The Influence Of Intellectual Capital On Profitability With Moderate Sales Growth In Energy Sector Companies Listed On The Indonesia Stock Exchange (IDX) In 2019-2023

M Reza Kurniawan[1], Irni Yunita[2]
[1,2]Fakultas Ekonomi Dan Bisnis, universitas Telkom Bandung, Indonesia sanjiredja051@gmail.com[1*], irniyunita@telkomuniversity.ac.id[2]

Abstract
In an increasingly competitive business world, financial performance is one of the main indicators that investors pay attention to in assessing a company's prospects. One common measure of profitability used is return on assets (ROA), which reflects the rate of return based on the company's assets. In addition to physical and financial capital, intellectual capital also plays an important role in increasing the value of the company. Intellectual Capital, which consists of Value Added Capital Employed (VACA), Value Added Human Capital (VAHU), and Structural Capital Value Added (STVA), has been widely studied in relation to company performance. This type of research is descriptive verification which aims to analyze the effect of VACA, VAHU, STVA on company performance as measured using ROA, and explore the role of company sales growth as a moderating variable. The research data used are 60 energy sector companies in 2019-2023 listed on the Indonesia Stock Exchange. The method used in this study is a quantitative approach with panel regression analysis and moderated regression analysis (MRA). The results of the study show that partially, VACA and VAHU have a significant positive effect on ROA, while STVA does not show a significant effect. Furthermore, the results of the moderation test show that sales growth (SGR) is able to strengthen the influence of VACA and STVA on ROA, but is not significant in moderating the relationship between VAHU and ROA. This finding indicates that the efficiency of physical capital use and human resource management are key factors in increasing the profitability of energy sector companies, and the role of structural capital becomes more effective when the company experiences growth. This study provides theoretical implications in the development of Intellectual Capital studies as well as managerial recommendations for companies to focus more on managing intellectual assets as strategic resources. In addition, the results of this study can be a consideration for investors in

[1] . INTRODUCTION

Company performance reflects how effectively management achieves organizational goals through the optimal use of strategic resources those that are valuable, scarce, difficult to replicate, and efficiently governed (Barney & Clark, 2007). In a competitive market landscape, sustaining such a strategic advantage is essential for long-term survival and growth (Hung et al., 2010). In this context, the financial performance trends of energy sector companies listed on the Indonesia Stock Exchange (IDX) during the 2019–2023 period provide meaningful insights into how these firms navigate operational efficiency and market dynamics.

Figure 1 illustrates the performance trends of energy sector companies listed on IDX during the 2019–2023 period based on two primary indicators: Return on Assets (ROA) and Sustainable Growth Rate (SGR). This is a summary of the data sources derived from the OSIRIS Database (Aprilia Nur Khasanah & Kusuma, 2020), specifically the financial statements of energy sector companies. Although there aren't as many dramatic swings, ROA generally exhibits an upward tendency. This demonstrates how businesses in the industry are progressively increasing the effectiveness of leveraging assets to produce revenues. However, the most striking phenomenon is seen in the Sustainable Growth Rate (SGR) or company growth, which has undergone drastic changes. In 2019, the SGR was in the negative, then jumped sharply in 2020 before falling significantly to the lowest level in 2021. This trend indicates the presence of instability in the company's continued growth, which is likely influenced by external factors such as the COVID-19 pandemic. After a major decline in 2021, the SGR rose again in 2022 and stabilized in 2023, although it has not fully recovered to safer levels. From this trend, it can be concluded that the energy

assessing the company's financial prospects through a more comprehensive non-financial approach **Keywords:** *intellectual capital, roa, company growth.*

sector faces challenges in maintaining sustainable growth despite increased profitability and market capitalization. The volatility of the SGR could be an indication that companies in the sector need to implement a more cautious strategy to avoid a sharp decline in growth in the future.

