0.90	Good Fit

Table 7 indicates that the structural model demonstrates an acceptable overall fit. The Standardized Root Mean Square Residual (SRMR) value of 0.061 is below the recommended threshold of 0.08, indicating a relatively small discrepancy between the observed and model-implied correlation matrices. Similarly, the Normed Fit Index (NFI) value of 0.921 exceeds the minimum criterion of 0.90, confirming that the proposed model fits the empirical data adequately. Therefore, both indices support the conclusion that the model has a good fit and is appropriate for subsequent interpretation of the structural relationships.

4.5 Hypothesis Testing

Table 8. Path Coefficients

Hypothesis	Relationship	β	t-value	p-value	Decision
H1	PCT → ERP	0.334	3.124	0.002	Supported
H2	PCT → FP	0.229	2.185	0.029	Supported
H3	CMS → ERP	0.527	5.764	<0.001	Supported
H4	CMS → FP	0.301	2.967	0.003	Supported
H5	ERP → FP	0.472	4.651	<0.001	Supported

Table 8 shows that all proposed hypotheses are statistically supported. Participation in Carbon Trading has a positive and significant effect on Emissions Reduction Performance ($\beta = 0.334$, $t = 3.124$, $p = 0.002$) and Financial Performance ($\beta = 0.229$, $t = 2.185$, $p = 0.029$), indicating that carbon market engagement contributes to both environmental and financial outcomes. Carbon Management Strategy also positively affects Emissions Reduction Performance ($\beta = 0.527$, $t = 5.764$, $p < 0.001$) and Financial Performance ($\beta = 0.301$, $t = 2.967$, $p = 0.003$), with its strongest influence observed on emissions reduction. Furthermore, Emissions Reduction Performance has a positive and significant effect on Financial Performance ($\beta = 0.472$, $t = 4.651$, $p < 0.001$), confirming that improved environmental performance contributes to superior financial outcomes.

Discussion

The findings demonstrate that participation in carbon trading positively and significantly improves emissions reduction performance. Companies engaged in carbon markets are more likely to strengthen emissions monitoring, optimize production processes, and invest in cleaner technologies because carbon trading creates economic incentives to reduce emissions beyond minimum regulatory requirements. This result supports the Natural Resource-Based View (NRBV), which positions environmental capabilities as strategic resources that can enhance sustainability performance. It is also consistent with prior evidence that market-based environmental instruments encourage technological innovation, cleaner production, and greater environmental efficiency [18], [19].

Participation in carbon trading also has a positive and significant effect on financial performance, although its effect is relatively smaller than the effects of carbon management strategy and emissions reduction performance. This finding indicates that involvement in carbon markets can generate economic value through reduced compliance costs, improved operational efficiency, enhanced corporate reputation, and potential revenue from carbon credit transactions [5], [6]. Therefore, participation in carbon trading should not be viewed solely as a regulatory obligation, but also as a strategic mechanism that can support corporate competitiveness and long-term financial sustainability.

Carbon management strategy has the strongest effect on emissions reduction

performance, indicating that internal organizational capabilities are more influential than external market participation in achieving measurable emissions reductions. Companies that systematically measure, monitor, report, and control carbon emissions, implement energy-efficiency programs, and adopt low-carbon technologies are better positioned to achieve their environmental targets. This finding strongly supports the NRBV argument that well-developed environmental management capabilities enable firms to utilize resources more efficiently, reduce ecological impacts, and produce superior environmental outcomes that competitors may find difficult to replicate [13], [14].

The results further show that carbon management strategy positively influences financial performance. Effective carbon management enables organizations to reduce energy consumption, improve resource utilization, control environmental risks, and strengthen operational efficiency. At the same time, proactive environmental practices improve corporate legitimacy and stakeholder confidence among investors, regulators, customers, and financial institutions. This finding is consistent with Stakeholder Theory, which suggests that responding effectively to environmental expectations can strengthen organizational relationships, reduce uncertainty, and ultimately enhance financial outcomes [30], [31].

Finally, emissions reduction performance has the strongest direct effect on financial performance, confirming that environmental improvement can serve as an important mechanism for economic value creation. Companies that successfully reduce emissions are more likely to benefit from lower energy and operating costs, reduced regulatory exposure, stronger reputations, and greater investor confidence. Overall, the findings indicate that carbon management strategy is the primary driver of emissions reduction performance, while emissions reduction performance is the key pathway through which carbon-related initiatives improve financial outcomes. The study therefore contributes to sustainability accounting literature by showing that integrating carbon trading participation with strong internal carbon management capabilities can simultaneously strengthen environmental and financial performance in Indonesia's evolving energy sector.

