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Multidimensional Sustainability Drivers and Asset Efficiency: Moderating Role of Environmental Performance

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ABSTRACT

This study examines the effect of multidimensional sustainability practices, including circular economy practices, environmental investment, and corporate sustainability disclosure, on asset efficiency, with environmental performance as a moderating variable. The research uses a quantitative approach with panel data from 37 energy sector companies listed on the Indonesia Stock Exchange from 2020–2024, yielding 185 observations analyzed using Moderated Regression Analysis (MRA) in EViews 13. The results indicate that circular economy practices positively affect asset efficiency, while environmental investment has a negative effect. Corporate sustainability disclosure does not significantly affect asset efficiency. Environmental performance weakens the effects of circular economy practices and sustainability disclosure on asset efficiency, while moderating the effect of environmental investment. From a theoretical perspective, the findings extend legitimacy theory, stakeholder theory, signaling theory, and the resource-based view by demonstrating that the effectiveness of sustainability initiatives depends on implementation quality and environmental performance conditions. From a practical perspective, managers should integrate sustainability initiatives into operational processes and balance environmental commitments with efficiency objectives to maximize asset utilization. This study offers novelty by integrating multiple sustainability dimensions within an efficiency-based framework and examining the dual role of environmental performance as both a direct determinant and a moderating factor of asset efficiency.

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1. INTRODUCTION

The shift toward sustainability has affected how corporate performance is measured, moving the focus away from financial results and toward resource efficiency. Accounting provides reliable information for decision-making, performance evaluation, and accountability. Rising environmental damage, climate change pressures, and regulation have compelled companies to embrace sustainability (Amosh and Khatib, 2023; Liu et al., 2024; Martiny et al., 2024). In environmental and sustainability accounting, environmental cost management, sustainability reporting, and resource efficiency measurement have emerged as critical tools for ensuring corporate accountability and performance. Asset efficiency is measured by Total Asset Turnover (TATO), which reflects a corporation's ability to use its assets to generate income (Amir et al., 2023; Nengzih, 2022; Tanveer et al., 2025; Vegter et al., 2023). However, empirical evidence indicates that TATO values in the energy sector range from 0,10 to 0,87, remaining below the industry benchmark of 2 (Brigham and Houston, 2022; Kasmir, 2020).

Circular economy practices enhance resource utilization through recirculation, waste reduction, and lifecycle optimization (Bao and Yu, 2022; Kamruzzaman and Newaz, 2025; Vegter et al., 2023; Velte, 2023; Zhong and Wang, 2023). Prior studies report mixed findings regarding their efficiency benefits (Acerbi et al., 2020; Amir et al., 2023; Murali et al., 2025; Sarfraz et al., 2023). Environmental investment is also expected to improve efficiency by supporting cleaner production, waste reduction, and energy conservation (Chen et al., 2022; Khuong et al., 2022; Ning et al., 2023; Pusuluru et al., 2026; Rehman et al., 2024; Ren et al., 2024; Wulandari and Akbar, 2025). Nevertheless, some studies suggest that high initial costs and delayed returns may reduce short-term efficiency (Erbetta et al., 2022; Yu et al., 2025). Sustainability disclosure may support efficient resource allocation by reducing information asymmetry and improving decision-making quality (Ananzeh, 2022; Dan et al., 2023; Githaiga, 2025; Lei et al., 2024; Sormin et al., 2026; Wang et al., 2024), but prior studies show that sustainability practices are just symbolic rather than substantive (Fang, 2023; Kamruzzaman and Newaz, 2025; Nengzih, 2022).

The research used PROPER as an indicator of environmental performance to moderate the independent variables; it reflects a firm's ability to manage environmental impacts and comply with regulatory requirements. Firms with stronger environmental performance are generally better able to translate sustainability initiatives into operational outcomes (Kementerian Lingkungan Hidup dan Kehutanan, 2025; Wulandari et al., 2026; Aydoğmuş et al., 2022; Bao and Yu, 2022). Firm size is included as a control variable because larger firms possess greater resources and capabilities that may influence asset efficiency (Liu et al., 2024; Matsali et al., 2025; Sormin et al., 2026).

