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## **The Effect of Artificial Intelligence Integration and Big Data Analytics on Sustainability reporting Audit Quality with ESG Disclosure and Operational Complexity as Moderating Variables**

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***Abstract:***

*This study investigates the effects of Artificial Intelligence (AI) and Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ) with ESG Disclosure (ESGD) and Operational Complexity (OC) as moderating variables. This research addresses the limited empirical evidence regarding the effectiveness of digital audit technologies in sustainability assurance practices, particularly within Indonesian energy sector companies. The research applied a quantitative associative method based on secondary data derived from the annual and sustainability reports of energy companies listed on the IDX for the 2022–2024 period. The purposive sampling technique resulted in 46 companies with 138 observations. The data were analyzed using SPSS version 25 by applying descriptive statistical analysis, classical assumption testing, and Moderated Regression Analysis (MRA). The findings indicate that Big Data Analytics significantly affects Sustainability Reporting Audit Quality, while Artificial Intelligence does not significantly affect Sustainability Reporting Audit Quality. In addition, ESG Disclosure and Operational Complexity are unable to moderate the relationships between AI, BDA, and Sustainability Reporting Audit Quality. These findings suggest that AI implementation in Indonesian energy companies remains relatively limited due to technological readiness and sustainability assurance challenges, whereas BDA has been more effectively utilized in sustainability auditing practices. Theoretically, this study extends to the sustainability auditing literature through the integration of digital audit technologies, ESG disclosure, and operational complexity within a single research framework based on Stakeholder Theory and Contingency Theory. Practically, the findings imply that companies and auditors should strengthen ESG data integration, technological readiness, and digital audit competencies to improve sustainability assurance practices.*

**Keywords:** *Artificial Intelligence, Big Data Analytics, ESG Disclosure, Operational Complexity, Sustainability Reporting Audit Quality*

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## **1. Introduction**

Sustainability reporting has become an increasingly important aspect of corporate accountability due to growing stakeholder awareness regarding environmental, social, and governance (ESG) issues. Corporations are no longer judged merely by their economic results, but also by their responsibility toward environmental protection, social concerns, and effective corporate governance. In Indonesian, the issuance of OJK Regulation No. 51/POJK.03/2017 regarding Sustainable Finance has increased the demand for transparent sustainability disclosures among listed companies, particularly those operating in environmentally impactful sectors like energy.

The energy sector faces greater pressure from regulators, investors, and society to provide credible and transparent sustainability reporting due to its high environmental exposure and contribution to carbon emissions. As sustainability reporting becomes more complex, companies and auditors increasingly require advanced technological capabilities to process ESG-related information effectively. This condition has encouraged the adoption of digital audit technologies such as Artificial Intelligence (AI) and Big Data Analytics (BDA) in sustainability assurance practices.

Artificial Intelligence enables auditors to automate ESG data analysis, detect anomalies, and improve audit efficiency, while Big Data Analytics facilitates the processing of large-scale ESG-related data in real time, thereby improving transparency and audit effectiveness (Hezam et al., 2023; Ikhsan et al., 2022). Ekaristi et al. (2025) further explained that AI and Big Data Analytics increasingly contribute to ESG performance measurement and sustainability-related information management. Yu (2025) also emphasized that Artificial Intelligence supports ESG performance evaluation through adaptive analytical systems and automated data processing capabilities. Based on Stakeholder Theory, companies are encouraged to improve sustainability reporting quality and assurance practices to maintain stakeholder trust and legitimacy.

Despite the growing importance of AI and BDA in auditing practices, the implementation of these technologies in Indonesian sustainability auditing remains relatively limited. Many companies still utilize digital technologies primarily for operational monitoring rather than comprehensive sustainability assurance systems. Pratama et al. (2023) stated that the implementation of artificial intelligence in auditing still faces challenges related to technological readiness, infrastructure limitations, and human resource capability. Huda and Tjandrakirana DP (2025) also emphasized that digital audit transformation may increase operational and audit costs when organizations are not fully prepared to integrate AI and Big Data technologies effectively.

Earlier research has largely examined the role of AI and BDA in financial auditing and general audit quality. However, limited studies have specifically examined their influence on Sustainability Reporting Audit Quality within the context of ESG assurance practices in developing countries. In addition, prior studies rarely investigate the moderating roles of ESG Disclosure and Operational Complexity

simultaneously in explaining the relationship between digital audit technologies and sustainability reporting audit quality. Vivianita et al. (2022) explained that ESG disclosure practices among companies remain heterogeneous and are influenced by organizational capability and reporting quality. Meanwhile, Ghasemaghaei et al. (2018) emphasized that the effectiveness of data analytics technologies depends significantly on organizational analytical competency and decision-making capability. Hence, this study focuses on analyzing the impact of Artificial Intelligence together with Big Data Analytics on the quality of sustainability reporting audits, with ESG disclosure and operational complexity acting as moderating variables in listed energy sector companies during the 2022–2024 observation period.

## **2. Theoretical Background and Hypothesis Development**

**Stakeholder Theory:** Stakeholder Theory explains that firms are responsible not solely to shareholders but also to broader stakeholders affected by corporate activities, including investors, regulators, communities, and environmental groups. Increasing stakeholder demand for transparent, accountable, and credible ESG-related information has encouraged companies to improve the quality of sustainability reporting and sustainability assurance practices. In this context, sustainability reporting audits function as an important mechanism to ensure the reliability and legitimacy of ESG disclosures. Companies with higher-quality sustainability assurance are more likely to gain stakeholder trust and maintain corporate legitimacy.