The resource-based view (RBV) contends that the presence of unique resources utilized for the company's benefit influences performance rather than being exclusively decided by generic criteria. These specialized resources include measurable physical assets such as property and equipment, as well as intangible elements such as collective knowledge, brand reputation, and corporate culture; however, in this day and age, companies must pay greater attention to intangible resources. The performance of the business will be impacted by how intangible assets are managed as an added value (Widnyana et al., 2021). In order to build and explain how information is created, employed, and applied to enhance a company's value and success, intellectual capital (IC) is seen as a significant intangible asset (Schiavone et al., 2014). Utilizing internal resources must also be a top priority for businesses in order to succeed (Soewarno & Tjahjadi, 2020).

The VAIC technique, which is founded on the resource-based idea that a corporation uses both intellectual and physical capital as an indicator of its total efficiency to be able to create added value, provides the basis for measuring intellectual capital. Value Added Capital Coefficient (VACA), Value Added Human Capital Coefficient (VAHU), and Structural Capital Value Added (STVA) are the three parts of VAIC.

A growing body of research highlights that a company's value and competitive capabilities are increasingly derived from intangible assets, particularly intellectual capital (IC) (Huang & Huang, 2020). Businesses benefit from IC in ways like boosting social networks and brand equity (Liu & Jiang, 2020). Furthermore, IC offers businesses a number of advantages, including increased business innovation (Adesina, 2019; Ornek and Ayas, 2015), cost efficiency (Barrena-Martínez et al., 2020), increased relevance of accounting information (Hayati & Putra, 2015), and fostering employee satisfaction and retention. As a strategic intangible asset, intellectual capital is both a catalyst for innovation and a driver of long-term profitability and value creation (Chowdhury et al., 2019); (Schiavone et al., 2014).

Several studies have researched IC and company performance. Research conducted by (Andreeva & Garanina, 2016) emonstrated that human, structural, and employed capital components of IC significantly influence financial performance in Russian manufacturing firms. Similarly (Ibarra Cisneros & Hernandez-Perlines, 2018) found that human, technological, organizational, and relational aspects of IC positively impact the financial outcomes of SMEs in Mexico's manufacturing sector. Complementing these findings, Inkinen (2015) concluded that IC contributes to firm performance through its role in interaction, combination, and mediation processes, particularly by driving innovation and strategic development.

This study adds the moderation variable of sustainable growth rate (SGR) or company growth, departing from Selfiani (2024) who researches IC on company performance with the moderation of company growth in companies listed in the Kompas100 index on the IDX in 2021, it was found that company growth strengthens the relationship between IC and company performance in terms of return on asset (ROA), Companies with high IC can increase the attractiveness of companies to investors and creditors by increasing operational efficiency, innovation, and transparency in corporate governance (Campanella et al., 2025). Thus, companies with strong IC are more likely to gain better access to the funding necessary for sustainable growth (Jilani et al., 2020); (Sohu et al., 2024).

This study intends to examine the impact of IC components, such as VACA, VAHU, and STVA, on financial performance as determined by return on assets (ROA), while accounting for company growth as a moderating variable. This analysis is based on the phenomenon description and prior research. The study's methodology, moderated regression analysis (MRA), enables us to examine the potential effects of company expansion on the correlation between the IC component and the financial success of the organization. A firm in the energy sector that was listed between 2019 and 2023 on the IDX is the subject of this study. The selection of the energy sector is based on its strategic role in the national economy as

well as industrial dynamics, which are influenced by internal factors such as innovation capacity and risk management, as well as external factors such as energy price volatility and industry regulations. The purpose of this study is to ascertain the state of STVA, VAHU, and VACA in energy sector firms that are listed on the IDX for the 2019–2023 timeframe. Furthermore, this study seeks to ascertain how ROA is impacted by the VACA, VAHU, and STVA. Additionally, during the 2019–2023 timeframe, this study intends to examine whether company expansion can mitigate the impact of VACA, VAHU, and STVA on ROA in energy sector companies listed on the IDX.

3. METHOD

This study applies a quantitative research approach to examine the relationship between VACA, VAHU, STVA to ROA and the moderation of corporate growth in energy sector companies listed on the IDX in 2019-2023. This quantitative research method directs researchers to analyze a specific population or sample. The data for this study were obtained using analytical tools and then processed quantitatively or statistically to provide objective results that can be measured numerically (Sugiyono, 2021). The following are the characteristics of this study. This study uses a quantitative method because it focuses on numerical data processing and statistical analysis to test the relationship between independent variables, dependent variables, and moderation variables.