This study draws on legitimacy, signaling, stakeholder, and resource-based view theories. Legitimacy theory argues that businesses adopt sustainability practices in response to societal demands, while signaling theory argues that disclosing sustainability practices helps close information gaps and improve corporate reputation (Dowling and Pfeffer, 1975; Suchman, 1995; Spence, 1973). Stakeholder theory stresses the need to respond to stakeholder expectations. Resource-based view theory, by contrast, argues that sustainable practices serve as strategic resources for organizations, making business processes more efficient (Hörisch et al., 2020; Awan and Sroufe, 2022; Li et al., 2025).

Despite the growing sustainability literature, several gaps remain. Prior studies mainly focus on profitability measures such as ROA and ROE, which do not fully capture resource utilization efficiency. In addition, researchers often examine sustainability variables separately rather than integrating them into a unified framework. Moreover, research on the moderating role of

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environmental performance in shaping efficiency outcomes remains limited. Therefore, this study adopts an efficiency-based approach by examining multidimensional sustainability practices and incorporating environmental performance as a moderating variable.

2. METHODS

This study uses a quantitative approach with descriptive and verificative methods, which enable objective measurement and statistical testing of the relationships between sustainability practices and asset efficiency. The verificative method examines the effects of circular economy practices, environmental investment, and corporate sustainability disclosure on asset efficiency, as well as the moderating role of environmental performance. Secondary data were obtained from annual and sustainability reports of companies listed on the Indonesia Stock Exchange, as well as official company websites, covering 2020–2024. The sampling technique employed is purposive sampling, with criteria including energy sector companies that consistently publish financial and sustainability reports. Based on these criteria, the final dataset consists of 185 panel data observations. Panel data analysis is selected because it combines cross-sectional and time-series dimensions, allowing a more comprehensive assessment of firm behavior over time. EViews 13 was used for data processing and analysis 1as it supports for panel data regression and statistical testing.

The analysis includes descriptive statistics, classical assumption tests, panel data regression, and Moderated Regression Analysis (MRA). Moderated Regression Analysis (MRA) was employed to examine the moderating role of environmental performance. Consistent with the classification proposed by (Sharma et al., 1981), environmental performance is treated as a quasi-moderator because it functions both as an independent variable and as an interaction term. The operational definitions of variables are presented in **Table 1**.

Table 1. Operational variable definition

Variable	Dimension	Indicator	Scale
Asset Efficiency	Efficiency of asset utilization (Dan et al., 2023)	TATO = Sales / Total Assets	Ratio
Circular Economy Practice	Resource optimization and waste reduction (Al-Najjar et al., 2025; Esposito et al., 2023)	CEI = Score CEI/Total Score	Ratio
Environmental Investment	Environmental cost allocation (Sormin et al., 2026)	ENI = Environmental Cost/Earning's After Tax	Ratio
Corporate Sustainability Disclosure	Environmental, social, governance, and reporting disclosure (Wulandari et al., 2026)	CSD = ED + SD + GD + SR + GRI	Ratio
Environmental Performance	Environmental compliance and performance level (Kementerian Lingkungan Hidup dan Kehutanan, 2025)	PROPER rank (Gold=5; Green=4; Blue=3; Red=2; Black=1)	Ordinal
Firm Size	Company size based on total assets (Kumar et al., 2023)	SIZE = Ln (Total Assets)	Ratio

Source: Data processed by researcher, 2026.

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Circular economy practices are measured using a disclosure score index comprising ten indicators across four dimensions: performance, investment, policy, and resource efficiency. Each indicator is scored (0-3) based on the level of disclosure, where 0 indicates no disclosure, 1 represents basic narrative, 2 reflects quantitative information, and 3 indicates comprehensive and measurable disclosure. The indicators cover the definition and recognition of circular economy practices, energy conservation and emissions-reduction performance, resource reuse practices, emissions-reduction programs, cost efficiency, significant environmental investments, recurring environmental expenditures, financial incentives, policy implementation, and resource reuse or recycling ratios. Environmental investment is proxied by environmental costs normalized by earnings after tax. Corporate sustainability disclosure (CSD) is measured by the presence of environmental disclosure (ED), social disclosure (SD), governance disclosure (GD), sustainability reporting (SR), and compliance with GRI Standards 2021. Environmental performance is measured using PROPER ratings (1–5), while firm size is measured using the natural logarithm of total assets; the method is described in detail.

3. RESULTS AND DISCUSSION

To clarify the research framework, **Figure 2** presents the proposed research model, illustrating the relationships among circular economy practices, environmental investment, corporate sustainability disclosure, and asset efficiency. The model further identifies environmental performance as the moderating variable and firm size as the control variable, providing a comprehensive overview of both the direct and moderating relationships investigated in this study.