**Contingency Theory:** Contingency Theory states that the effectiveness of organizational systems depends on situational conditions such as technological readiness, organizational complexity, environmental uncertainty, and external pressures. In sustainability auditing practices, the implementation of Artificial Intelligence (AI) and Big Data Analytics (BDA) may produce different outcomes across organizations because their effectiveness depends on ESG data quality, organizational capability, operational conditions, and regulatory support. Therefore, ESG Disclosure and Operational Complexity are considered contingency factors that may influence the effectiveness of digital audit technologies in improving Sustainability Reporting Audit Quality.

**Artificial Intelligence and Sustainability Reporting Audit Quality:** Artificial Intelligence (AI) enables auditors to automate ESG data analysis, detect anomalies, and improve audit efficiency in sustainability assurance practices. AI-based auditing systems also support continuous monitoring, predictive analysis, and automated verification processes that may improve the credibility and transparency of sustainability reporting. Hezam et al. (2023) explained that digital audit technologies improve audit effectiveness through stronger analytical capability and information processing efficiency. Similarly, Ikhsan et al. (2022) found that Artificial Intelligence and data analytics technologies improve fraud detection capability and support more effective auditing processes through automated data analysis systems. Ekaristi et al. (2025) further emphasized that AI increasingly contributes to ESG performance measurement and sustainability-related information management. Based on

Stakeholder Theory, the implementation of AI may strengthen stakeholder trust and organizational legitimacy through more credible sustainability assurance practices. Therefore, companies implementing AI technologies are expected to improve Sustainability Reporting Audit Quality.

*H<sub>1</sub>: Artificial Intelligence affects Sustainability Reporting Audit Quality.*

**Big Data Analytics and Sustainability Reporting Audit Quality:** Big Data Analytics (BDA) allows auditors to analyze substantial amounts of ESG-related data more effectively, thereby improving audit transparency, risk identification, and decision-making quality. Based on Contingency Theory, the effectiveness of digital audit technologies depends on organizational capability and information processing efficiency. In sustainability assurance practices, BDA supports predictive analysis, real-time monitoring, and more comprehensive ESG data verification. Hezam et al. (2023) found that Big Data Analytics improves audit effectiveness through stronger information processing systems. Sofyani et al. (2025) also explained that Big Data Analytics-based audit systems improve audit performance and audit judgment quality through more integrated auditing processes. In addition, Salijeni et al. (2019) argued that big data technologies transform audit practices by strengthening analytical capability and real-time auditing effectiveness. Therefore, companies implementing Big Data Analytics more effectively are expected to improve Sustainability Reporting Audit Quality.

*H<sub>2</sub>: Big Data Analytics affect Sustainability Reporting Audit Quality.*

**ESG Disclosure a Moderating Variable:** ESG Disclosure reflects the extent of environmental, social, and governance information disclosed in sustainability reports. Companies with broader ESG disclosure generally provide more comprehensive sustainability-related information, thereby increasing the need for effective digital auditing technologies. Based on Stakeholder Theory, transparent ESG disclosure strengthens corporate accountability and increases stakeholder demand for credible sustainability assurance. Extensive ESG disclosure may also improve the effectiveness of AI and BDA because auditors obtain broader ESG-related information that can be processed through digital audit technologies. Vivianita et al. (2022) explained that ESG disclosure practices are influenced by organizational capability and reporting quality. In addition, Aulia and Kurniawati (2023) stated that broader sustainability disclosure increases the importance of effective assurance systems and governance quality in improving sustainability reporting credibility. Therefore, ESG Disclosure is expected to strengthen the relationships between AI, BDA, and Sustainability Reporting Audit Quality.

*H<sub>3</sub>: ESG Disclosure moderates the relationship between Artificial Intelligence and Sustainability Reporting Audit Quality.*

*H<sub>4</sub>: ESG Disclosure moderates the relationship between Big Data Analytics and Sustainability Reporting Audit Quality.*

**Operational Complexity a Moderating Variable:** Operational Complexity reflects the complexity of organizational structures, operational segments, and business diversification, which may increase sustainability auditing challenges due to the broader scope of ESG information that must be managed and verified. Based on

Contingency Theory, the effectiveness of digital audit technologies depends on organizational conditions such as operational structures, technological capability, and information processing complexity. Companies with higher operational complexity generally require more adaptive audit systems and stronger technological integration to ensure reliable sustainability reporting. Ghasemaghaei et al. (2018) explained that the effectiveness of data analytics technologies depends significantly on organizational analytical competency and decision-making capability. Huda and Tjandrakirana DP (2025) also emphasized that digital audit implementation requires stronger technological readiness and organizational capability, particularly within complex operational environments. Therefore, Operational Complexity is expected to strengthen the relationships between Artificial Intelligence, Big Data Analytics, and Sustainability Reporting Audit Quality.

*H<sub>5</sub>: Operational Complexity moderates the relationship between Artificial Intelligence and Sustainability Reporting Audit Quality.*

*H<sub>6</sub>: Operational Complexity moderates the relationship between Big Data Analytics and Sustainability Reporting Audit Quality.*

### **3. Methodology**

This research used a quantitative associative design in order to investigate the linkage among Artificial Intelligence (AI), Big Data Analytics (BDA), ESG Disclosure, Operational Complexity, and Sustainability Reporting Audit Quality. Based on Sugiyono (2019), quantitative studies focus on hypothesis testing by utilizing quantifiable variables and statistical techniques. The study involved energy industry companies publicly listed on the IDX between 2022 - 2024. The energy sector was selected due to its high environmental exposure, extensive ESG-related activities, and increasing pressure regarding sustainability reporting transparency. The sample was determined using a purposive sampling method by selecting companies that consistently issued annual and sustainability reports throughout the research period. Based on these criteria, 46 companies were selected, resulting in 138 observations. The study utilized annual and sustainability reports gathered from the official IDX website and individual corporate websites.