5. CONCLUSION

This study concludes that participation in carbon trading and carbon management strategies significantly improve emissions reduction and financial performance among Indonesian energy companies. Carbon trading encourages stronger emissions monitoring, cleaner technology adoption, operational efficiency, and regulatory compliance, while also generating financial benefits, although these depend on carbon market maturity, pricing, transaction volume, and regulatory certainty. Carbon management strategy exerts the strongest influence on emissions reduction performance because systematic carbon measurement, reduction planning, energy efficiency, low-carbon technology adoption, and continuous evaluation enable firms to achieve meaningful environmental improvements. It also enhances financial performance through improved resource efficiency, lower operational and environmental costs, reduced climate-related risks, and stronger corporate reputation. Moreover, the positive effect of emissions reduction performance on financial performance confirms that environmental and economic objectives are complementary, as lower emissions can reduce energy consumption, improve production efficiency, strengthen investor confidence, and expand access to sustainable financing. These findings support the Natural Resource-Based View by demonstrating that carbon management capabilities constitute valuable strategic resources and support Stakeholder Theory by showing that proactive carbon practices strengthen corporate legitimacy and responsiveness. Therefore, Indonesian energy

companies should integrate carbon trading into a comprehensive carbon management framework, while policymakers should strengthen market governance, emissions reporting, verification mechanisms, carbon price certainty, and incentives for low-carbon investment.

REFERENCES

[1] J. Du, J. Cheng, and K. Ali, "Modelling the green logistics and financial innovation on carbon neutrality goal, a fresh insight for BRICS-T," *Geol. J.*, 2023, doi: 10.1002/gj.4732.

[2] X. Wang, L. Sun, H. K. Razzaq, and ..., "The dynamic role of ecological innovation and sustainable finance in improving green productivity: evidence from China," *Economic research …*. hrcak.srce.hr, 2023.

[3] E. Rosca, J. Reedy, and J. C. Bendul, "Does frugal innovation enable sustainable development? A systematic literature review," *Eur. J. Dev. …*, 2018, doi: 10.1057/s41287-017-0106-3.

[4] P. A. Taqwin, "The Impact of Ethics in Business Through Sustainable Procurement Practices in the Energy Sector," *Int. J. Bus. Technol. Manag.*, vol. 6, no. 2, pp. 626–635, 2024.

[5] P. Zhou, M. Han, and Y. Shen, "Impact of Intelligent Manufacturing on Total-Factor Energy Efficiency: Mechanism and Improvement Path," *Sustain.*, vol. 15, no. 5, pp. 1–22, 2023, doi: 10.3390/su15053944.

[6] Q. Wang and Z. Dong, "Technological innovation and renewable energy consumption: a middle path for trading off financial risk and carbon emissions," *Environ. Sci. Pollut. Res.*, 2022, doi: 10.1007/s11356-021-17915-3.

[7] A. D. A. Tasci, "A critical review and reconstruction of perceptual brand equity," *Int. J. Contemp. Hosp. Manag.*, vol. 33, no. 1, pp. 166–198, 2021, doi: 10.1108/IJCHM-03-2020-0186.

[8] T. Dogru *et al.*, "Generative Artificial Intelligence in the Hospitality and Tourism Industry: Developing a Framework for Future Research," *J. Hosp. Tour. Res.*, p. 10963480231188664, Jul. 2023, doi: 10.1177/10963480231188663.

[9] C. Tolliver, A. R. Keeley, and S. Managi, "Green bonds for the Paris agreement and sustainable development goals," *Environ. Res. …*, 2019, doi: 10.1088/1748-9326/ab1118.

[10] K. Q. Zhang, H. H. Chen, L. Z. Tang, and S. Qiao, "Green finance, innovation and the energy-environment-climate nexus," *Frontiers in Environmental …*. frontiersin.org, 2022. doi: 10.3389/fenvs.2022.879681.

[11] K. A. Gopinath *et al.*, "Impact of organic and integrated production systems on yield and seed quality of rainfed crops and on soil properties," *Front. Nutr.*, vol. 10, no. May, 2023, doi: 10.3389/fnut.2023.1127970.

[12] L. Xin, H. Sun, X. Xia, H. Wang, H. Xiao, and X. Yan, "How does renewable energy technology innovation affect manufacturing carbon intensity in China?," *Environmental Science and …*. Springer, 2022. doi: 10.1007/s11356-022-20012-8.