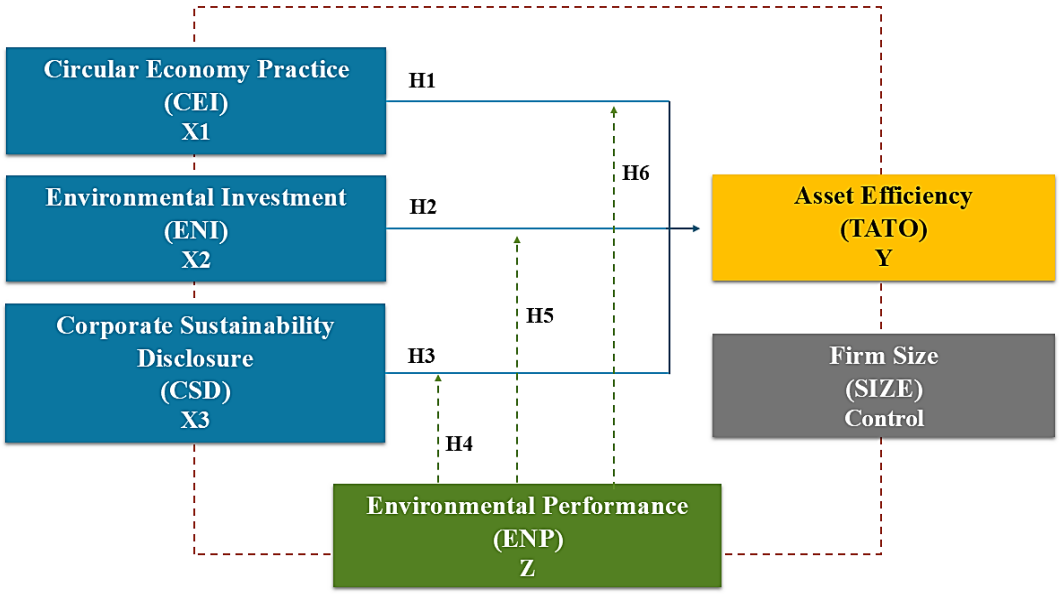

Figure 2. Research Construct.

Using **Figure 2**, the first step in the analysis is descriptive statistics. The findings will be based on 37 energy companies.

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Table 2. Statistic descriptive

	Mean	Median	Max	Min	SD	Obs.
TATO	0,730	0,567	2,777	0,001	0,532	185
CEI	0,705	0,800	1,000	0	0,250	185
ENI	1,324	0,387	29,686	-8,561	3,614	185
CSD	0,912	1,000	1,000	0,600	0,126	185
ENP	2,114	3,000	5,000	0	2,046	185
SIZE	30,641	30,107	40,998	25,222	2,983	185

Source: Output EViews 13 (data processed by researchers, 2026).

As shown in **Table 2**, asset efficiency, measured by Total Asset Turnover (TATO), has a mean of 0,730, with a minimum of 0,001 and a maximum of 2,777, indicating substantial variation in firms' efficiency in utilizing their assets. The average TATO is below the benchmark ratio of 2,0, suggesting that the average firms in the energy sector have not utilized their assets efficiently (Brigham and Houston, 2022; Kasmir, 2020). Circular Economy Initiatives (CEI) have a mean value of 0,705, with values ranging from 0 to 1, suggesting that most firms are engaged in circular economy activities to a moderate or high extent, although some variation. Environmental Investment (ENI) has a mean of 1,324, a very wide range from -8,561 to 29,686, and an unusually high standard deviation of 3,614, suggesting considerable differences in environmental investment levels among firms (Driastuti et al., 2024; Nengzih, 2022).). Corporate Sustainability Disclosure (CSD) achieves a relatively high mean value of 0,912, with the highest possible score being 1,000, indicating that the sampled firms generally provide extensive sustainability disclosures. This finding suggests a high level of compliance with the Global Reporting Initiative (GRI) Standards 2021, which emphasize comprehensive sustainability reporting to enhance transparency (Global Reporting Initiative, 2021). In addition, the environmental performance (ENP) has a mean of 2,114 on a scale ranging from 0 to 5. This indicates that, on average, the sampled firms have not yet achieved the higher PROPER performance categories, suggesting room for improvement in environmental performance (Kementerian Lingkungan Hidup dan Kehutanan, 2025; Mukti and Kusuma, 2024). Variable SIZE, measured with the natural logarithm of total assets, has a mean value of 30,641, with values ranging from 25,222 to 40,998. These statistics indicate that the sample is dominated by relatively large firms with substantial asset bases. This finding aligns with previous studies suggesting that larger firms generally have greater financial resources and operational capacity to support business activities and sustainability initiatives (Fahmi, 2020; Kasmir, 2020).