The dependent variable examined in this study is Sustainability Reporting Audit Quality (SRAQ), which refers to the extent to which sustainability audits ensure that ESG-related information is accurate, transparent, reliable, and compliant with applicable standards. This variable was measured using an audit quality scoring index consisting of assurance type, audit frequency, ESG materiality disclosure, and third-party independent verification. Each indicator was measured using an ordinal scale ranging from 0 to 3, and the total score was converted into percentage form. Higher scores indicate better sustainability reporting audit quality characterized by more transparent and reliable sustainability assurance practices.

Artificial Intelligence (AI) was measured using a dummy variable based on disclosures regarding the use of AI technologies in ESG auditing activities, such as anomaly detection, automated ESG analysis, and natural language processing systems. A score of 1 indicates that the company disclosed the implementation of AI

in sustainability auditing activities, while 0 indicates no disclosure. Meanwhile, Big Data Analytics (BDA) was measured using an ordinal scale ranging from 0 to 3 based on the level of ESG data utilization and digital analytics implementation within the company, including digitalization systems, real-time monitoring, and advanced analytics capabilities. Higher scores indicate greater utilization of Big Data Analytics technologies in supporting ESG auditing and sustainability assurance processes.

The moderating variables in this study are ESG Disclosure and Operational Complexity. ESG Disclosure was assessed through an ESG Disclosure Index constructed with reference to the Global Reporting Initiative (GRI) Standards and the Indonesian Financial Services Authority Regulation No. 51/POJK.03/2017 on Sustainable Finance. The index was calculated by comparing the proportion of ESG items reported by the corporation with the total ESG disclosure indicators. Higher index values indicate broader and more transparent ESG disclosure practices. Operational Complexity was measured using the natural logarithm of the number of operational segments disclosed by the company, where higher values indicate more complex operational structures and broader organizational diversification.

Data analysis in this research involved descriptive statistics, classical assumption testing, hypothesis testing, and Moderated Regression Analysis (MRA) with the assistance of SPSS version 25 based on Ghazali (2018). Descriptive statistical methods were utilized to explain the distribution of variables through minimum values, maximum values, mean scores, and standard deviations. In addition, normality, multicollinearity, heteroscedasticity, and autocorrelation tests were conducted to confirm the suitability of the regression model with the BLUE assumptions.

This study employed Moderated Regression Analysis (MRA) to examine the moderating roles of ESG Disclosure and Operational Complexity in the relationships between AI, BDA, and Sustainability Reporting Audit Quality. To reduce model complexity and minimize multicollinearity among interaction variables, the moderation analysis was conducted using separate regression models. The first model examined the direct effects of AI and BDA on Sustainability Reporting Audit Quality. The second model examined ESG Disclosure as a moderating variable through interaction terms between AI and ESG Disclosure as well as between BDA and ESG Disclosure. The third model examined Operational Complexity as a moderating variable through interaction terms between AI and Operational Complexity as well as between BDA and Operational Complexity.

The regression models used in this study are presented as follows:

Model 1: Direct Effect Model

$$SRAQ = \beta_0 + \beta_1 AI + \beta_2 BDA + \epsilon$$

Model 2: ESG Disclosure Moderation Model

$$SRAQ = \beta_0 + \beta_1 AI + \beta_2 BDA + \beta_3 ESGD + \beta_4 (AI * ESGD) + \beta_5 (BDA * ESGD) + \epsilon$$

Model 3: Operational Complexity Moderation Model

$$SRAQ = \beta_0 + \beta_1 AI + \beta_2 BDA + \beta_3 OC + \beta_4 (AI * OC) + \beta_5 (BDA * OC) + \epsilon$$

Where:

SRAQ	=	Sustainability Reporting Audit Quality
AI	=	Artificial Intelligence
BDA	=	Big Data Analytics
ESGD	=	ESG Disclosure
OC	=	Operational Complexity
E	=	Error term

#### 4. Empirical Findings/Result

##### Descriptive Statistics

Descriptive statistical analysis was conducted to summarize the characteristics of the study variables consisting of Artificial Intelligence (AI), Big Data Analytics (BDA), ESG Disclosure (ESGD), Operational Complexity (OC), and Sustainability Reporting Audit Quality (SRAQ). The descriptive statistical results are presented in Table 1.

**Table 1. Descriptive Statistics Results**

Variabel	N	Minimum	Maximum	Mean	Std. Deviation
AI	138	0,00	1,00	0,1884	0,39246
BDA	138	0,00	3,00	1,3478	1,02275
ESGD	138	0,16	0,92	0,5797	0,18708
OC	138	0,00	1,39	0,3430	0,50238
SRAQ	138	0,17	1,00	0,5604	0,25268
Valid N (listwise)	138				

**Source: Authors' Computation using SPSS 04.26**

As shown in Table 1, the Artificial Intelligence (AI) variable exhibits a mean of 0.1884, indicating that the implementation of AI among energy sector companies remains relatively limited. Meanwhile, Big Data Analytics (BDA) shows a higher mean value of 1.3478, suggesting that companies have adopted data analytics technologies more extensively than AI-based auditing systems. ESG Disclosure (ESGD) has a mean value of 0.5797, indicating relatively moderate ESG transparency practices among companies during the observation period. In addition, Operational Complexity (OC) has a mean value of 0.3430, reflecting differences in operational diversification and business complexity across companies. Sustainability Reporting Audit Quality (SRAQ) has a mean value of 0.5604, suggesting that the quality of sustainability assurance practices among energy sector companies is relatively moderate. The standard deviation values also indicate variations in technological readiness, ESG disclosure practices, and sustainability assurance quality among companies included in the research sample.

##### Classical assumption test

##### Test of normalcy

The purpose of the normality test was to examine the distribution of residuals within the regression model. To perform this assessment, the study utilized the One-Sample Kolmogorov–Smirnov Test, with the findings summarized in Table 2.