Data is gathered from each company's official website, as well as from the annual report that is accessible on the IDX official website. In addition, financial statements are also summarized through the OSIRIS database. Once the data is collected, the researcher reviews and categorizes the relevant reports based on pre-established criteria to determine the sample and data required. The data used includes annual publication reports from energy sector companies listed on the IDX during the period 2019 to 2023. The data analysis technique used is panel regression to examine the direct effect of each VAIC component on ROA, with the selection of the best model through Breusch-Pagan and Hausman tests. Furthermore, moderated regression analysis (MRA) is used to assess whether SGR moderates the relationship between VAIC components and ROA. Data processing was performed using STATA version 14 statistical software to ensure accurate and reliable results.

4. RESULTS AND DISCUSSION

In this study, descriptive statistical data analysis was carried out to find out the general picture of the data as a sample used in this study. In this study, the variables used include dependent variables, namely, financial performance measured through ROA. Furthermore, the independent variables of the Intellectual Capital component are VACA, VAHU, and STVA with the variable of Company Growth Moderation (SGR).

Analysis of Panel Regression Model Estimation Results

Prior to proceeding to the Moderated Regression Analysis (MRA) stage, a Panel regression was conducted based on the model used in this study, which included Models (3.1), (3.2), and (3.3). In order to choose between the Random Effect Model (REM) and the Common Effect Model (CEM), the first test is the Breusch & Pagan Lagrangian Multiplier Test (LM Test). The Hausman Test, sometimes referred to as Correlated Random Effects, comes next. The purpose of the test was to select between the REM and the Fixed Effect Model (FEM). Table 1 below shows the findings of the Hausman and LM tests used in this investigation.

Table 1 Regression Results of Model Panel (3.1), Model (3.2), Model (3.3)

Variabel	LENGTH		
	Model PLS/CEM	**Model REM**	Model FEM
Constant VACA	-3.574	-2.135	-0.74
Prob. Constant VACA	0.007	0.158	0.551
COW	44.68	39.029	33.538
Prob. VACA	0.000	0.000***	0.000

Constant VAHU	0.036	-0.551	-0.551
Prob. Constant VAHU	0.972	0.747	0.747
VAHU	0.726	0.776	0.776
Prob. VAHU	0.000	0.000***	0.000
Constant STVA	4.863	4.937	4.863
Prob. Constant STVA	0.000	0.006***	0.000
TELUGU	1.06	3.34	1.06
Prob. TELUGU	0.399	0.742	0.399
Breusch & Pagan LM Test VACA	0.000		
Breusch & Pagan LM Test VAHU	0.000		
Breusch & Pagan LM Test STVA	0.000		
Hausman Test VACA		0.333	
Hausman Test VAHU		0.103	
Hausman Test STVA		0.365	

Source: STATA Data Processing Results 14 (2025)

The results of the Breusch and Pagan LM Test which showed a probability value of 0.000 for the three variables VACA, VAHU, and STVA (p-value < 0.05), one can draw a conclusion that REM model is better than the CEM model.

Furthermore, to determine the best model between the REM and the FEM, the Hausman Test is performed. The results showed a probability value for the VACA variable of 0.333, VAHU of 0.103, and STVA of 0.365, all of which were greater than 0.05 (p-value > 0.05). Thus, it can be concluded that the best model used in this study is the REM.

The regression results in the REM model on the dependent variable Return on Assets (ROA) show several important findings as follows:

1. The VACA variable had a significant positive effect on ROA with a coefficient of 39,029 and a significance level of 0.000 (p < 0.01). This shows that increasing the efficiency of using employed capital will significantly improve the financial performance of energy sector companies. So H1 is accepted.
2. The VAHU variable also showed a significant positive effect on ROA with a coefficient of 0.776 and a significance value of 0.000 (p < 0.01). This means that the higher the contribution of human resources in creating added value, the higher the profitability produced by the company. Then H2 is accepted.
3. In contrast, the STVA variable had a non-significant effect on ROA, with a coefficient of 3.34 and a significance value of 0.742 (p > 0.05). So H3 was rejected.