After carrying out the descriptive analysis, the following stage will involve establishing which of the panel data models, the common effect model (CEM), fixed effect model (FEM), and random effect model (REM) suits the research. The findings from this analysis have been presented in **Table 3** below.

Table 3. Selection model test

Testing	Prob.	Sig.	Conclusion	Result
Chow	0,000	0,050	(0,000<0,050)	**FEM**
Hausman	0,018	0,050	(0,018<0,050)	**FEM**
LM	0,000	0,050	(0,000<0,050)	REM

Source: Output EViews 13 (data processed by researchers, 2026).

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The Chow test produced a p-value of 0,000, which is below the 0.05 significance level, indicating that the Fixed Effects Model (FEM) is preferred over the Common Effects Model (CEM). Subsequently, the Hausman test yielded a p-value of 0.018, which is also below 0.05, confirming that the Fixed Effects Model (FEM) is preferred over the Random Effects Model (REM). Although the Lagrange Multiplier test also shows a p-value of 0.000, which is lower than 0.050, it indicates that the REM is preferred. Therefore, the Fixed Effects Model is the best model for this research. Based on the model selection results, the Fixed Effects Model (FEM) was selected as the most appropriate model for the analysis. Normality testing is not required, as it is not a prerequisite for BLUE, and FEM emphasizes coefficient consistency over residual normality (Basuki and Prawoto, 2021; Gujarati, 2012). In panel data, not all classical assumptions should be tested; therefore, this study focuses on the multicollinearity and heteroscedasticity tests to ensure model reliability, as shown in **Table 4**.

Table 4. Classic assumption test

Variables	Multicollinearity						Heteroscedasticity
	TATO	CEI	ENI	CSD	ENP	SIZE	
TATO	1,000						
CEI	0,067	1,000					0,288
ENI	0,032	0,173	1,000				0,484
CSD	-0,036	0,678	0,167	1,000			0,829
ENP	0,227	0,559	0,159	0,471	1,000		0,078
SIZE	-0,065	-0,034	0,006	0,083	0,277	1,000	0,055
CEI*ENP							0,228
ENC*ENP							0,901
CSD*ENP							0,211

Source: Output EViews 13 (data processed by researchers, 2026).

As shown in **Table 4**, all pairwise correlation coefficients among the independent variables are below the 0,80 threshold, indicating no multicollinearity in the regression model. This condition ensures that each independent variable makes a unique contribution to the analysis. Furthermore, the heteroscedasticity test indicates that all p-values are greater than 0,05, suggesting that the model does not exhibit heteroscedasticity and that the residuals are homoscedastic. Thus, the model meets the main assumptions of classical linear regression.

Table 5. Hypothesis test

	Model 1		Model 2		
Variable	Coef.	Prob.	Coef.	Prob	Results
C	-4,607	0,003	-5,132	0,001	
CEI	1,208	0,021**	1,167	0,043	H1 Accepted
ENI	-0,010	0,080*	-0,012	0,271	H2 Accepted
CSD	-0,028	0,939	0,439	0,320	H3 Rejected
SIZE	0,148	0,002	0,153	0,002	
ENP			0,862	0,010	
CEI*ENP			-0,585	0,098*	H4 Accepted
ENI*ENP			0,000	0,887	H5 Rejected
CSD*ENP			-0,398	0,049**	H6 Accepted
R-Square	0,878		0,885		
F-Statistic	0,000		0,000		

Notes: *p<0,10, **p<0,05, ***p<0,01

Source: Output EViews 13 (data processed by researchers, 2026).