**Table 2. Results of the Normality Test**

Variabel	Monte Carli Sig.(2-tailed)	Description
Unstandardized residual	0,200	Data is Normally Distributed

**Source: Authors' Computation using SPSS 04.26**

As presented in Table 2, the normality test generated a significance value of 0.200, which surpassed the 0.05 criterion. This result confirms that the residual values are distributed normally, implying that the regression model meets the normality requirement. Hence, the model is deemed suitable for further hypothesis evaluation and regression analysis.

### **Test of Multicollinearity**

The multicollinearity test was conducted to examine if the independent variables in the regression equation were highly associated with one another. Ideally, a regression model should not contain strong linear relationships among its independent variables. To detect multicollinearity, the study referred to the Tolerance and Variance Inflation Factor (VIF) measurements.

**Table 3. Results of the Multicollinearity Test**

Variabel	Tolerance	VIF	Description
AI	0,591	1,693	No multimulticollinearity occurs
BDA	0,576	1,736	No multimulticollinearity occurs
ESGD	0,883	1,132	No multimulticollinearity occurs
OC	0,866	1,155	No multimulticollinearity occurs

**Source: Authors' Computation using SPSS 04.26**

Referring to Table 3, each independent variable demonstrates a Tolerance score above 0.10 and a Variance Inflation Factor (VIF) below the critical threshold of 10. The Artificial Intelligence (AI) variable records a Tolerance value of 0.591 with a VIF of 1.693, whereas Big Data Analytics (BDA) shows a Tolerance level of 0.576 and a VIF value of 1.736. Meanwhile, ESG Disclosure (ESGD) has a Tolerance value of 0.883 and a VIF value of 1.132, while Operational Complexity (OC) presents a Tolerance score of 0.866 with a VIF value of 1.155. These outcomes indicate that the regression model does not experience multicollinearity issues, meaning the independent variables are not highly correlated and remain suitable for further regression procedures.

### **Test of Heteroscedasticity**

The heteroscedasticity test was conducted to assess the consistency of residual variance within the regression model. An appropriate regression equation should not indicate heteroscedasticity symptoms. In this research, the Glejser method was utilized to test for heteroscedasticity.

**Table 4. Result of the heteroscedasticity Test**  
**Source: Authors' Computation using SPSS 04.26**

According to the findings of the Glejser heteroscedasticity test, Artificial Intelligence, Big Data Analytics, ESG Disclosure, and Operational Complexity recorded significance values of 0.750, 0.091, 0.339, and 0.837, respectively. The significance values for all variables are higher than 0.05, confirming the absence of heteroscedasticity in the regression model. Accordingly, the model meets the homoscedasticity criterion, which implies that the residual variances are distributed consistently across the independent variables, making the model suitable for subsequent statistical testing and hypothesis evaluation.

#### **Autocorrelation Test**

The autocorrelation assesment was conducted to determine if residuals from one observation period were associated with those from the preceding period. The Durbin–Watson method was employed to assess autocorrelaion.

**Table 5. Results of the Autocorrelation Test**

dU	Durbin-Watson	Description
1,845	1,791	No autocorrelation occurs

**Source: Authors' Computation using SPSS 04.26**

The Durbin–Watson analysis generated a value of 1.791. Based on the commonly accepted Durbin–Watson criterion, a regression model is considered free from autocorrelation when the DW statistic lies between  $-2 < DW < +2$ . Since the obtained score of 1.791 is included within this interval, the regression model can be interpreted as not having autocorrelation issues. Consequently, the model satisfies the required classical assumptions and can be regarded as reliable for subsequent analytical and hypothesis-testing procedures, indicating that the residuals are independent across observation periods.

#### **Moderated Regression Analysis**

In this study, Moderated Regression Analysis (MRA) was conducted using three regression models tested gradually to examine the effect of Artificial Intelligence (AI) and Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ), as well as the moderating role of ESG Disclosure (ESGD) and Operational Complexity (OC).

**Table 6. Results of the Moderated Regression Analysis, Model 1**

Variabel	Sig. (2-tailed)	Description			
AI	0,750	No heteroscedasticity occurs			
BDA	0,091	No heteroscedasticity occurs			
ESGD	0,339	No heteroscedasticity occurs			
OC	0,837	No heteroscedasticity occurs			
Model	Unstandardized Coefficients	Stand. Coef.	t	Sig.	
	B	Std. Error	Beta		
(Constant)	0,200	0,019		10,670	0,000

AI	-0,91	0,49	-0,191	-1,859	0,065
BDA	0,084	0,22	0,392	3,809	0,000

**Source: Authors' Computation using SPSS 04.26**

The results reported in Table 6 yield the following regression equation:

The regression analysis in Model 1 produced the following equation:

$$\text{SRAQ} = 0,200 - 0,091 \text{ AI} + 0,084 \text{ BDA} + e$$

The regression results show that the constant value is 0.200, indicating that if the Artificial Intelligence (AI) and Big Data Analytics (BDA) variables are assumed to be constant, the Sustainability Reporting Audit Quality (SRAQ) value will be 0.200. The Artificial Intelligence (AI) variable has a coefficient value of -0.091 with a significance value of 0.065 ( $> 0.05$ ), indicating that AI does not significantly affect Sustainability Reporting Audit Quality, although the coefficient shows a negative relationship. In contrast, the Big Data Analytics (BDA) variable has a coefficient value of 0.084 with a significance value of 0.000 ( $< 0.05$ ), indicating that Big Data Analytics has a significant positive effect on Sustainability Reporting Audit Quality. Overall, these findings suggest that Big Data Analytics has been more effectively implemented in supporting sustainability auditing practices, while Artificial Intelligence implementation remains relatively limited among energy sector companies.