Analysis of the Results of the Estimation of the Moderation Regression Model

Based on the model created in this study, which contained Models (3.4), (3.5), and (3.6), moderation regression was performed in order to answer the model that was then included in the MRA stage.

Table 2 Regression Results of Model Panel (3.4), Model (3.5), Model (3.6)

	Coefficient	Itself.
(Constant) VACA	1.099	0.350
COW	10.872	0.004***
COW*SGR	0.496	0.000***
(Constant) VAHU	-0.68	0.691
VAHU	0.777	0.000***
VAHU*SGR	0.006	0.874
(Constant) STVA	5.545	0.000***
TELUGU	-6.58	0.000***
STVA*SGR	2.98	0.001***

Source: STATA Data Processing Results 14 (2025)

Variabel LENGTH

The REM Regression Model's findings provided insight into how the interaction between the SGR and the IC components (VACA, VAHU, and STVA) affected the financial performance (ROA) of businesses in the energy industry. The following is an interpretation of each model:

1. The VACA variable had a significant positive effect on ROA with a coefficient of 10.872 and a significance level of 0.004 ($p < 0.01$), showing that the efficiency of using employed capital has a direct impact on increasing the company's profitability. In addition, the interaction of VACA*SGR was also significantly positive for ROA, with a coefficient of 0.496 and a significance of 0.000 ($p < 0.01$). This shows that the company's growth strengthens the influence of VACA on ROA. In other words, when a company experiences good growth, the efficiency of capital employed is more effective in driving financial performance. Then H4 was accepted
2. The VAHU variable showed a significant positive influence on ROA with a coefficient of 0.777 and a significance value of 0.000 ($p < 0.01$), indicating that the higher the contribution of human capital, the higher the level of profitability of the company. However, the VAHU*SGR interaction was not significant, with a coefficient of 0.006 and a significance value of 0.874 ($p > 0.05$). This means that the company's growth does not strengthen or weaken the influence of VAHU on ROA, so that the contribution of human capital to financial performance is relatively stable regardless of the company's growth dynamics. Then H5 was rejected
3. In this model, the STVA variable actually showed a significant negative influence on ROA with a coefficient of -6.580 and a significance of 0.000 ($p < 0.01$), which means that an increase in structural capital does not necessarily increase profitability; Even under certain conditions, it has a negative impact. However, the STVA*SGR interaction showed a significant positive effect on ROA, with a coefficient of 2.980 and a significance of 0.001 ($p < 0.01$). These findings indicate that corporate growth can reverse the direction of STVA's influence from negative to positive on ROA, so that the role of structural capital will become more effective when supported by healthy corporate growth. So H6 was accepted.

The Effect of Value Added Capital Employed Coefficient on ROA

The results showed that VACA had a significant positive effect on ROA with a coefficient value of 39,029 and a significance level of 0.000 ($p < 0.01$). This suggests that the more effectively a business uses its employed capital, both financial and physical the more value is created, which eventually boosts the business's bottom line. This result supports the idea that intellectual capital can grow into a valuable asset that helps businesses gain a competitive edge (Indiyati, 2018). All knowledge, human skills, information, organizational technology, intellectual property, and customer relationships that are regarded as

intangible assets and prospective sources of future revenue are together referred to as intellectual capital. Customers can receive greater value from intellectual capital, which can also boost a business's competitive edge.

The Effect of Value Added Human Capital Coefficient on ROA

VAHU was also shown to have a significant positive effect on ROA with a coefficient of 0.776 and a significance level of 0.000 ($p < 0.01$). This shows that investments in human resources, such as training, competency development, and talent management, significantly increase the company's productivity and profitability. These findings support Suharman et al. (2023), who assert that effective employee placement, ongoing performance reviews, competency development backed by organizational infrastructure, and effective employee communication skills are critical to promoting the learning and growth viewpoint.