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Based on the results of the hypothesis test, the model regression is as follows:

Model 1:

TATO = -4,607 + 1,208CEI - 0,010ENI - 0,028CSD + 0,148SIZE + εit

Model 2:

TATO = -5,132 + 1,167CEI - 0,012ENI + 0,439CSD + 0,862ENP - 0,585(CEI*ENP) + 0,000 (ENI*ENP) - 0,398(CSD*ENP) + 0,002SIZE + εit

Based on the hypothesis test results in Model 1, circular economy practices (CEI) have a coefficient of 1,208 and a p-value of 0,021, which is below the 0,05 significance level, indicating that H1 is accepted. In other words, the test result supports the alternative hypothesis that circular economy practices have a positive and significant impact on asset efficiency. The positive coefficient indicates that firms that implement these practices more effectively tend to achieve higher asset efficiency. This finding suggests that implementing circular economy practices improves asset utilization by enabling firms to generate more output from existing assets without increasing their asset base. In the energy industry, operations are extremely capital-intensive, requiring substantial investment in facilities and production plants. Therefore, firms in the sector can improve operational efficiency by adopting circular economy practices that enhance asset efficiency. Implementation of these practices improves material and energy efficiency in the production process, resulting in better asset economic efficiency. Consistent with the Resource-Based View (RBV), circular economy practices are strategic organizational capabilities that enhance effective resource utilization and contribute to organizational efficiency. Firms that implement circular economy practices tend to have stronger resource management capabilities than those that do not. The competitive advantage derived from these capabilities enables firms to create greater value by utilizing their resource base more efficiently. Thus, efficiency improvements come from using existing resources more effectively rather than acquiring additional resources. These findings can also be explained through Stakeholder Theory and Legitimacy Theory. As interest in sustainability grows, businesses need to incorporate operations that address societal concerns. Circular economy practices enable organizations to gain more legitimacy among stakeholders. Moreover, sustainability initiatives improve business process efficiency by enhancing organization-wide coordination and operational discipline. In addition, the positive coefficient suggests that the benefits of implementing circular economy practices exceed the associated implementation costs. Although implementing circular economy practices requires organizational changes and involves additional costs, the resulting economic benefits outweigh these implementation costs. This conclusion corroborates the findings in previous works by Bao and Yu (2022), Geissdoerfer et al. (2025), Khuong et al. (2022), Vegter et al. (2023), Velte (2023), Vitolla et al. (2023), and Zhong and Wang (2023) showing that the implementation of the circular economy contributes to increased operational efficiency and organizational performance. Thus, the greater the implementation of circular economy practices, the higher the level of asset efficiency achieved by firms.

Based on the hypothesis testing results for Model 1, Environmental Investment (ENI) has a coefficient of −0,010 with a p-value of 0,080, indicating statistical significance at the 10% level. Therefore, H2 is supported. These findings demonstrate that environmental investment has a significant negative effect on asset efficiency. The negative coefficient indicates that firms allocating greater resources to environmental investment tend to exhibit lower asset efficiency. This suggests that the benefits of environmental investments may not be realized immediately, as improvements in productivity and revenue generation often take time to materialize. As explained earlier, environmental investment in the energy sector includes pollution control, emission reduction, environmental monitoring, and waste management, among others.

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However, such activities require significant upfront investment and offer no immediate benefit. Profits are delayed while costs remain high, reducing the efficiency of the firm's assets. From a Resource-Based View perspective, environmental investment can be a strategic resource that creates long-term competitive advantage. Yet the effectiveness of environmental investment depends on its efficient integration into operations. If investments are compliance-based, they may improve the environmental situation, but they will not boost productivity or operational efficiency. For this reason, a company can realize any economic advantage from environmental investment only in the long run, once it incorporates these practices into its production processes and resource allocation. Signaling theory could explain the same result.

Environmental investment could signal to regulators and investors a firm's willingness to pursue sustainable development practices. Yet, while environmental investment would earn external recognition, internal processes would not change, since the economic cost of this investment would exceed any efficiency it could generate. Moreover, the negative relationship suggests that environmental investment should be viewed as a long-term strategic commitment, with its economic benefits being realized over time rather than immediately. This pattern is particularly common in capital-intensive industries such as the energy sector, where environmental investments typically require substantial financial resources and extended implementation periods before generating measurable economic returns. These findings are consistent with previous studies, including those by Awan and Sroufe (2022), Chen et al. (2022), Erbetta et al. (2022), Kurniawan and Ethika (2024), Nengzih (2022), Ning et al. (2023), Purike (2026), Rehman et al. (2024), Wulandari and Akbar (2025), Yu et al. (2025). The findings suggest that high environmental costs can adversely affect short-term efficiency, particularly because of substantial costs and delayed economic benefits. Therefore, when considering environmental investment, organizations should think long-term rather than focus on short-term efficiency gains.