**Table 7. Results of the Moderated Regression Analysis, Model 2**

Model	Unstandardized Coefficients		Stand. Coef. Beta	t	Sig.
	B	Std. Error			
(Constant)	0,087	0,030		2,260	0,005
AI-ESGD	-0,547	0,396	-0,343	-1,381	0,170
BDA-ESGD	-0,117	0,111	-0,183	-1,054	0,294

**Source: Authors' Computation using SPSS 04.26**

The regression analysis in Model 2 produced the following equation:

$$\text{SRAQ} = 0,087 - 0,547 (\text{AI} * \text{ESGD}) - 0,117 (\text{BDA} * \text{ESGD}) + e$$

The regression results show that the constant value is 0.087, indicating that if the interaction variables are assumed to be constant, the value of Sustainability Reporting Audit Quality (SRAQ) will be 0.087. The interaction variable between Artificial Intelligence and ESG Disclosure (AI-ESGD) has a coefficient value of -0.547 with a significance value of 0.170 ( $> 0.05$ ), indicating that ESG Disclosure (ESGD) is unable to moderate the effect of Artificial Intelligence on Sustainability Reporting Audit Quality. Similarly, the interaction variable between Big Data Analytics and ESG Disclosure (BDA-ESGD) has a coefficient value of -0.117 with a significance value of 0.294 ( $> 0.05$ ), indicating that ESG Disclosure is also unable to moderate the effect of Big Data Analytics on Sustainability Reporting Audit Quality. Overall, these findings suggest that ESG Disclosure does not function as a moderating variable in the relationship between Artificial Intelligence, Big Data Analytics, and Sustainability Reporting Audit Quality.

**Table 8. Results of the Moderated Regression Analysis, Model 3**

Model	Unstandardized Coefficients		Stand. Coef.	t	Sig.
	B	Std. Error	Beta		
(Constant)	0,195	0,020		9,598	0,000
AI OC	0,213	0,115	0,240	1,855	0,066
BDA OC	-0,036	0,054	-0,087	-0,667	0,506

**Source: Authors' Computation using SPSS 04.26**

The regression analysis in Model 3 produced the following equation:

$$\text{SRAQ} = 0,195 + 0,213 (\text{AI} * \text{OC}) - 0,036 (\text{BDA} * \text{OC}) + e$$

The regression results show that the constant value is 0.195, indicating that if the interaction variables are assumed to be constant, the value of Sustainability Reporting Audit Quality (SRAQ) will be 0.195. The interaction variable between Artificial Intelligence and Operational Complexity (AI–OC) has a coefficient value of 0.213 with a significance value of 0.066 ( $> 0.05$ ), indicating that Operational Complexity (OC) is unable to moderate the effect of Artificial Intelligence on Sustainability Reporting Audit Quality, although the coefficient shows a positive direction. Meanwhile, the interaction variable between Big Data Analytics and Operational Complexity (BDA–OC) has a coefficient value of -0.036 with a significance value of 0.506 ( $> 0.05$ ), indicating that Operational Complexity is also unable to moderate the effect of Big Data Analytics on Sustainability Reporting Audit Quality. Overall, these findings suggest that Operational Complexity does not function as a moderating variable in the relationship between Artificial Intelligence, Big Data Analytics, and Sustainability Reporting Audit Quality.

## Hypothesis Testing

### t-Testing

The hypothesis were evaluated through a partial t-test based on the following criteria:

1. If the significance value is less than 0.05 and the absolute value of t-count is greater than t-table, the hypothesis is accepted.
2. If the significance value is greater than 0.05 and the absolute value of t-count is less than t-table, the hypothesis is rejected.

The t-table value obtained in this study is 1.979 ( $\alpha = 0.05$ ;  $n = 138$ ;  $k = 8$ ).

**Table 9. t-Test Results, Model 1**

Variabel	t	Sig.	Description
AI	-1,859	0,065	H1 is rejected
BDA	3,809	0,000	H2 is accepted

**Source: Authors' Computation using SPSS 04.26**

Based on the testing results in Model 1, the following conclusions can be drawn:

1. Effect of Artificial Intelligence (AI) on Sustainability Reporting Audit Quality (SRAQ):

The Artificial Intelligence (AI) variable has a significance value of  $0.065 > 0.05$  and a t-count value of  $-1.859 < 1.979$ , indicating that Artificial Intelligence does not significantly affect Sustainability Reporting Audit Quality (SRAQ); therefore, H1 is rejected. These findings suggest that the implementation of AI among energy sector companies remains relatively limited and has not yet been optimally integrated into sustainability auditing practices. The insignificant effect may occur because many companies still utilize AI primarily for operational monitoring rather than comprehensive sustainability assurance activities. In addition, limited technological infrastructure, lack of auditor expertise, and low AI integration in ESG auditing processes may reduce the effectiveness of Artificial Intelligence implementation in improving sustainability reporting audit quality.

## 2. Effect of Big Data Analytics (BDA):

The Big Data Analytics (BDA) variable has a significance value of  $0.000 < 0.05$  and a t-count value of  $3.809 > 1.979$ , indicating that Big Data Analytics significantly affects Sustainability Reporting Audit Quality (SRAQ); therefore, H2 is accepted. These findings suggest that companies implementing Big Data Analytics more effectively tend to produce higher sustainability reporting audit quality. Big Data Analytics enables companies and auditors to process large-scale ESG-related data more efficiently, improve audit transparency, detect anomalies more accurately, and support sustainability-related decision-making processes. Consequently, the implementation of Big Data Analytics contributes positively to improving sustainability reporting audit quality.