[13] M. Gomez and C. Grady, "A balancing act: the interplay of food supply chain resilience and environmental sustainability in American cities," *Environ. Res. Lett.*, vol. 18, no. 12, 2023, doi: 10.1088/1748-9326/ad0608.

[14] N. Al-Abdelmalek *et al.*, "Transforming Challenges into Opportunities for Qatar's Food Industry: Self-Sufficiency, Sustainability, and Global Food Trade Diversification," *Sustain.*, vol. 15, no. 7, 2023, doi: 10.3390/su15075755.

[15] T. A. Kurniawan, A. Maiurova, M. Kustikova, and ..., "Accelerating sustainability transition in St. Petersburg (Russia) through digitalization-based circular economy in waste recycling industry: A strategy to promote carbon …," *J. Clean. …*, 2022.

[16] S. A. R. Khan, P. Ponce, and Z. Yu, "Technological innovation and environmental taxes toward a carbon-free economy: An empirical study in the context of COP-21," *J. Environ. Manage.*, 2021.

[17] C. W. Su, L. D. Pang, R. Tao, X. Shao, and M. Umar, "Renewable energy and technological innovation: Which one is the winner in promoting net-zero emissions?," *Technol. Forecast. …*, 2022.

[18] G. Carton and J. Parigot, "Orchestration of Natural Resources as a Sustainable Alternative to the Resource-Based View Paradigm," in *Academy of Management Proceedings*, Academy of Management Briarcliff Manor, NY 10510, 2022, p. 15767.

[19] J. Barney and S. L. Hart, "A natural-resource-based view of the firm," *Acad. Manag. Rev.*, vol. 20, no. 4, pp. 986–1014, 1995.

[20] Y. M. Basri, G. Gusnardi, D. N. Tassanee, D. P. H. Indrapraja, R. N. Sari, and V. Ratnawati, "Social innovation and financial performance of social enterprises: the mediating role of social and environmental performance," *Cogent Bus. Manag.*, vol. 12, no. 1, p., 2025, doi: 10.1080/23311975.2025.2551283.

[21] M. Maychellina, "Implementation of Carbon Trading: Mechanisms of Execution and Legal Protection for Shareholders on the Indonesia Carbon Exchange," *jhbbc*, pp. 188–194, 2024.

[22] A. Rachmaniar, A. P. Supriyadi, and H. Pradana, "Carbon trading system as a climate mitigation scheme: why Indonesia should adopt it?," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 2021, p. 12015.

[23] S. Liu, W. Tang, and J. Zhang, "China's Carbon Emission Trading Mechanism: Realistic Challenges and Practical Pathways," *Highlights Business, Econ. Manag.*, vol. 43, pp. 87–91, Dec. 2024, doi: 10.54097/epvbhr86.

[24] W. B. Group, "Indonesia Country Climate and Development Report," *World Bank Gr. A to Z 2016*, pp. 189a – 190, 2015, doi: 10.1596/978-1-4648-0484-7_world_bank_group.

[25] X. Ji, M. Umar, S. Ali, W. Ali, K. Tang, and ..., "Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries," *… Dev.*, 2021, doi: 10.1002/sd.2132.

[26] L. Li, G. Li, I. Ozturk, and S. Ullah, "Green innovation and environmental sustainability: Do clean energy investment

and education matter?," *Energy Environ.*, 2022, doi: 10.1177/0958305X221115096.
[27] A. S. Riffianto and T. Suryani, "Kapabilitas keuangan usaha kecil dan menengah penghasil produk unggulan," 2017, doi: 10.14414/jbb.v6i1.722.
[28] X. Li, C. Liang, and F. Ma, "Forecasting stock market volatility with a large number of predictors: New evidence from the MS-MIDAS-LASSO model," *Ann. Oper. Res.*, 2022, doi: 10.1007/s10479-022-04716-1.
[29] A. Cheffo, "Carbon trading opportunities and challenges in Africa," 2019.
[30] D. Fitriani, "Navigating dual logics: A framework for integrating financial performance and social impacts in Indonesian village-owned enterprises (BUMDES)," *Int. J. Innov. Res. Sci. Stud.*, vol. 8, no. 3, pp. 3492–3500, 2025, doi: 10.53894/ijirss.v8i3.7279.
[31] C. Xiao, "Why Stakeholder Theory is 'Non-exploitative,'" *Acad. J. Manag. Soc. Sci.*, vol. 2, no. 3, pp. 26–30, 2023.