Based on the hypothesis test results in Model 1, corporate sustainability disclosure (CSD) has a coefficient of 0,028 and a probability of 0,939, which is higher than the significance level of 0,05, indicating that H3 is rejected. The insignificant coefficient indicates that corporate sustainability disclosure is not significantly associated with asset efficiency. This finding suggests that variations in sustainability disclosure do not significantly explain differences in firms' asset efficiency. Accordingly, sustainability disclosure alone may not be sufficient to improve asset utilization or operational efficiency. Despite the increasing trend of firms disclosing ESG information to show transparency in their operations, such disclosures will not necessarily improve production activities. In simple terms, firms' sustainability disclosure may increase visibility; however, it does not increase their ability to maximize asset productivity. According to Signaling Theory, sustainability disclosure is expected to reduce information asymmetry and signal a firm's commitment to sustainability initiatives.

Nevertheless, the insignificant effect suggests that sustainability disclosure alone may not be sufficient to influence stakeholders' assessments of corporate performance. Instead, stakeholders may place greater emphasis on tangible operational outcomes. Without observable improvements in asset efficiency or resource utilization, sustainability disclosures may provide a weaker signal of a firm's economic performance. Sustainability disclosure therefore operates more as a mode of communication than as a factor that improves efficiency. The results can also be explained using the concept of legitimacy. Corporations disclose information because they strive to meet societal expectations and achieve organizational legitimacy. However, this does not necessarily imply that firms have undertaken the organizational and operational transformations required to improve asset utilization. Instead, firms may focus on preparing sustainability reports in accordance with reporting frameworks

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such as the GRI Standards without fully integrating sustainability principles into their core business processes.

Furthermore, the energy sector is highly capital-intensive, and asset efficiency depends primarily on factors such as production capacity, technological effectiveness, operational management, and asset utilization. Consequently, sustainability disclosure alone may not significantly influence asset efficiency, as firms' operational performance depends more on the effective management and utilization of internal resources than on the external disclosure of sustainability information. The result is in line with the previous findings by Driastuti et al. (2024), Fang (2023), Kamruzzaman and Newaz (2025), Nengzih (2022), Rosharlianti and Laia (2025), Velte (2023), Wulandari (2026) on the lack of improvement in firm performance through sustainability disclosure unless there is sustainability implementation. Thus, sustainability disclosure should not be seen as a means of achieving asset efficiency but as a complementary process that ensures transparency and accountability. Higher levels of sustainability disclosure are associated with greater corporate transparency; however, this study found no significant relationship with asset efficiency.

Based on the hypothesis testing results for Model 2, Environmental Performance (ENP) has a p-value of 0,010, indicating a significant direct effect on asset efficiency. In addition, the interaction term between Circular Economy Initiatives and Environmental Performance (CEI*ENP) has a coefficient of −0,585 with a p-value of 0,098, indicating significance at the 10% level. Therefore, H4 is supported. Because Environmental Performance (ENP) is significant as both an independent variable and an interaction term, it functions as a quasi-moderator. The results indicate that Environmental Performance (ENP) has a significant direct effect on asset efficiency and simultaneously moderates the relationship between Circular Economy Initiatives (CEI) and asset efficiency. The negative interaction coefficient suggests that environmental.

Performance attenuates the positive effect of circular economy practices on asset efficiency. Although firms implementing circular economy practices tend to achieve higher asset efficiency, the magnitude of this positive effect decreases as environmental performance improves. One possible explanation is that firms with higher environmental performance must comply with more stringent environmental management standards, systems, processes, and control mechanisms. Although these activities strengthen environmental management, they also require additional financial resources, administrative effort, and managerial attention. Consequently, firms may allocate more resources to maintaining high environmental performance than to maximizing operational efficiency. As a result, the efficiency gains associated with circular economy practices may be partially offset. From the perspective of Legitimacy Theory, firms with stronger environmental performance may face greater pressure to meet stakeholders' expectations and comply with increasingly stringent environmental regulations. Consequently, they may prioritize regulatory compliance and organizational legitimacy, reducing managerial flexibility to pursue operational efficiency. This trade-off may help explain why environmental performance weakens the positive relationship between circular economy practices and asset efficiency. This finding can also be interpreted through the Resource-Based View (RBV). While environmental performance reflects valuable organizational capabilities, maintaining high environmental standards requires continuous allocation of organizational resources. Consequently, part of these resources may be directed toward sustaining environmental performance rather than enhancing the efficiency gains generated by circular economy practices**.** Circular economy practices are organizational capabilities that improve resource management. However, broader implementation of circular economy practices may require additional investment in environmental management systems, internal controls, and regulatory compliance. Consequently, firms may allocate a greater share