**Table 10. t Test Results, Model 2**

Variabel	t	Sig.	Description
AI ESGD	-1,381	0,170	H3 is rejected
BDA ESGD	-1,054	0,294	H4 is rejected

**Source: Authors' Computation using SPSS 04.26**

Based on the testing results in Model 2, the following conclusions can be drawn:

### 1. ESG Disclosure (ESGD) Moderates the Effect of Artificial Intelligence (AI) on Sustainability Reporting Audit Quality (SRAQ):

Based on the testing results, the significance value is  $0.170 > 0.05$  and the t-count value is  $-1.381 < 1.979$ , indicating that ESG Disclosure (ESGD) is unable to moderate the effect of Artificial Intelligence (AI) on Sustainability Reporting Audit Quality (SRAQ); therefore, H3 is rejected. These findings suggest that broader ESG disclosure does not necessarily strengthen the effectiveness of Artificial Intelligence implementation in sustainability auditing activities. Although companies disclose extensive ESG-related information, the quality of sustainability reporting audits still depends more on technological readiness, audit system integration, and auditor capability in utilizing Artificial Intelligence technologies.

### 2. ESG Disclosure (ESGD) Moderates the Effect of Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ):

Based on the testing results, the significance value is  $0.294 > 0.05$  and the t-count value is  $-1.054 < 1.979$ , indicating that ESG Disclosure (ESGD) is unable to moderate

the effect of Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ); therefore, H4 is rejected. These findings suggest that the extent of ESG disclosure does not strengthen or weaken the effect of Big Data Analytics on sustainability reporting audit quality. Although companies disclose broader ESG-related information, the effectiveness of Big Data Analytics implementation still depends more on organizational capability in processing, integrating, and utilizing ESG-related data effectively.

**Table 11. t Test Results, Model 3**

Variabel	t	Sig.	Description
AI OC	1,855	0,066	H5 is rejected
BDA OC	-0,667	0,506	H6 is rejected

**Source: Authors' Computation using SPSS 04.26**

Based on the testing results in Model 3, the following conclusions can be drawn:

1. Operational Complexity (OC) Moderates the Effect of Artificial Intelligence (AI) on Sustainability Reporting Audit Quality (SRAQ):

Based on the testing results, the significance value is  $0.066 > 0.05$  and the t-count value is  $1.855 < 1.979$ , indicating that Operational Complexity (OC) is unable to moderate the effect of Artificial Intelligence (AI) on Sustainability Reporting Audit Quality (SRAQ); therefore, H5 is rejected. These findings suggest that companies with more complex operational structures do not necessarily strengthen the influence of Artificial Intelligence on sustainability reporting audit quality. Although operational complexity generally increases sustainability auditing challenges, the effectiveness of Artificial Intelligence implementation still depends more on technological integration, organizational digital maturity, and auditor readiness rather than operational complexity alone.

2. Operational Complexity (OC) Moderates the Effect of Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ):

Based on the testing results, the significance value is  $0.506 > 0.05$  and the t-count value is  $-0.667 < 1.979$ , indicating that Operational Complexity (OC) is unable to moderate the effect of Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ); therefore, H6 is rejected. These findings suggest that operational complexity does not significantly strengthen or weaken the effect of Big Data Analytics on sustainability reporting audit quality. Although companies with more complex operational systems generally require more sophisticated data processing technologies, the effectiveness of Big Data Analytics implementation still depends more on technological capability, ESG data integration quality, and organizational readiness in utilizing digital auditing systems effectively.

**F-Test**

The F-test aims to assess whether the independent variables jointly influence the dependent variable and to evaluate the feasibility of the regression model (goodness of fit).

**Table 12. F Test Results, Model 1**

Model		F	Sig.
1	Regression	7,408	0,001
	Residual		
	Total		

**Source: Authors' Computation using SPSS 04.26**

According to the F-test findings for Model 1, the significance value obtained is  $0.001 < 0.05$  and the F-count value is  $7.408 > 2.44$ , indicating that the regression model fulfills the goodness-of-fit criteria. These findings suggest that Artificial Intelligence (AI) and Big Data Analytics (BDA) simultaneously affect Sustainability Reporting Audit Quality (SRAQ). Although Artificial Intelligence does not show a significant partial effect, the simultaneous implementation of AI and BDA collectively contributes to explaining variations in Sustainability Reporting Audit Quality.

**Table 13. F Test Results, Model 2**

Model		F	Sig.
2	Regression	9,814	0,000
	Residual		
	Total		

**Source: Authors' Computation using SPSS 04.26**

According to the F-test findings for Model 2, the significance value obtained is  $0.000 < 0.05$  and the F-count value is  $9.814 > 2.44$ , indicating that the regression model fulfills the goodness-of-fit criteria. These findings suggest that Artificial Intelligence (AI), Big Data Analytics (BDA), ESG Disclosure (ESGD), and the interaction variables simultaneously affect Sustainability Reporting Audit Quality (SRAQ). The inclusion of ESG Disclosure and interaction variables also improves the explanatory capability of the regression model in explaining sustainability reporting audit quality, although the moderating effects are not statistically significant in the partial test.

**Table 14. F Test Results, Model 3**

Model		F	Sig.
3	Regression	3,751	0,03
	Residual		
	Total		

**Source: Authors' Computation using SPSS 04.26**

According to the F-test findings for Model 3, the significance value obtained is  $0.030 < 0.05$  and the F-count value is  $3.751 > 2.44$ , indicating that the regression model

fulfills the goodness-of-fit criteria. These findings suggest that Artificial Intelligence (AI), Big Data Analytics (BDA), Operational Complexity (OC), and the interaction variables simultaneously affect Sustainability Reporting Audit Quality (SRAQ). The inclusion of Operational Complexity and interaction variables also contributes to the explanatory capability of the regression model in explaining sustainability reporting audit quality, although the moderating effects are not statistically significant in the partial test

### Coefficient of Determination (R Square)

The coefficient of determination analysis is used to assess how well the independent variables to explain the variation in the dependent variable. The higher the Adjusted R Square value, the greater the explanatory capability of the regression model.