The Effect of Structural Capital Value Added on ROA

In contrast to the other two components, STVA had no significant effect on ROA, with a coefficient of 3.34 and a significance level of 0.742 ($p > 0.05$). This shows that in the context of energy sector companies, the organization's internal systems, procedures, and infrastructure have not been able to make a direct contribution to profitability. This may be because robust structural processes have not been fully optimized or have not been directly integrated with the value creation strategy.

The effect of company growth in moderating VACA on ROA

According to the moderation results, ROA was significantly positively impacted by the interaction between VACA and SGR, with a coefficient of 0.496 and a significance level of 0.000 ($p < 0.01$). This indicates that the impact of efficient use of capital on financial performance can be amplified by business expansion. In this regard, expanding businesses are better able to maximize the use of their capital in generating value addition. According to study by (Marbun & Ulpah, 2024), businesses with rapid growth rates are typically better at managing utilized capital to promote value creation and long-term financial performance improvement.

The effect of company growth in moderating the Value Added Human Capital Coefficient on ROA

ROA was not significantly impacted by the interaction between VAHU and SGR, with a coefficient of 0.006 and a significance level of 0.874 ($p > 0.05$). This demonstrates that company expansion has no moderating effect on the correlation between financial performance and human capital. **The influence of company growth in moderating Structural Capital Value Added to ROA**

The findings demonstrated that, with a coefficient of 2.980 and a significance level of 0.001 ($p < 0.01$), the interaction between STVA and SGR significantly increased ROA. This indicates that the expansion of the business can turn the detrimental impact of STVA on financial performance around. In this context, strong growth may facilitate the more effective utilization of organizational systems and structures in support of value creation. This research corroborates the research of Astuti et al. (2017), where STVA is institutionalized knowledge owned by an organization that is stored in databases, manuals, and systems. Additionally, the company's wealth of experience and understanding. Processing, software, patents, copyrights, and possibly most importantly the expertise and experience of the company's employees are examples of capital. Investment in STVA is one of the crucial elements taken into account as the business expands, enabling it to better develop a competitive edge.

5. CONCLUSION

This research presents a comparative analysis of Dissolved Gas Analysis (DGA) for flaxseed oil and a blend of flaxseed oil (50%) with coconut cooking oil (50%), subjected to thermal aging at 170°C for 5 hours with copper immersion. The findings highlight significant differences in gas evolution patterns, indicating variations in thermal stability and oxidative degradation between the two oil compositions. The results demonstrate that flaxseed oil exhibits higher thermal degradation, as evidenced by elevated concentrations of CO_2, CO, and C_2H_6, suggesting increased oxidation and hydrocarbon breakdown. In contrast, the flaxseed-coconut oil blend shows improved oxidative stability, with lower gas concentrations, indicating enhanced resistance to thermal stress. The presence of copper as a catalytic agent further influences gas formation, accelerating oxidation reactions in both oil samples. These findings underscore the potential of vegetable-based insulating oils as sustainable alternatives to conventional mineral oils in transformer applications. The flaxseed-coconut oil blend emerges as a promising candidate due to its enhanced

thermal stability, which could contribute to improved performance and longevity in electrical insulation systems. Further research is recommended to explore long-term aging effects, dielectric properties, and compatibility with transformer materials.

REFERENCES

[1] Sorte, S., Salgado, A., Monteiro, A. F., Ventura, D., Martins, N., & Oliveira, M. S. A. (2025). Advancing power transformer cooling: The role of fluids and nanofluids—A comprehensive review. Materials, 18(5), 923. https://doi.org/10.3390/ma18050923

[2] Karthik, M., Nuvvula, R. S. S., Dhanamjayulu, C., & Khan, B. (2024). Appropriate analysis on properties of various compositions of fluids with and without additives for liquid insulation in power system transformer applications. Scientific Reports, 14, Article 17814. https://doi.org/10.1038/s41598-024-17814-6