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of their resources to maintaining environmental performance rather than improving operational efficiency, thereby weakening the positive effect of circular economy practices on asset efficiency. These results align with findings from Aydoğmuş et al. (2022), Bao and Yu (2022), Chen et al. (2022), Ning et al. (2023), Wulandari (2026), and Yavuz et al. (2025). Therefore, environmental performance serves as a contextual factor that moderates the relationship between circular economy practices and asset efficiency. The results indicate that the positive effect of circular economy practices on asset efficiency diminishes as environmental performance increases.

From the hypothesis test results in Model 2, environmental performance (ENP) significantly influences asset efficiency. In contrast, the interaction term between environmental investment and environmental performance (ENI*ENP) has a coefficient of 0,000 with the probability of 0,887, which is higher than 0,05. Hence, H5 is rejected. The significant direct effect of Environmental Performance (ENP), together with the insignificant interaction effect, indicates that ENP acts as a predictor moderator. In other words, environmental performance directly influences asset efficiency but does not alter the effect of environmental investment on asset efficiency. In essence, this finding suggests that the effect of environmental investment on asset efficiency does not vary across different levels of environmental performance. Therefore, environmental investment and environmental performance appear to influence asset efficiency through different mechanisms. Environmental investment reflects a firm's allocation of financial resources to sustainability-related initiatives, whereas environmental performance reflects the effectiveness of its environmental management practices and regulatory compliance efforts. Therefore, higher environmental performance does not enhance the effect of environmental investment on asset efficiency. From the perspective of the Resource-Based View (RBV), environmental investment can be regarded as a valuable strategic resource. However, its contribution to asset efficiency depends primarily on how firms utilize these investments in their operations rather than on the level of environmental performance achieved. High environmental performance may result from various factors, including organizational capabilities, regulatory compliance, technological advancement, and effective environmental management practices. However, none of these factors necessarily enhances the contribution of environmental investment to asset efficiency. Accordingly, the results indicate that environmental performance does not significantly moderate the relationship between environmental investment and asset efficiency. This finding can also be interpreted through the lens of Signaling Theory. Environmental performance signals a firm's commitment to environmental responsibility and sustainable business practices. However, this signal does not appear to strengthen the effect of environmental investment on asset efficiency. Although strong environmental performance may enhance stakeholders' perceptions of a firm's sustainability commitment, it does not necessarily ensure that environmental investments will translate into higher asset efficiency. Therefore, environmental investment and environmental performance can operate through independent mechanisms.

Furthermore, in the energy sector, environmental investment is often driven by regulatory requirements and environmental responsibilities rather than by short-term efficiency objectives. Such expenditures primarily support regulatory compliance and environmental risk management rather than directly improving asset efficiency. Consequently, higher environmental performance does not strengthen the effect of environmental investment on asset efficiency. The above result is in agreement with findings of various other researchers who have found that environmental performance does not necessarily enhance the influence of environmental costs on firm performance (Kang et al., 2023; Kurniawan and Ethika, 2024; Nengzih, 2022; Ning et al., 2023; Rehman et al., 2024; Ren et al., 2024). It can be concluded that

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environmental performance should be seen as a determinant of asset efficiency in its own right, and not an element that influences the effect of environmental spending on business success.