**Table 15. R Square Test Results, Model 1**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,316	0,100	0,086	0,17689

**Source: Authors' Computation using SPSS 04.26**

According to the coefficient of determination analysis in Model 1, the Adjusted R Square value obtained is 0.086 or 8.6%. These findings indicate that Artificial Intelligence (AI) and Big Data Analytics (BDA) are able to explain 8.6% of the variation in Sustainability Reporting Audit Quality (SRAQ), whereas the remaining 91.4% may be attributed to factors not included in the proposed model. The relatively low Adjusted R Square value indicates that sustainability reporting audit quality is influenced not only by technological factors such as AI and BDA, but also by various organizational, governance, and environmental factors not included in this study. Variables such as auditor digital competency, corporate governance quality, sustainability commitment, ESG assurance standards, organizational readiness, and regulatory compliance may also significantly influence sustainability reporting audit quality. This finding suggests that sustainability assurance practices are multidimensional and cannot be explained solely by digital technology adoption. Therefore, future studies are encouraged to incorporate additional explanatory variables and broader organizational factors to improve the explanatory power of sustainability auditing research models.

**Table 16. R Square Test Results, Model 2**

Model	R	Square	Adjusted R Square	Std. Error of the Estimate
2	0,522	0,273	0,245	0,16081

**Source: Authors' Computation using SPSS 04.26**

According to the coefficient of determination analysis in Model 2, the Adjusted R Square value obtained is 0.245 or 24.5%. These findings indicate that Artificial Intelligence (AI), Big Data Analytics (BDA), ESG Disclosure (ESGD), and the interaction variables (AI×ESGD and BDA×ESGD) are able to explain 24.5% of the variation in Sustainability Reporting Audit Quality (SRAQ), while the remaining 75.5% is explained by other variables outside the research model. Compared to Model 1, the Adjusted R Square value in Model 2 increases significantly, indicating that the

inclusion of ESG Disclosure and interaction variables improves the explanatory capability of the regression model in explaining sustainability reporting audit quality, although the moderating effects are not statistically significant in the partial test. Nevertheless, the relatively moderate explanatory power suggests that ESG disclosure alone is insufficient to explain sustainability assurance effectiveness without considering additional factors such as ESG data quality, institutional support, auditor expertise, and digital audit system integration. Future studies may further examine the role of sustainability governance mechanisms, ESG assurance frameworks, and organizational digital maturity in improving sustainability reporting audit quality.

**Table 17. R Square Test Results, Model 3**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	0,354	0,125	0,092	0,17633

**Source: Authors' Computation using SPSS 04.26**

According to the coefficient of determination analysis in Model 3, the Adjusted R Square value is 0.092, equivalent to 9.2%. The results suggest that Artificial Intelligence (AI), Big Data Analytics (BDA), Operational Complexity (OC), and the interaction variables (AI×OC and BDA×OC) account of 9.2% of the variability in Sustainability Reporting Audit Quality (SRAQ), whereas the remaining 90.8% may be attributed to factors not incorporated into the proposed model. The relatively low Adjusted R Square value in Model 3 indicates that Operational Complexity and the interaction variables contribute only slightly to enhancing the predictive power of the regression model. This finding suggests that operational complexity is not a dominant factor influencing sustainability reporting audit quality in energy sector companies. The results also imply that the effectiveness of sustainability assurance practices depends more on organizational technological readiness, ESG information systems, sustainability governance quality, and auditor competency than merely on operational diversification. Therefore, future studies are encouraged to explore additional variables such as sustainability-oriented corporate culture, board governance effectiveness, external assurance quality, and technological integration capability to obtain a more comprehensive understanding of the determinants of sustainability reporting audit quality.

## 5. Discussion

The results demonstrate that Artificial Intelligence (AI) has no significant affect on Sustainability Reporting Audit Quality (SRAQ). Although AI is theoretically expected to improve audit effectiveness through automation, anomaly detection, and ESG data analysis, its implementation in Indonesian energy companies remains relatively limited and has not been fully integrated into sustainability assurance practices. This finding suggests that technological adoption alone is insufficient to improve sustainability reporting audit quality without adequate organizational readiness, technological infrastructure, ESG data standardization, and auditor competency development. Many companies still utilize AI primarily for operational monitoring rather than comprehensive sustainability assurance activities. This result aligns with Pratama et al. (2023), who explained that AI implementation in auditing

practices still faces challenges related to technological readiness, infrastructure limitations, and human resource capability. Huda and Tjandrakirana DP (2025) also emphasized that digital audit transformation may increase operational and audit costs when organizations are not fully prepared to integrate AI technologies effectively. However, this finding differs from Ekaristi et al. (2025), who found that AI and Big Data Analytics increasingly contribute to ESG performance measurement and sustainability-related information management. The difference may occur because companies in developed digital environments generally possess more mature technological infrastructures and stronger organizational digital capabilities compared to many Indonesian companies.

The insignificant effect of AI compared to the significant effect of BDA may indicate different levels of technological maturity. While BDA technologies have been widely adopted through ERP systems, digital monitoring platforms, and ESG data integration tools, AI-based auditing applications remain relatively nascent and require more advanced infrastructure, specialized expertise, and organizational readiness. Consequently, companies may obtain immediate assurance benefits from BDA implementation, whereas the benefits of AI may only emerge after reaching a higher level of digital maturity.