[3] Pranav, P., Sneha, E., & Rani, S. (2021). Vegetable oil-based cutting fluids and their behavioral characteristics in machining processes: A review. Industrial Lubrication and Tribology, 73(9). https://doi.org/10.1108/ILT-08-2020-0310

[4] Nivethaa, R., Simmakya, S., & Sivakanthan, S. (2024). Analysis of oxidative stability and fatty acid profile of coconut oil and flaxseed oil blends. Grasas y Aceites, 75(3), e567. https://doi.org/10.3989/gya.0318231

[5] Rabail, R., Aadil, R. M., Sahar, A., & others. (2024). Nutritional and physicochemical analysis of edible oil blend with improved ratios of cardioprotective nutritional indices and physicochemical properties. Food Measure, 18, 3584–3594. https://doi.org/10.1007/s11694-024-02429-6

[6] Ali, M. S., Abu Bakar, A. H., Omar, A., Abdul Jaafar, A. S., & Mohamed, S. H. (2023). Conventional methods of dissolved gas analysis using oil-immersed power transformer for fault diagnosis: A review. Electric Power Systems Research, 216, 109064. https://doi.org/10.1016/j.epsr.2022.109064

[7] Nouri, B., & Ojaghi, M. (2024). Power transformer fault diagnosis via gas chromatography: A review of techniques and standards. Electrical Engineering & Computer Sciences, Advanced online publication. https://doi.org/10.30503/eecs.2024.479067.1061

[8] bail, R., Shabbir, M. A., Sahar, A., Miecznikowski, A., Kieliszek, M., & Aadil, R. M. (2021). An intricate review on nutritional and analytical profiling of coconut, flaxseed, olive, and sunflower oil blends. Molecules, 26(23), 7187. https://doi.org/10.3390/molecules26237187

[9] Obebe, E. O., Hadjadj, Y., Oparanti, S. O., & Fofana, I. (2025). Enhancing the performance of natural ester insulating liquids in power transformers: A comprehensive review on antioxidant additives for improved oxidation stability. Energies, 18(7), 1690. https://doi.org/10.3390/en18071690

[10] Joshi, A., Hegde, M., & Zanwar, A. (2023). Modulation of essential fatty acid levels in coconut oil with flaxseed oil. Grasas y Aceites, 74(2), e503. https://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/view/1992

[11] Yeasmin, M. S., Chowdhury, T. A., Rahman, M. M., Rana, G. M. M., Uddin, M. J., Ferdousi, L., Muzahid, A. A., Barmon, J., Ghos, B. C., Saha, B. K., & Khan, M. S. (2024). A comparison of indigenous vegetable oils and their blends with optimal fatty acid ratio. Applied Food Research, 4(1), 100421. https://doi.org/10.1016/j.afres.2024.100421

[12] MidlandsNZ. (2024). The science behind cold-pressed flaxseed oil: Why it matters for manufacturers. https://www.midlandsnz.com/the-science-behind-cold-pressed-flaxseed-oil-why-it-matters-for-manufacturers

[13] Sarmiento, L. (2025). Flax (Linum usitatissimum). Jardinería On. https://en.jardineriaon.com/very-common-flax.html [14] Wang, J., & Zhu, D. (2025). Nutritional properties and applications of cold-pressed flaxseed oil. Nutrients, 17(11), 1791. https://doi.org/10.3390/nu17111791

[15] Yang, J., Wen, C., Duan, Y., Deng, Q., Peng, D., Zhang, H., & Ma, H. (2021). The composition, extraction, analysis, bioactivities, bioavailability, and applications in food systems of flaxseed (Linum usitatissimum L.) oil: A review. Trends in Food Science & Technology, 118(Part A), 252–260. https://doi.org/10.1016/j.tifs.2021.09.020

[16] Divya, P. M., Roopa, B. S., Manusha, C., & et al. (2023). A concise review on oil extraction methods, nutritional and therapeutic role of coconut products. Journal of Food Science and Technology, 60(1), 441–452. https://doi.org/10.1007/s13197-022-05352-0

[17] Subroto, E., Pangawikan, A. D., Yarlina, V. P., & Ramadhani, A. P. (2021, March). The extraction, purification, and recent applications of coconut oil in food products: A review. International Journal of Emerging Technologies in Learning (iJET), 11(5), 234–240.