In relation to the results obtained from hypothesis testing using Model 2, it was found that environmental performance (ENP) positively affects asset efficiency and there is a coefficient value of -0,398 for the interaction between corporate sustainability disclosure and environmental performance (CSD*ENP) having a probability of 0,049 which is lower than 0,05, so the H6 is accepted. Because Environmental Performance (ENP) is significant both independently and through its interaction with corporate sustainability disclosure, it is classified as a quasi-moderator. Accordingly, ENP has a significant direct effect on asset efficiency and simultaneously moderates the relationship between corporate sustainability disclosure and asset efficiency. The negative interaction coefficient suggests that environmental performance reduces the impact of sustainability disclosure on asset efficiency. The results indicate that, although sustainability disclosure enhances transparency and accountability, its effectiveness in improving asset efficiency declines as firms achieve higher levels of environmental performance. These findings suggest that asset efficiency is more closely associated with actual environmental performance than with sustainability disclosure alone. From a Signaling Theory perspective, sustainability disclosure is expected to reduce information asymmetry and signal a firm's commitment to sustainable practices. However, when a firm already demonstrates strong environmental performance, stakeholders may place greater emphasis on its observable environmental outcomes than on sustainability disclosures. In this case, the incremental value of sustainability disclosure as a signalling tool is not expected to be significant since the firm's environmental performance already indicates its sustainability commitment. This finding suggests that the effectiveness of sustainability disclosure in improving asset efficiency declines as environmental performance increases. The finding can also be interpreted through the lens of Legitimacy Theory. Firms with strong environmental performance may already possess a high degree of organizational legitimacy because they have demonstrated compliance with regulatory requirements and met stakeholders' environmental expectations. Consequently, additional sustainability disclosure may provide limited incremental value in strengthening legitimacy or improving organizational outcomes. Under these circumstances, firms are likely to prioritize maintaining high environmental standards, regulatory compliance, and sustainable operational practices over expanding sustainability disclosures, thereby weakening sustainability reporting's contribution to asset efficiency. Furthermore, the energy sector requires considerable investment in environmental management systems, environmental monitoring, and regulatory compliance to achieve and maintain high levels of environmental performance. Higher levels of environmental performance may encourage managers to prioritize maintaining environmental standards and mitigating environmental risks over expanding sustainability disclosure, thereby reducing sustainability disclosure's contribution to asset efficiency. Consequently, the contribution of sustainability disclosure to explaining variations in asset efficiency becomes less pronounced, as environmental management practices appear to play a more prominent role in influencing asset efficiency. The results of the study are supported by the findings of Driastuti et al. (2024), Fang (2023), Kamruzzaman and Newaz (2025), Nengzih (2022), Rosharlianti and Laia (2025), and Velte (2023), which indicated that sustainability disclosures are only effective when in line with environmental performance levels. The findings suggest that environmental performance functions as a contextual factor that moderates the relationship between sustainability disclosure and asset efficiency rather than strengthening the effect of sustainability disclosure on asset efficiency.

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Firm Size (SIZE) was included as a control variable to control for differences in firms' resource capacity and operational scale that may affect asset efficiency. According to **Table 5**, SIZE has a significant positive influence on asset utilization efficiency, with coefficients of 0,148 and 0,153 and a probability value of 0,002. The results imply that large firms utilize assets more efficiently than small ones. Large firms typically have greater financial capacity, access to advanced technologies, and superior managerial capabilities, allowing them to operate more efficiently and maximize output from their existing assets. From the perspective of the Resource-Based View (RBV), firm size reflects a firm's strategic resource base, providing access to financial, technological, and organizational resources that support operational effectiveness and competitive advantage. From the perspective of Signaling Theory, larger firms also signal greater organizational stability, resource availability, and operational capability, thereby strengthening stakeholders' confidence in the firm's long-term prospects (Liu et al., 2024; Sormin et al., 2026; Wulandari and Akbar, 2025).

4. CONCLUSION

This study examines the effects of circular economy practices, environmental investment, and corporate sustainability disclosure on asset efficiency, with environmental performance serving as a moderating variable. The findings show that circular economy practices significantly improve asset efficiency, suggesting that effective resource management and the circular use of resources enable firms to generate greater revenue from their existing assets. Environmental investment is negatively associated with asset efficiency, which may be attributed to substantial upfront investment costs and the delayed realization of economic benefits. Corporate sustainability disclosure does not significantly influence asset efficiency, suggesting that disclosure alone is insufficient to improve firms' operational performance. Moreover, environmental performance directly influences asset efficiency. It also serves as a quasi-moderator in the relationships between the circular economy, sustainability disclosures, and asset efficiency, while functioning as a predictor-moderator in the relationship between environmental investments and asset efficiency.

The findings imply that sustainability initiatives should be integrated into core business operations rather than implemented solely to satisfy regulatory compliance requirements. Businesses are encouraged to prioritize sustainability initiatives that enhance resource management and improve resource productivity while aligning environmental activities with operational efficiency objectives. Regarding environmental accounting, the findings highlight the importance of measuring environmental costs, environmental performance, and sustainability initiatives as key components in assessing organizational performance. From a management accounting perspective, evaluating sustainability-related expenditures should extend beyond regulatory compliance to include their contribution to operational efficiency.

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