In contrast, Big Data Analytics (BDA) has a significant positive effect on Sustainability Reporting Audit Quality. These findings indicate that companies utilizing BDA technologies are more capable of processing ESG-related information, improving audit transparency, and strengthening sustainability assurance effectiveness. Compared to AI technologies, BDA systems are generally more practical and easier to implement because they focus on data integration, analytical processing, predictive analysis, and real-time monitoring rather than intelligent automation systems requiring highly advanced infrastructures. Consequently, BDA may provide more immediate practical benefits in sustainability auditing practices, particularly within emerging-market contexts where technological readiness remains uneven across organizations. This finding supports Hezam et al. (2023), who found that Big Data Analytics improves audit effectiveness through stronger analytical capabilities and information processing efficiency. Similarly, Sofyani et al. (2025) explained that Big Data Analytics-based audit systems improve audit performance and audit judgment quality through better analytical accuracy and integrated information processing systems.

The moderation analysis further indicates that ESG Disclosure (ESGD) is unable to moderate the relationships between Artificial Intelligence, Big Data Analytics, and Sustainability Reporting Audit Quality. These findings suggest that broader ESG disclosure does not necessarily strengthen the effectiveness of digital audit technologies in sustainability assurance practices. Although companies disclose extensive ESG-related information, sustainability reporting audit quality still depends more on organizational technological readiness, audit system integration, and auditor competency rather than merely on the quantity of ESG disclosure. This finding is consistent with Vivianita et al. (2022), who explained that ESG disclosure practices among companies remain heterogeneous and are influenced by differences in

organizational capability and reporting quality. Aulia and Kurniawati (2023) also stated that broader sustainability disclosure alone does not automatically improve assurance quality without strong governance systems and effective sustainability assurance mechanisms.

Furthermore, Operational Complexity (OC) is unable to moderate the relationships between Artificial Intelligence, Big Data Analytics, and Sustainability Reporting Audit Quality. These findings indicate that companies with more complex operational structures do not necessarily experience stronger effects from digital audit technology implementation. Although operational complexity generally increases ESG auditing challenges due to broader operational diversification and more complicated information systems, the effectiveness of AI and BDA implementation still depends more on technological integration, organizational digital maturity, and ESG data management capabilities than on operational complexity itself. This finding supports Ghasemaghaei et al. (2018), who explained that the effectiveness of data analytics technologies depends significantly on organizational analytical competency and decision-making capability. Huda and Tjandrakirana DP (2025) also emphasized that digital audit implementation requires stronger technological readiness and organizational capability, particularly within complex operational environments. One possible explanation is that many Indonesian energy companies are still in the transition phase toward digital sustainability assurance systems, causing operational complexity to function more as an organizational challenge than as a factor strengthening digital audit technology effectiveness.

From a theoretical perspective, these findings support Contingency Theory by demonstrating that the effectiveness of digital audit technologies depends on organizational conditions such as technological readiness, ESG data integration, and organizational digital maturity. The results also reinforce Stakeholder Theory, which highlights the importance of transparent and credible sustainability assurance practices in maintaining stakeholder trust and organizational legitimacy. Velte (2021) further explained that sustainability assurance quality depends not only on disclosure practices but also on governance quality, assurance systems, and organizational accountability mechanisms. However, the insignificant effect of AI and the insignificant moderating roles of ESG Disclosure and Operational Complexity indicate that digital transformation in sustainability assurance practices within emerging-market environments remains highly dependent on organizational capability development and institutional readiness.

## **6. Conclusions**

This current research investigates the effects of Artificial Intelligence (AI) and Big Data Analytics (BDA) on Sustainability Reporting Audit Quality (SRAQ) with ESG Disclosure and Operational Complexity as moderating variables in energy sector companies listed on the IDX during 2022–2024. The results suggest that Artificial Intelligence does not significantly affect Sustainability Reporting Audit Quality, suggesting that AI implementation in sustainability assurance practices among

Indonesian companies remains relatively limited and has not yet been fully integrated into ESG auditing systems. In contrast, Big Data Analytics has a significant positive effect on Sustainability Reporting Audit Quality, indicating that data analytics technologies contribute substantially to enhancing ESG data processing, audit efficiency, and sustainability assurance effectiveness.

The moderation analysis further shows that ESG Disclosure and Operational Complexity are unable to moderate the relationships between AI, BDA, and Sustainability Reporting Audit Quality. These findings indicate that broader ESG disclosure and more complex operational structures do not automatically strengthen the effectiveness of digital audit technologies. Instead, the effectiveness of AI and BDA implementation depends more on technological readiness, organizational digital maturity, ESG data integration quality, and auditor competency in utilizing digital auditing systems.

The findings support Stakeholder Theory and Contingency Theory by demonstrating that the success of digital audit technologies is influenced by organizational and technological conditions within sustainability assurance practices. This present research the sustainability auditing literature through the incorporation of AI, BDA, ESG Disclosure, and Operational Complexity into a unified research framework within the context of sustainability assurance practices in emerging markets.

Practically, companies are encouraged to strengthen ESG data integration systems, improve digital infrastructures, and enhance organizational technological readiness to support more effective sustainability assurance practices. Auditors are also encouraged to improve digital competencies in utilizing AI- and BDA-based auditing technologies, while regulators are expected to strengthen sustainability assurance standards and digital auditing guidelines to support technology-based sustainability assurance practices in Indonesia.

The scope of this study is confined to energy-related companies listed on the IDX during 2022–2024 period, potentially limiting the broader applicability of the findings. In addition, the relatively low adjusted R-square values indicate that Sustainability Reporting Audit Quality may also be influenced by other factors such as auditor competency, corporate governance quality, sustainability commitment, ESG assurance maturity, and regulatory compliance. Accordingly, subsequent research is recommended to include additional explanatory factors, wider industry coverage, and extended observation periods in order to enhance the depth and comprehensiveness of sustainability auditing studies.

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