[18] Doble Engineering Company. (2025). Myrkos: Portable dissolved gas analyzer. https://www.doble.com/product/morganschaffer-myrkos/

[19] International Electrotechnical Commission. (2023). IEC 60567: Oil-filled electrical equipment – Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids Guidance. https://standards.iteh.ai/catalog/standards/iec/da66d488-a27f-42e9-9083-fdd45f43c1c0/iec-60567-2023

[20] El-Faraskoury, A., Ward, S. A., Mansour, D. A., Ibrahim, S. A., & Badawi, M. (2023). Oil condition assessment for aged transformers based on dissolved gas analysis. In Proceedings of the 2023 24th International Middle East Power Systems Conference (MEPCON). IEEE.

[21] Wang, N., Li, C., Li, B., Jiang, Y., Zhang, S., Wang, D., Tang, Y., & Hu, X. (2024). Activation of cotton with transition metal-based chlorides: Correlation of generation of pore structures with evolution of oxygen-containing species. Journal of Environmental Chemical Engineering, 12(5), 113378. https://doi.org/10.1016/j.jece.2024.113378

[22] Zulkefli, N. I. H., Khiar, M. S. A., Ab Ghani, S., Sutan Chairul, I., & Che Musni, M. A. (2025). Assessing the effectiveness of natural ester fluid retrofilling in mitigating the deposition of copper sulfide on kraft paper insulation. Jurnal Kejuruteraan, 37(3), 1207–1214.

[23] Allen, N. S., & Edge, M. (2020). Perspectives on additives for polymers. 1. Aspects of stabilization. Vibrational Spectroscopy, https://doi.org/10.1002/vnl.21807
[24] Wang, F., Zhang, H., Wang, H., Hayireding, D., Gao, C., & Zhang, G. (2025). Investigating the formation of trace metal contamination in insulating oil: From electrical erosion and chemical corrosion perspectives. IEEE Access, 13.
[25] Riedmann, C., Schichler, U., Häusler, W., & et al. (2022). Online dissolved gas analysis used for transformers – Possibilities, experiences, and limitations. Elektrotechnik & Informationstechnik, 139(2), 88–97. https://doi.org/10.1007/s00502-02200992-8
[26] Lalitha, S. D., & Anitha, G. (2025). Enhanced power transformer fault diagnosis using key chemical gases with DGA, integrating machine learning and traditional methods. Iranian Journal of Chemistry and Chemical Engineering (IJCCE), 44(5).
[27] Oparanti, S. O., Rao, U. M., & Fofana, I. (2023). Natural esters for green transformers: Challenges and keys for improved serviceability. Energies, 16(1), 61. https://doi.org/10.3390/en16010061
[28] Lin, H., Guo, J., Zhang, Z., Li, S., Yang, D., & Zhang, H. (2024). An investigation of the behaviour of copper electronic state evolution on the failure of oil-paper insulation systems. Journal of Physics: Conference Series, 2800, 012016. https://doi.org/10.1088/1742-6596/2800/1/012016
[29] Durairaj, K. P., Mahalingam, K. R., Perumalsamy, A., & lainnya. (2025). Evaluating methyl ester from used cooking oil as liquid insulation with solid insulation for transformers. Electrical Engineering. https://doi.org/10.1007/s00202-025-03079-7 [30] Rafiq, M., Shafique, M., Ateeq, M., & lainnya. (2024). Natural esters as sustainable alternating dielectric liquids for transformer insulation system: Analyzing the state of the art. Clean Technologies and Environmental Policy, 26, 623–659. https://doi.org/10.1007/s10098-023-02688-9
[31] Amalanathan, A. J., Sarathi, R., Zdanowski, M., Vinu, R., & Nadolny, Z. (2023). Review on gassing tendency of different insulating fluids towards transformer applications. Energies, 16(1), 488. https://doi.org/10.3390/en16010488